Modern Technologies in Geography Education – Mobile and Virtual Approaches for Extracurricular Environments

Kumulative Dissertation
zur Erlangung des Grades Doktor
der Naturwissenschaften
(Dr. rer. nat.)

im Fachbereich Geographie
der Philipps-Universität Marburg

vorgelegt von
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Marburg (Lahn), September 2023

Am Fachbereich Geographie
der Philipps-Universität Marburg (Hochschulkennziffer: 1180)
am 30. September 2023 eingereicht.

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Die Dissertation wurde am 15.12.2023 in Marburg verteidigt und ist angenommen.

Danksagung

Als erster in einer Familie, die bislang eher wenig bis keine Berührungspunkte mit der akademischen Welt hatte, eine Promotion anzustreben ist etwas ganz Besonderes. Herausforderung, Chance und Privileg mögen passende Bezeichnungen sein, vor allem ist es jedoch ein großes Abenteuer. Ich bin sehr dankbar, dass ich die Reise in so ein einzigartiges Abenteuer antreten durfte. Auch wenn dabei jeder Schritt auf einem oft ungewissen Pfad letztendlich eigenverantwortlich getan werden musste, gab es doch Wegweiser, Orientierungshilfen, Begleiter und Unterstützung in Form wunderbarer Menschen, ohne die ich, trotz großer Anstrengungen nie zum Ziel gefunden hätte.

Mein größter Dank gilt dabei Carina Peter, die mir diesen Weg geebnet, mich an seinen Gabelungen und Kreuzungen beraten und damit sicher auch vor der einen oder anderen Sackgasse bewahrt hat.
Ähnliches lässt sich über die AG Geographiedidaktik der Philipps-Universität sagen. Meinen lieben Kolleginnen und Kollegen danke ich für die angenehme Arbeitsatmosphäre, aber auch für ehrliche Meinungen und Feedback.
Dem Team des Projekts Natur 4.0 sei gedankt, dass sie mich an den inhaltlichen Stationen meiner Expedition freundschaftlich aufgenommen und mich mit wertvollem „indigenem Wissen“ aus ihrer Welt ausgestattet haben.
Ich möchte mich auch bei meiner Mentorin und Freundin Petra Lindemann-Matthies bedanken, die bereits mein vorheriges „akademisches Abenteuer“ begleiten durfte, mir Mut gemacht hat auch dieses zu bestreiten und mir dabei mit ihrem Rat zur Seite stand.
Es finden sich zum Glück auch auf einer Abenteuerreise manchmal Menschen, die einen, zumindest einen Teil des Weges, begleiten möchten. Meinem guten Freund und Kollegen Max Morshäuser danke ich von Herzen dafür, dass er sich nicht nur bereit erklärt hat, ein Stück in meine Richtung mitzugehen, sondern durch seine gestalterischen Beiträge sogar einen beachtlichen Teil des Reisegepäcks mit mir geschultert hat.
Klassische Abenteurer kehren meist erst am Ende ihrer langen Reise zu ihren Liebsten nach Hause zurück. Ich bin sehr dankbar, dass das nicht auf mich zutrifft und ich zu jedem Zeitpunkt bei meinen lieben Eltern, meiner verständnisvollen Frau Noud und meinen wunderbaren Kindern einen sicheren Hafen zum Entspannen und Auftanken anlaufen konnte, um dann mit neuer Energie wieder in mein Abenteuer zu starten.

Phillip Bengel

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Abbreviations

AFT	Actual field trip
AI	Artificial intelligence
ANOVA	Analysis of variance
AR	Augmented reality
BA	Bachelor’s degree (category in TOG)
BAE	Benefits and easement (psychom. dimension in MTAI)
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung
CAS	Computer attitude scale
CRA	Content-related attitudes
CTRL	Control group
DFG	Deutsche Forschungsgemeinschaft
DGBL	Digital game-based learning
DGfG	Deutsche Gesellschaft für Geographie
EFA	Exploratory factor analysis
ESD	Education for sustainable development
FOS	Field of science
GIS	Geographic information system
GEO	Students of geography (category in FOS)
GPS	Global positioning system
HSSC	Students of human and social sciences (category in FOS)
INT	Intimidation (psychom. dimension in MTAI)
IP	Investigation point
IPCC	Intergovernmental panel on climate change
ITEEA	International technology and engineering educators association
iVFT	Immersive virtual field trips
LOC	Loss of control (psychom. dimension in MTAI)
MA	Master’s degree (category in TOG)
mDGBL	Mobile digital game-based learning
MT	Modern technology
MTAI	Modern technology attitude index
MTI	Modern technology interest
NEP	New ecological paradigm (scale)
NSC	Natural sciences (category in FOS)
PATT	Pupil’s attitude towards technology (scale)
QQ	Quantile-quantile (plot)
SEM	Semester
SENSO	Science education and natural system observation

SSK	Subject-specific knowledge
sTQ	Short technology questionnaire
TE	Technology education
TOE	Time of enquiry
TOG	Type of graduation
UNESCO	United Nations Educational, Scientific and Cultural Organization
VFT	Virtual field trips
VR	Virtual reality
XR	Mixed reality

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1 Introduction

This research is motivated by the exploration of the positive effects of technology-based mobile and virtual teaching and learning concepts in extracurricular geography education. In recent years, using digital media as educational tools to enhance learning experiences beyond the traditional classroom setting gained increased attention (Mirsharapovna et al., 2022; Bernacki et al., 2020).

In today's rapidly evolving digital environments, the integration of digital media in education has become increasingly important (Banks & Williams, 2022). In addition, to the transfer of subject-specific knowledge and related competences (DGfG, 2020), another purpose of modern geography education can be to promote a digital literacy and to prepare students for an active participation in a technologically advanced society (Peter & Sprenger, 2022). People who are technologically and digitally literate are considered to be able to use suitable tools and systems in a conscious and sensible manner, as well as recognize and critically evaluate any potential consequences on people and the environment and the significance of such effects (Supahar, 2023; Reddy et al., 2020). As a scientific and educational subject, geography plays a unique role in analyzing the intricate relationships between people, technology, and the environment (Dorsch et al., 2020; Ash et al., 2018). By incorporating digital media into extracurricular geography classes, educators can provide students with the necessary tools and skills to navigate and critically evaluate the geospatial dimensions of our interconnected world (Thürkow et al., 2020). However, in a heterogeneous society, there can be very different personal prerequisites depending on age group, attitudes or gender that might jeopardize respective approaches (Marth & Bogner, 2019). Even if we live now in a society where, e. g. gender differences are less important than in the past, this does not mean that they do not exist in some areas (Kampshoff & Wiepke, 2012). By teaching technological content and using technological tools, one should therefore at least be sensitive to potential inequalities, and if necessary, address them in suitable ways (Thaler & Hofstätter, 2012).

In order to accomplish sensitive and efficient education, teachers need to be adequately equipped. Also, their personal attitudes toward digital media and the corresponding technology play an important role here. After all, teachers represent a significant link between learners and society (Reichhart, 2017; Kunter et al., 2011). Their personal attitude directly and indirectly affects the students, for example, in their role model function or through their subject-related competencies (Kunter et al., 2011). Thus, before examining students as the primary target group, we also need to perceive and examine teachers as key figures in their role as multipliers.

In the hands of qualified educators, technology and digital media, including digital games, interactive maps, and online resources, offer immersive and engaging experiences that can enhance students' understanding of geography (Gryl, 2022). With the use of these tools, educators may provide engaging learning environments that give students the chance to explore geographical concepts, engage with actual data, and research the effects of human activity on the environment (Lude et al., 2013). Through these engaging activities, students can get a greater understanding of how technology shapes our world and improve their ability to deal with the opportunities and problems that come with a society in the age of digitality (Huff et al., 2012).

Even if the study of human-technology-environment relationships might, in a first approach, seem to be a philosophical issue (Verbeek, 2023), from a systemic and process-oriented perspective, it could also be located in the field of geography. The subject seeks to comprehend the dynamic interactions between human societies, the environment and the interdependencies of technological advancements in a spatio-temporal manner (Otto, 2016). By incorporating digital media into extracurricular geography education, students are provided with the opportunity to examine these relationships through various spatial and professional perspectives in a hands-on and experiential manner. Digital games, for instance, can simulate complex geospatial scenarios, allowing students to analyze the consequences of technological choices and their environmental implications (Schaal, 2020). Through these investigations, students could develop a deeper understanding of the intricate connections between human activities, technology, and the environment.

The cooperative research project Natur4.0 - Sensing Biodiversity, which was implemented in the Philipps University forest from 2019 to 2022, offered the ideal framework to convert the points mentioned above into practical educational concepts and investigate them using empirical quasi-experimental studies (Friess et al., 2019). Two variants of a technology-based learning experience trail for conveying environmental science content, methods, and technology were developed, implemented and examined as the central subject of this thesis. Namely, the SENSO-Trail (Science Education and Natural Systems Observation) as a location-based concept supported by mobile digital media and the SENSO-Trail360 which is identical in content and structure, but a purely virtual variant of the first one. The dissertation is intended to contribute to a better comprehension of the potential benefits, challenges, and implications of integrating technology approaches such as mobile or virtual multi-perspective and digital game-based learning in extracurricular geography education. The studies in this dissertation aim to identify some of the above-named concepts' most relevant success factors, their differences, effects, and developments, as well as further implications of the approaches, e. g., in relation to the promotion of technological literacy. The subsequent sections will delve further into the theoretical framework to introduce the chosen approaches and outline the resulting research objectives of this work.

1.1 Theoretical Framework

To establish the theoretical foundation for understanding the integration of technology-based learning in extracurricular geography education, it seems essential to explore several key concepts. At the beginning of this section, the concept of technological literacy is clarified. Subsequently its significance as an aim of modern learning environments in geography education, next to more basic educational goals, like knowledge transfer and attitudinal chances, is explained. This is followed by an introduction of the individual approaches, which were chosen as elements to create the new educational concepts presented in this work.

1.1.1 Promoting Technological Literacy in Geography Education

When discussing the development of a culture of digitality in today's society, two views are often propagated. On the one hand, there is a technological determinist attitude, according to which people are exposed to the effects of technological progress (Banse et al., 2002). On the other hand, there is a view that focuses on

"[…] pedagogical action, the development potential of human judgment and the performance of human behavior” (Allert & Richter et al. 2017, p. 19). Considering this dichotomy, Mitcham (1994) describes two dimensions that characterize a person's technological competence as a literate member of a digital culture. One is what a person thinks about the "nature" of technology, and the other is how they interact with it, recognizing the socio-cultural context. Although there have been other attempts to define Technological Literacy over the last decades (ITEEA, 2023; Gómez-Trigueros et al., 2019; Loveland & Love, 2017; Dyrenfurth & Kozak, 1991), Mitcham’s definition in particular shows the potential of geographic education approaches for the promotion of relevant competences. A central aim in geographic education is the consideration of human-environment systems (Mehren et al., 2016), which can be extended by a technologically sensitive perspective (Ash et al., 2018). In this context, the role and characteristics of technology, as a social construct, can be critically reflected, as it is described in Mitcham’s second dimension. On the other hand, since geography as a science implements many technological elements itself, one can also find direct access to the deterministic nature of technology, in terms of analyzing its structures, functions, and processes (Brucker, 2017), for example. In geography lessons, technologies, such as remote sensing, geographic information systems (GIS) and global positioning systems (GPS) can not only be explained in their function and application, but they can also be considered on a meta-level to reflect their social, cultural or ecological effects (Belling, 2021; DeMers, 2016). Concludingly, the subject of geography demonstrates the importance of promoting technological literacy in the age of digitality, and at the same time presents itself as a valuable tool for doing so. From the multitude of concepts and approaches in geography didactics that are suitable for this purpose, those that are relevant to this work will be presented in the following.

1.1.2 Extracurricular Education for Geography

Extracurricular places of learning are best defined by their central features, as Sauerborn and Brühne (2020) have done in the following, freely excerpted section:

> *Extracurricular learning describes original encounters outside the classroom. In out-of-school places, the learner is directly confronted with his or her spatial environment. The possibility of an active (co-)design as well as the possibility of a primary experience of multi-perspective educational contents by the learner are central characteristics of extracurricular learning. (Sauerborn & Brühne, 2020, p.27)*

Further they state that, compared to other forms of teaching, extracurricular learning environments make high didactic demands (Sauerborn & Brühne, 2020). This can bring opportunities but also challenges for teaching outside the classroom. Kuske-Janßen et al. (2020) first address the positive effects of extracurricular environments on learning by opening up and extending the learning opportunities offered by schools. Further, they state that extracurricular places of learning bring variety into the school day and open up new learning paths that promote the interest, motivation, and effectiveness of the learners. Through personal experiences, students have the opportunity to observe, classify, examine, and evaluate natural and cultural spatial reality (Baar & Schönknecht, 2018). Learning objects are presented in a simplified way in school for better clarity and reduced to the essentials (Messmer et al., 2011). Complex issues, such as the natural processes in a forest ecosystem for instance, cannot always be taught in a reduced form in a classroom. Extracurricular places of learning offer the possibility to leave this formal-abstract model world and to apply other approaches in order to grasp the complexity of the real world (Neeb, 2012). Thereby, the close connection to the everyday and living world of the students coincides with the demands of school pedagogy (Baar & Schönknecht, 2018). However, the extent to which extracurricular places of learning address the students' lives depends on the individual experience of each student and their personal mindset in relation to the provided content.

The numerous opportunities of extracurricular learning sites are also faced with challenges. Structural, financial, and organizational problems can make it difficult to access, and pedagogical and didactic ones to implement the educational measures successfully (Klippel et al., 2019). For promising lessons at extracurricular places, it therefore seems all the more important to pay attention to the correct staging, choice of approaches, and preparation of materials, tools, and media to ensure that the rich opportunities of extracurricular learning environments can be exploited (Brade & Dühlmeier, 2022).

Educators can cope with some challenges by incorporating modern technology and digital media into extracurricular geography education (Salsabila et al., 2022). They also further enhance the learning experience and offer interactive and immersive learning opportunities that bridge the gap between theory and practice (Brendel & Mohring, 2020).

1.1.3 Multi-Perspective Learning in Extracurricular Geography Education

In extracurricular geography education, well-composed digital media concepts can facilitate multi-perspective learning. They do so by giving access to various sources of information, representing diverse points of view, simulating complex spatial scenarios, and providing the option for a simple and targeted change between all those elements. Multi-perspectivity, as a central didactic principle in geography lessons, aims to provide an approach for better comprehending complex realities (Hintermann, 2018). First of all, the term perspective refers to a spatial-visual point of view of viewing specific physical-material phenomena. Therefore, the conscious use of different scales and spatial references enables multi-perspective learning and supports well-founded assessments and actions (Chreiska-Höbinger et al., 2019). In addition, according to Chreiska-Höbinger et al. (2019), multi-perspectivity is also characterized by conscious changes in professional or personal perspectives and different views of the world and of human beings. By engaging with multiple perspectives, learners can develop a more nuanced understanding of subject-related issues, challenge preconceived ideas, and cultivate a global mindset (Stradling, 2003). For geography education, those conscious changes in spatial, personal, or professional perspectives are interesting because the sensory perception of humans allows the observation of things from only one specific perspective at a time. Multi-perspectivity opens up a plurality of views of reality and conceptions of truth (Gryl, 2010). Therefore, single media elements, digital or analog, also do not depict reality but only individual-specific perspectives on it.

1.1.4 Mobile Digital Learning in Extracurricular Geography Education

Digital media devices, such as computers, smartphones, or tablets, are an integral part of everyday life for young people in modern society (Tully, 2019;

Birkelbach et al., 2018; Dávideková, 2016). They offer great potential for innovative educational approaches. However, with regard to the media used, it must also be considered that different learning effects can be expected depending on the form of coding (e. g., text, image, or sound), modality (auditory or visual), and the attributes of the target group (e. g., age, attitudes, previous knowledge, individual learning preferences, etc.) (Brünken & Leutner, 2008). Empirical studies show that dual-coded, e. g., audiovisual, information achieves better learning effects (Mayer et al., 2001). For example, the learning process is promoted more if the explanatory text of an animation is set to audible instead of readable information (Unterbruner, 2007). According to the modality principle, however, a balance should be sought in the selection of media in order not to place too great a burden on the learners' working memory (cognitive load) (Brünken & Leutner, 2008).

The latest technological developments create a growing number of options for location-based mobile or virtual learning approaches that bridge the gap between a real and a digital (learning) world (Lude et al., 2013; Bleck et al., 2012). Mobile digital learning has emerged as a powerful educational approach, leveraging the ubiquity of mobile devices to deliver educational content anytime and anywhere. Mobile technologies enable learners to engage with geospatial information, access real-time data, and participate in location-based activities. Mobile digital learning is thus a process in which "the learner can access information, knowledge, and learning opportunities independently of time and place [and] actively deal with them [...]" (Lude et al., 2013, p. 8). The portability and connectivity of mobile devices facilitate the seamless integration of digital media into extracurricular geography education, allowing students to explore geospatial data, conduct self-paced field trips, and collaborate with peers beyond the confines of the traditional classroom. By harnessing the potential of mobile digital learning, educators can empower students to become active participants in their learning journey and facilitate a deeper understanding of geographic concepts in diverse contexts. Mobile learning is often used in geography didactics to teach locally bound phenomena or content in an on-demand and timely manner (Chatel & Falk, 2017). In a case like the observation of climatic site conditions in a forest, where corresponding information should be available mobile and independent of time, one speaks of mobile, place-based learning (Hiller et al., 2019).

1.1.5 Virtual vs. Actual Place-Based Learning

The comparison between virtual field trips (VFT) and actual field trips (AFT) is an essential consideration in the context of extracurricular geography education. Virtual field trips, as highlighted by Klippel et al. (2020), offer unique advantages such as cost-effectiveness, accessibility, and the ability to visit distant or inaccessible locations. They provide opportunities for students to explore different environments, cultural landscapes, and geographic features without the logistical constraints of physical travel. More advanced VFT uses 3D spatial design to provide students with a firsthand understanding of the spatial context, allowing them to virtually observe, collect information, and engage with real geographical issues through a simulated experience. However, the tangible experiences, sensory immersion, and the opportunity for direct interaction with the physical environment in AFTs seem not (yet) replaceable by technology. Nevertheless, the results of Supahar (2023) suggest that virtual learning settings can effectively contribute to the promotion of technological literacy.

1.1.6 Digital Game-Based Learning

As digitalization has progressed, the video games industry, which is worth billions of euros, has also continued to grow inexorably for over 30 years (Gameswirtschaft, 2022). This market thrives on the commitment and intrinsic motivation of the players. That is why game design bears excellent potential for educational purpose especially when it comes to arousing the interest of players, engaging them interactively in an exciting story, keeping their attention for as long as possible, and thus motivating them persistently (Prensky, 2003). Games manage to awaken a number of behaviors in the players that are also desirable for learning processes. Interest, independence, cooperation, goal orientation, and the ability to actively search for information and find creative solutions are all attributes of both a successful gamer and an engaged student (Prensky, 2003). If an attempt is made to combine a learning subject with digital game structures, e. g., to support the learning process through game enjoyment and flow experiences, the terms Serious Games or Digital Game-Based Learning (DGBL) are used (Rheinberg & Vollmeyer, 2003; Csiksentmihalyi et al., 1993). There are a growing number of studies in which DGBL has been used successfully, especially for teaching complex content, as can frequently be found in geography or ecology (Lux & Budke, 2020; Schaal et al., 2018; Sandbrook et al., 2015). As Prensky (2003) noted, game-based learning provides varieties for active learning, problem-solving, and critical thinking opportunities.

In the context of extracurricular geography education, digital games offer immersive and interactive environments where students can explore geographic phenomena, make decisions, and experience the consequences of their actions. By integrating game-based learning approaches, educators can create dynamic and engaging learning experiences that foster students' spatial thinking skills, encourage collaboration, and promote a deeper understanding of geographic structures, functions, and processes (Schaal, 2020).

1.2 Research Aims

This work is intended to contribute to a better comprehension of the potential benefits, challenges, and implications of integrating technology approaches such as mobile or virtual multi-perspective and digital game-based learning in extracurricular geography education. With the key didactical concepts, as introduced in the section above, the groundwork for understanding the potential of technology-based learning in extracurricular geography education is laid. Next, the core structure and central research aims of this work will be defined on this basis. In order to evaluate the design and composition of the applied concepts with regard to their educational effects and applicability, the following consecutive procedure seems to be appropriate: Parameters as success and influence variables have to be defined, and instruments have to be identified or constructed to allow their valid measurement. The initial situation of relevant target groups must be ascertained with regard to the parameters. Finally, the educational concepts must be implemented in field studies and their effects measured, compared and analyzed in order to be able to derive conclusions and recommendations for the application or further development of such approaches. Derived from this research idea, the concrete objectives in this process can be described as follows:

1. Assessment, adaptation, and validation of measurement instruments that allow a sufficiently detailed analysis of the selected study variables.

2. Examination of the technology-based educational concepts in actual extracurricular settings in terms of their short- and long-term transfer of subject-specific knowledge.

3. Comparison of a virtual and actual physical implementation of identical concepts, with regard to subject-specific knowledge transfer.

4. Analysis of selected personal factors and their different characteristics in their initial situation as well as their possible effects on knowledge transfer, their mutual conditions and their changeability through the application of the developed educational concepts.

1.3 Thesis Structure

The present work can be divided into three studies. which are structured as consecutive work steps (see figure 1.1), based on the model of a preliminary study, a main study, and a follow-up study. The studies are published in the form of three peer-reviewed articles, which are presented chronologically in the following chapters. They are included in their original version, with the exception of minor adjustments.

When it comes to evaluating innovative education in extracurricular learning venues, the expert literature reveals a variety of approaches, instruments, and methods for applying them. The aim of the pre-study is to refine, optimize, and validate the selection tailored to this specific case of application. For this purpose, a total of n = 357 students of the Philipps-Universität Marburg and among them n = 72 pre-service teachers of geography were surveyed online. The pre-study not only provided a valid measurement instrument for the subsequent evaluation studies but also delivered valuable results on the technology-related attitudes of future geography teachers, which can be interpreted in the overall context of this work.

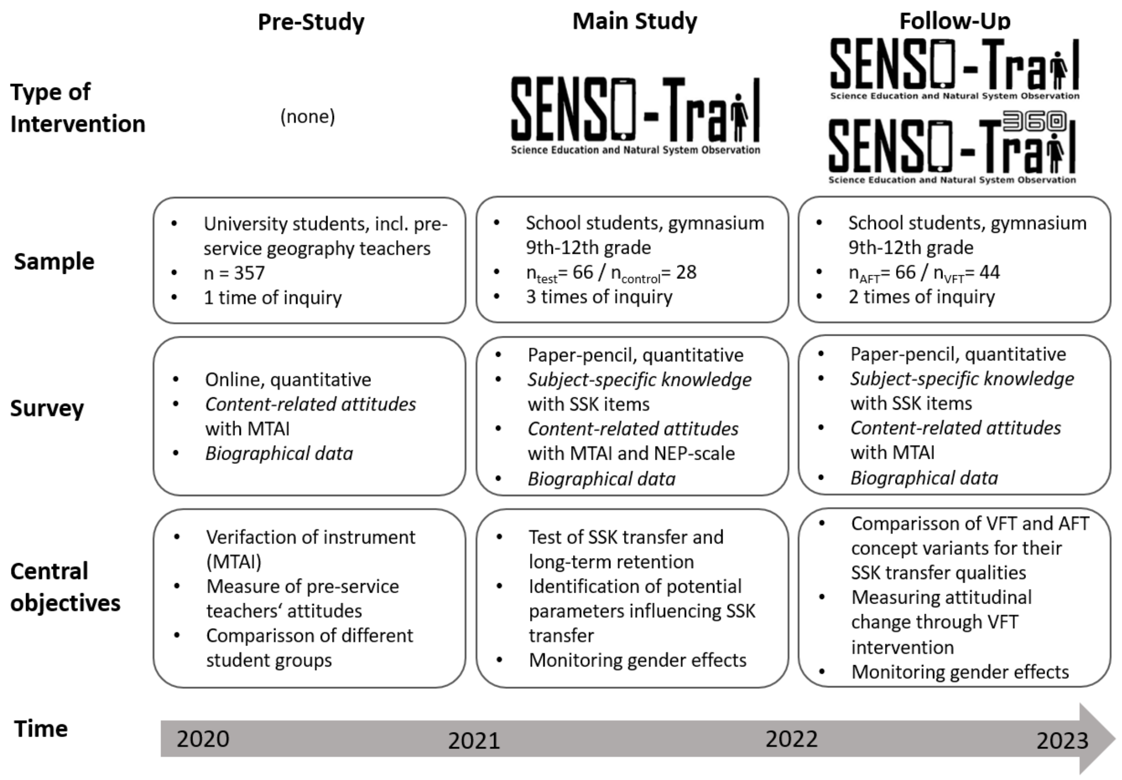

Figure 1.1 Thesis structure with three studies in chronological order and a selection of their most relevant attributes.

For the main study, the SENSO Trail (Science Education and Natural Systems Observation), a first variant of an innovative learning and experience concept is implemented in the research forest of Philipps University. The structure of this extracurricular learning unit follows the idea of a modular version of an educational trail and is mainly based on the use of mobile digital technologies, i. e., an app that is accessible on the participants' tablets. To date, technologically supported extracurricular learning concepts that pursue both mobile game-based learning and a multi-perspective approach have yet to be specifically evaluated. However, studies that deal with similar approaches at least neglect person-specific success factors, such as gender or the content-related attitudes of the participants. The object of this study is to fulfill this desideratum. To participate, n = 94 students from Hessian high schools were acquired. The subjects were randomly assigned to a test and a control group, to investigate the interventions abilities of transferring subject-specific knowledge. Furthermore, personal factors, such as gender or content-related attitudes, that could be potentially influencing or jeopardizing the learning process are investigated.

The central object of the follow-up study is a comparison between virtual (SENSO Trail360) and actually implemented (SENSO Trail) teaching concepts, as well as a more detailed examination of the attitudinal dimensions and their changeability in male and female participants. To this end, a purely virtual version of the concept, identical in content and structure to the trail described above, was developed. In this study, n = 110 students from high schools in Hesse participated, with one group running the actual trail in the forest and another running the virtual trail in a computer room. Following on from the results of the main study, however, the individual expressions of the participants' cognitive, behavioral and affective attitudes concerning modern technology are examined. To measure possible variabilities caused by the intervention, attitude data was surveyed before and after the participation in the virtual trail.

1.4 Methods

The core of this dissertation is the empirical evaluation of innovative educational concepts using modern technologies in extracurricular settings. For this purpose, a quantitative research approach was chosen, as it allows an efficient procedure with a larger sample size, e. g., in the case of school classes (Rasch et al., 2014; Bortz & Schuster, 2010). On the other hand, it was possible to determine a selection of concrete test variables on the basis of the subject-specific literature already in the planning phase and to generate hypotheses for which a quantitative approach is most suitable (Bühner, 2011). As outlined above, the practical work of the dissertation can be divided into three research studies. In the first study, an online survey was conducted with pre-service teachers, which was used to gain initial insights and to optimize and validate the questionnaire components (Moosbrugger & Kelava, 2012). With the help of a factor analysis, the Modern Technology Attitude Index (MTAI) was created, a three-dimensional scale that became a crucial component of the following studies (see appendix A).

In contrast to the first study, the second and third studies were quasi-experimental field studies with a pre-post follow-up design (second study) and a pre-post design (third study), respectively. The second study was designed to examine student participation in an approach implemented in a real forest. A comparison group was used to eliminate random effects. The test variables were collected on site immediately before and after participation and a third time eight weeks later in the respective schools. The third study was designed to compare identical concepts in virtual and real environments and took place in computer labs.

Paper-pencil questionnaires were used to collect data for the second and third studies (see appendix B). In addition to the aforementioned MTAI, the questionnaires included self-developed items to capture subject-specific knowledge, biographical data and, in the case of the second study, the New Ecological Paradigm Scale (NEP) by Dunlap et al. (2000) to measure attitudes toward nature and the environment.

Next to the already mentioned factor analysis and rudimentary descriptive statistics, multiple linear regression, different t-tests, and ANOVA were used for data analysis (Sauer; 2019; Bühner, 2011). The analysis tools used were the software R with the supplement R-Studio (version R-4.0.2 - RStudio Team, 2020) and JASP (version 0.14.1 - Wagenmakers, 2021).

Unless otherwise stated, all content of the presented work is solely the intellectual property of the author or (for the case of the research articles) co-author. Generative models were applied in accordance with the guidelines set out in the latest statement of the German research association (DFG, 2023). They were exclusively used to optimize linguistic quality, e. g. in terms of translation, sentence structure or vocabulary (Kutylowski, 2023; Grammarly Inc., 2023; Chat.openai.com, 2022).

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2 Attitudes of Pre-Service Teachers of Geography on Modern Technology.

This chapter has been published as:

Bengel, Phillip T.; Peter, Carina (2021): Modern Technology in Geography Education - Attitudes of Pre-Service Teachers of Geography on Modern Technology. In: Education Sciences 11 (11), S. 708. DOI: 10.3390/educsci11110708.

Received: 6 October 2021, accepted: 31 October 2021

Abstract

In this study, we focus on teachers' attitudes to compare and evaluate their ability and readiness to implement technology education in geography lessons. First, the lack of suitable measuring instruments for our intent was identified, and we thus attempted to develop the Modern Technology Attitude Index (MTAI) for remedy. An exploratory factor analysis helped to identify three distinguishable dimensions that depict areas of intimidation (INT), loss of control (LOC), and benefits and easement (BAE), with or through modern technology. The scales were then applied to German university students (n= 357). As a result, the pre-service geography teachers (n = 72) showed higher scores on the affinity scale than on the two aversion scales. Their subject-specific interest correlated negatively with intimidation and positively with the perceived benefits and easements of modern technology, while the perceived loss of control showed no significant correlation. This allows for the conclusion that the subject's technology-related interest has an influence on cognitive and behavioral attitudes, while this is not the case for affective ones. Further, there are indications that the much-discussed gender gap in technology topics might particularly be related to people's affective attitudes, while cognitive and behavioral dimensions seem not to be affected. Differing results in other studies on whether the gender gap still exists or not could be due to the fact that, in addition to growing social awareness and a generational change, the measuring tools used may have not yet been able to depict a sufficiently diverse range of attitudes.

Keywords: technology education; modern technologies; geography teacher education; attitude-study; factor analysis

2.1 Introduction

Two phenomena in particular are increasingly affecting life on our planet and are followed by long-term consequences and effects on societies and the environment: Together with climate change, environmental degradation with the loss of biodiversity, and the resulting ecological and social crises (Tolefson, 2019; BMZ, 2017; UNESCO, 2014; IPCC, 2012), humanity is facing a constantly accelerating technological progress and the associated digital shift in society (Albert et al., 2019; Dávideková, 2016; Tully, 2003). The latter might harbor social and ecological risks itself, but also brings great potential for solving some of the core problems of our time (Hodgson, 2020; Birkelbach et al., 2018; Seele & Lock, 2017; Peters 2013). Moreover, this is a core concern of geography and geography education when it comes to the major challenges facing humanity in the con-text of global change.

In scientific practices, the value of modern technology (MT) for geographic research has long been recognized and by now is inevitable. Modern climate and ecological models depend on automatically measuring and communicating sensor networks and big data approaches with the use of artificial intelligence to gain a more comprehensive spatial understanding of the functions, interactions, and development of complex systems (Gottwald et al., 2021). Geographical information systems (GIS) have mostly replaced the use of print media and maps in science and applied areas (Malaainine et al., 2021; Pourabbas, 2014), even if they continue to be used in school education. Spatial analyzes have reached a new level through global positioning systems (GPS) and remote sensing technologies, such as satellite-based or airborne surface scans at any scale (Ludwig et al., 2020).

MT, along with digitalization, has also conquered most people's professional and educational lives, most recently reinforced by the COVID-19 pandemic (Marston et al., 2020). This also results in new professions with special demands on the skills and knowledge of current and future generations.

MT has also become an indispensable element of societies around the globe (Marston et al., 2020). People live in Smart Homes equipped with the latest high-tech gadgets for more comfort-able and efficient living, while digital entertainment, information, and communication are permanently available via global data networks (Hasan et al., 2018; Alaa et al., 2017). Municipalities are developing fully networked cities based on the example of Industry 4.0 (Calbimonte et al., 2017), where full automation with sensor networks and intelligent control algorithms has proven to be advantageous for many reasons (Baba et al., 2019). This makes the entire supply system of a city, as well as its mobility structure, just as smart as the intelligent vehicles that move in it (Eiza et al., 2020).

Most technology innovations can come with both risks or negative effects on the environment and society as well as the potential and the opportunities that arise with them. Currently, technology development and production are partially interlinked with the exploitation of natural resources and human labor and the use of immature disposal or recycling strategies (Oswald et al., 2020, Kleine et al., 2012). Furthermore, the appearance of new technical aids has permanently changed the way how people cope and interact with their natural and social environments (Oswald et al., 2020; Welledits et al., 2020). The fact that people are confronted with technology on a daily basis does not automatically mean that everyone has now become a sovereign and responsible user (Küsel et al., 2020; Peters, 2013; Tully, 2003).

Nevertheless, the use of MT has the potential to cope with some of the current social and ecological challenges and offers many opportunities for the sustainable development of our future (Seele & Lock, 2017; Buthani & Paliwal, 2015). However, it would be wrong to just delegate the responsibility of solving today's environmental problems to technology without a literate society that has been educated and enabled to use it (Gómez-Trigueros et al., 2019; Huff et al., 2012).

Thus, basic technological and digital competencies must take the place of a predominant digital and technological distance in the population (Pfenning, 2018;

Blonder et al., 2017). To maintain or even facilitate a technologically literate ability to grasp, understand, and assess the potential of MT in social contexts, having an emancipated attitude for their sensible use is required (Birkelbach et al., 2018; Zinn, 2018; Schmayl, 1995).

Meanwhile, in schools, technology education (TE) is still mostly limited to specific educational formats or subjects. In the USA, the UK, and Australia, it is, for instance, the subject compound of science, technology, engineering, and math (STEM); in Malaysia, it is design and technology (DNT) and in German schools, there is math, informatics, natural sciences, and technology (MINT) (Rosman et al., 2019; Smith & Watson, 2019; Knogler & Wiesbeck, 2017). Geography in Germany is not a traditional MINT or STEM subject, although there are overlaps. Examples include digital geomedia and contents such as GIS, aerial and satellite photographs, or climate data and climate change. These are topics and methods of geographic education (e. g., German educational framework) (DGfG, 2020) that are directly connectable to STEM contexts. GIS, for example, is often required in geography curricula and frameworks in Germany, e. g., educational standards in geography for the intermediate school certification (DGfG, 2020). At the same time, there are various teaching materials for GIS in geography teaching (Healy & Walshe, 2020; Fargher, 2018), as well as GIS is discussed for higher education (Schulze et al., 2013). Furthermore, it is geography that, unlike other subjects, provides a framework from the outset to teach traditional science and MT in combined approaches (DeMers, 2016). Therefore, geography lessons bear a high potential to converge TE by not only keeping technology as an educational medium in the classroom but as an object of its content that needs to be critically examined (DGfG, 2020; Islahi & Nasrin, 2019).

It is a main focus of geography to recognize, understand, and evaluate the central economical, ecological, and societal challenges of mankind. Therefore, like no other subject, geography has the potential to capture and address the constantly evolving, technologically framed human-environment relationships in all their complexity.

Ultimately, however, the quality of a lesson is very much determined by the teacher (Kunter et al., 2011). Successful teaching for TE as an inclusive element of geography does not come from the mere existence of technologies in the classroom; the active involvement and support of teachers are crucial to foster students' competencies for the appropriate use of MT (Rosman et al., 2019).

> *Teachers who are expected to educate their students, as highly qualified and ethically sensitive individuals in technology and environmental issues [that have emerged in recent years] should themselves be sensitive to these issues. (Ceyhan & Sahin, 2018, p. 2)*

Therefore, teachers need to be capable of assessing and exploiting the profound possibilities that technologies can provide for an educational process (Islahi & Nasrin, 2019). Personal values, convictions, and attitudes affect those capabilities and eventually the learning outcome of the students (Kunter et al., 2011). Therefore, to ensure that technology is treated as a high-quality educational subject in geography lessons, it is essential to take a close look at the teacher's dispositions. In order to relate the role of geography teachers to the topic of societal technological literacy in geography for higher education and to assess and assure the quality of their practice, further research on teachers' attitudes towards technology is needed.

2.2 Theoretical Background

Kunter et al. (2011) describe the teacher as the central determinant of school success. In addition to motivational orientations (Kunter et al., 2011) and professional knowledge (Schulman, 1986), in the competency–theoretical approach of professionalism in the teaching profession, attitudes are particularly important dimensions of the professional competence of teachers (Brunner et al., 2006).

In people's mindsets, attitudes work like filters for new experiences and can determine people's behavior (Reichart, 2017; Kaiser & Wilson, 2000; Scott & Willits, 1994). Teachers' attitudes, in particular, not only determine their own way of thinking and acting but even more influence the knowledge, attitudes, and behavior of their students (Westerback, 1982). Studies with science teachers indicate that their attitudes towards the natural sciences have an impact on the attitudes of the students (Westerback, 1982). Accordingly, teacher convictions are a central aspect of teacher professionalism (Kunter et al.,2011). Westerback assumed already in 1982 that there was a positive correlation between teachers' attitudes toward their subjects and their professional knowledge. In later studies, it was found that individuals who have a positive attitude towards a topic are more likely to seek additional information about it than those who assign a topic area only low relevance (Blankenship & Wegener, 2008; Holbrook et al., 2005).

In general, attitudes are latent constructs that can be divided into cognitive, affective, and conative response behavioral dimensions (Eagly & Chaiken, 2011). A cognitive dimension of technological attitudes could, for instance, relate to the conscious exercise or loss of control on or with technology (Parasuraman, 2000). Other researchers describe perceived control as a separate, fourth dimension of attitude (Zanna & Rempel, 2008; Rosenberg et al., 1960). In our case, the presence or absence of control then contributes to the overall set of attitudes towards MT. It is similar to the contribution of affective elements; for example, for anxiety or trust that is evoked when the user is convinced of the technology's qualities or intimidated by its complexity (Osiceanu, 2015; Rosen & Weil; 1995). Finally, behavioral components also come into play. This includes, among others, a perceived easement or difficulty evoked in or through the operation of MT (Legris et al., 2003). Even if all three or four dimensions cover different psychometric areas, they do not necessarily have to be present as a unit, but can also shape the attitude as individual factors (Eagly & Chaiken, 2011).

In the past, when it comes to examining technological attitudes in the educational context, the focus was much more on the learners than on the teachers. Researchers have identified students' attitudes towards technology as important factors influencing the success of learning about those topics and their behavior (Islahi & Nasrin, 2019; Ardies et al., 2013; van Rensburg et al., 1999; Wolters, 1989). The most examined predictors for relations to technology in both groups are interest, age, gender, and the personal content focus (Gómez-Trigueroz et al., 2019; Islahi & Nasrin, 2019; Marth & Bogner, 2019; Niiranen, 2016; Potvin & Hasni, 2014a; Potvin & Hasni, 2014b; Riconscente, 2014; Ardies et al., 2013).

Studies show a positive connection between teacher and student interest (Riconscente, 2014). Reichhart (2017) sees the teacher's interest also as a relevant factor influencing the teacher's attitudes. Interest in MT should therefore be considered in this context.

The age of the examined groups could also play an influential role depending on the target variable. For example, Kubiatko (2012) found that older students have fewer positive attitudes towards geography than younger. In a meta-study from 2014, Potvin identified 24 international studies that reported a decline of either motivation, interest, or attitudes towards science and technology with age or school year. One year later, a study on French and Belgian students' attitudes towards technology came to the same conclusion (Ardies et al., 2013). Gómez-Trigueros et al. (2019) found that future teachers show a lack of knowledge of certain technological concepts essential for their future teaching that differs with age.

Even if there are no known gender differences in attitudes towards geography (Kubiatko et al., 2012), the gender gap in technological issues has been studied and discussed for years (Marth & Bogner, 2019; Niiranen, 2016; Virtanen, 2015; Thaler & Hofstätter, 2012; Wolters, 1989; Nickel & Pinto, 1986). Despite all efforts at gender equality over the past decades, males, in general, seem to be more likely to perceive technology as something positive and even show higher levels of technological self-efficacy (Marth & Bogner, 2019; Potvin & Hasni, 2014a; Huffman et al., 2013). Studies with teachers only, however, show a more controversial situation. A recent study with 482 secondary teachers in India could not find any gender-specific differences in attitudes towards information technology (Islahi & Nasrin, 2019). The authors state that "rapid development and infiltration of technology in every aspect of the society to the point that technology has become an indispensable part of our daily lives, may have had an effect of equalizing difference between males and females." (Islahi & Nasrin, 2019, p. 45) Ceyhan and Sahin (2018) came to a similar result for teachers' technological knowledge. Stöckert et al. (2020), on the other hand, report findings of significant gender differences within pre-service teachers and other university students, when it comes to social aspects or interests related to technology.

The same group found that university students' social adjustment to technology differs significantly with their faculty affiliation. Ceyhan (2018) also reports that teachers' ethical opinions about technology vary with their branches (e. g., science teacher or classroom teacher). This can be of interest since the natural science disciplines (e. g., math, informatics, physics, and biology) might be more closely related to technological topics than human and social subjects are (such as psychology, politics, or languages). Rosen and Weil (1995) even report increased technophobia among secondary school teachers in the humanities subjects compared to others. Geography teachers are put in a position of exception since they have to combine perspectives from both areas and most of their disciplines, and therefore also should be open to technology-related issues.

A great variety of technical terms exists to describe a person's set of mind concerning certain topics (HGD, 2018; Uitto et al., 2011; Davidov et al., 2008; Cobern, 1991). In this study, we focus on attitudes, as for one, they are known to influence teachers' qualities (see above) (Reichhart, 2017; Ardies et al., 2013; Kunter et al., 2011), secondly, they can be expected to have a significant influence on students (Reichhart, 2017; Flath & Schockemöhle, 2009; Westerback, 1982), and third, due to rather clear definitions, their measurability seems quite efficiently compared to other more abstract constructs, such as “orientations,” “world view,” or “beliefs” (HGD, 2018; König, 2012; Cobern, 1991). Therefore, the term attitudes seem suitable and tangible enough to conduct meaningful research.

According to Tücke (2003), attitudes allow people to classify and evaluate their individual way of thinking, feelings, and experiences with regard to their environment. They are largely determined by the person's socio-cultural environment, knowledge, and beliefs (Reichhart, 2017). Even the strength of an attitude can vary (Eagly & Chaiken, 2011; Mio & Haddock, 2009).

We assume that for the successful integration of TE in geography lessons, teachers' attitudes towards MT state an important factor (Jencuis & Paez, 2003). In order to depict the respective characteristics and to describe differences and influencing parameters, it seems necessary to identify or develop appropriate instruments for the measurement of attitudes towards MT. Potentially suitable instruments were searched for, inspected, and assessed according to their actual suitability.

In summary, the following research gap can be derived: Despite the importance of MT for teaching geography, there is a lack of knowledge on teachers' attitudes toward MT for the subject. This study aims to fill the gap and provide answers to the following questions:

(1) How can teachers' attitudes towards MT be measured and what attributes and qualities does the corresponding instrument have?

(2) What are the actual attitudes of pre-service geography teachers to MT?

2.3 Materials and Methods

To achieve the aim of the study, the following methodological steps were chosen. In a first step, existing measurement instruments and items were reviewed and evaluated for their suitability for use. In the second step, the suitable items were tested in mixed pretest procedures before they were used in the final step to measure the pre-service teachers' attitudes and compare them with peers of different ages, subjects, or types of graduation in a cross-sectional study.

2.3.1 Review of Measurement Instruments

When it comes to measuring teachers' attitudes towards MT, in particular, instruments are scarce. Some limit their research to certain technological areas or contexts such as information technologies (Gómez-Tigueros et al., 2019; Islahi & Nasrin, 2019) or social aspects of technology (Stöckert & Bogner, 2020; Marth & Bogner, 2019) or focus on the use of mobile devices (Heflin et al., 2017) and computers only (Deniz, 2007; McCarthy, 1998; Nickell & Pinto, 1986).

Tools to examine relations towards general technology used in educational settings mostly focus on the learners (Ankiewicz, 2019; Crawford et al., 2017; Ardies et al. 2015; Potvin & Hasni, 2014a; Ardies et al., 2013; Bitner & Bitner, 2007; Pierce et al., 2007; van Rensburg et al., 1999; Wolters, 1989; Shulman, 1986). Two frequently used instruments here are the Pupil's Attitude Towards Technology (PATT) Scale (Ankiewicz, 2019; Volk & Yip, 1999; van Rensburg et al., 1999; Wolters, 1986), which was not developed for the target group of teachers and is therefore not very suitable, as well as the short Technology Questionnaire (sTQ, Marth & Bogner, 2019), which, however, is less substantial as it depicts only two dimensions for this study. The few instruments used to examine teachers' relations towards technology, on the other hand, either focus on their sensitivity, intentions, interest, or thoughts (Stöckert & Bogner, 2020; Ceyhan & Sahin, 2018;

Anderson et al., 2011; McRobbie et al., 2000), rather than the dimensions of their actual attitudes.

A compact scale that queries the most important dimensions of technology attitudes and can be used for adults, especially teachers in geography lessons, has yet to be developed. However, the valid Computer Attitude Scale (CAS) by Nickell and Pinto (1986) fulfills the central requirements. Since its creation, the scale has proven itself in several international studies and different settings (Tussyadiah et al., 2017; Tsai & Tsai, 2003; Harrison & Rainer, 1992), and its alignment has already been successfully adapted once for the measurement of people's comfort with robots (Sims et al., 2009). At the time of its development, computers could be seen as the central representative of MT and their increasing use in people's everyday life was aimed to be reflected from different perspectives in the items of the CAS. Even if later users of the scale report certain factors, e. g., "positive and negative attitudes toward computers" and "intimidation toward computers" supposedly being covered by the scale (Rainer & Miller, 1996; Harrison & Rainer, 1992) the authors do not explicitly name any sub-dimensions. However, the creators discuss a substantial range of attitudinal reactions that should be reflected in their tool. They refer to positive aspects, such as the perceived ease of work and comfort, as well as critical points, such as anxiety and discomfort, that could be triggered by technology use. Finally, they developed a 20-item scale (eight positive and twelve negatives) that shows broad applicability and good internal consistency. Furthermore, none of the other instruments sighted (see above) seem to meet the requirements as well or be comparable in terms of their general validity with the CAS by Nickell and Pinto. Since they even suggested further validation and application of their scale in educational settings themselves, (Nickell & Pinto, 1986) it seems promising to pick up where they left off.

2.3.2 Survey

First of all, CAS by Nickell and Pinto was translated into the German language and the content of its items was adapted in line with the times and further purpose. A first version of the scale consisted, similar to the original instrument, of 20 Likert-scaled items, each with four possible answers: "fully agree," "tend to agree," "tend to disagree," and "strongly disagree". Before the actual investigation, the modified items were tested and optimized in two pre-testing phases in late 2020; first, with the help of cognitive techniques, e. g. think aloud, probing, and paraphrasing (Lenzner et al., 2016). The sampling was composed of students from different age groups to citizens. The results showed high comprehensibility of the items in the cognitive procedures as well as a good fit to CAS by Nickell and Pinto. Subsequently, a descriptive statistical evaluation, including factor analysis, was conducted on the scale.

Finally, a total of 14 items within three subscales recording different dimensions of attitudes to MT were compiled (see appendix A). The factor analysis (see 2.4.1) confirmed the presence of three factors in the transformed scales. The newly created Modern Technology Attitude Index (MTAI) describes the affinities and aversions towards MT as:

- Intimidation (INT),
- Loss of Control (LOC), and
- Benefits and Easement (BAE).

After construction and pretesting of the MTAI, the complete measurement instrument included three parts:

1. The first part of the questionnaire consisted of questions aiming at the personal data of the students, such as age (AGE), gender (SEX), and specific data concerning their studies such as the count of semesters studied (SEM), the aimed type of graduation (TOG), and the field of science (FOS) they are studying.
2. In a second part, the respondents were asked to indicate their interest in the main topic of modern technology (MTI), each on a scale from 1–10. 1 equals “not interested” and 10 “strongly interested”.
3. The third and final part aimed at the student’s attitudes via MTAI.

2.3.3 Data Collection

The research presented in this article aimed to investigate and compare attitudes towards MT of German university students, with a focus on pre-service geography teachers. The methods are descriptive and based on quantitative data. n = 357 took part in an overall survey of all students at Philipps University, Germany. In a cleaned dataset, a total of 343 subjects could be analyzed by the use of their provided data. 209 female and 130 male (diverse genders (n_d = 4) were also recorded, but could not be taken into account for the calculations due to matters of group size) participants were classified according to their field of science (FOS; as geography = GEO, natural sciences = NSC, or human and social sciences = HSSC) and differentiated according to the type of graduation (TOG; as TE = teacher, bachelor = BA, master = MA, or other, less common forms of study (such as "Magister" or "Staatsexamen," which can, for instance, be found in the disciplines of medicine and pharmacy in Germany) = Else). 139 studied geography (72 of them for teaching) and the other 197 (students with missing or no clear assignment (e. g., because of double enrolment), were recorded (n = 7) but excluded from this listing) other subjects in the humanities or natural science subjects (see table 2.1).

Table 2.1: Frequencies of type of graduation (TOG).

FOS[1].	TOG	Frequency
Geography	Bachelor	61
	Else	0
	Master	6
	Teacher	72
	Total	139
HSSC[2]	Bachelor	27
	Else	18
	Master	15
	Teacher	28
	Total	88
NSC[3]	Bachelor	65
	Else	3
	Master	32
	Teacher	9
	Total	109

[1] field of science; [2] human and social sciences; [3] natural sciences; (cases with missing information or not clear assignment were excluded from this table).

The age of all participants ranged between 18 and 60 years (pre-service teacher geography, 19 to 32 years) and the semester between 1 and 13. For geography pre-service teachers, see figure 2.1.

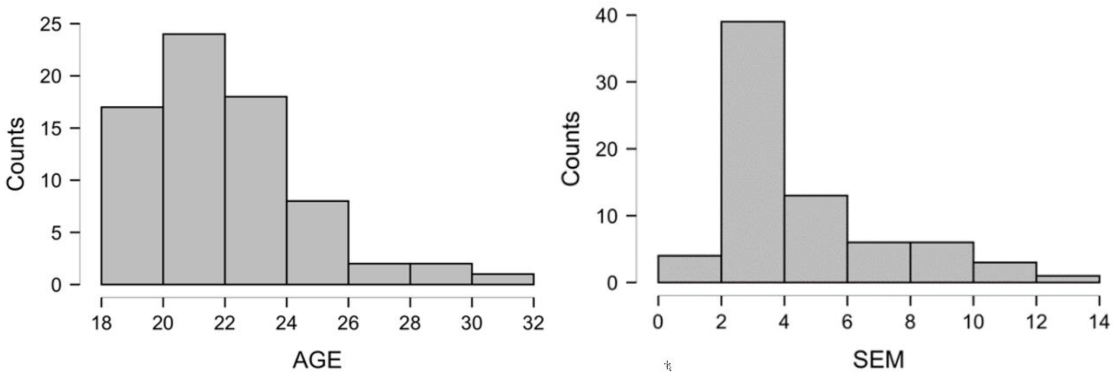

Figure 2.1 Age and semester of pre-service geography students.

The data was collected in the winter of 2020/21. Therefore, an online survey was shared with the students via e-mail and, in the case of the institute for geography, also during lectures.

The questionnaire for an online survey was generated using SoSci Survey (Leiner, 2016) and was made available to users via www.soscisurvey.de (May 12th 2021). The free statistical software R and the additional program R-Studio, version R-4.0.2, were used for the cleansing of the data and the classic test theory, including factor analysis, for the development of the instrument (RStudio Team, 2020). Descriptive methods were conducted with the free statistical software JASP, version 0.14.1 (Wagenmakers, 2021). The data presented in this study are openly available via the research data repository of Philipps University: https://data.uni-marburg.de/handle/dataumr/138 (October 4th 2021) (Bengel, 2021).

2.3.4 Data Analysis

The MTAI was composed by using multivariate analysis techniques for item selection and identification of subdimensions through the examination of factor loadings, eigenvalues, and explanation of variance (Costello & Osborne, 2005). For further adjustments methods of classic test theory for assessment of difficulty, variance, and selectivity of the items and internal consistency by using Cronbach's Alpha were taken into account (Moosbrugger & Kelava, 2012; Bühner, 2011). For the examination of underlying structures of the MTAI, an exploratory factor analysis (EFA) with oblimin rotation was chosen, for a sample of n = 343 (Cohen, 2013; Costello & Osborne, 2005). EFA with oblique rotation was used because this makes it possible to undertake a data-driven exploration, considering the fact that latent variables might correlate and could contain some unexplained variance (Ardies et al., 2015; Costello & Osborne, 2005). Additionally, the difficulty, selectivity, and variance of all items were examined and the results were used for a conclusive compilation of our instrument (Moosbrugger & Kevala, 2012). For the descriptive analyses in our study, the means of the final MTAI scales for each case were calculated as test values.

2.3.5 Scores

By convention, a level of statistical significance of alpha = 5% (= 0.05) was determined for the analyzes. Each item was assigned a weightage ranging from 4 (strongly agree) to 1 (strongly disagree) for favorable items. The scales INT and LOC were defined to measure dimensions of disfavor, while BAE was measuring favor of MT. The attitude score of an individual was the mean of item scores on each scale.

To measure differences between several groups, separated field of science (FOS), or type of graduation (TOG) within the sample, the one-way ANOVA was used (Cohen, 2013). The fulfillment of the prerequisites, homogeneity of variance, and normally distributed residuals were confirmed with Levene's test and a quantile–quantile (QQ) plot (Lakomý et al., 2020; Döring & Bortz, 2016; Marden, 2004; Brown & Forsythe, 1974). A post-hoc test with Bonferroni p-value adjustment was used to identify any individual differences (Bortz & Schuster, 2010). Since test mean values cannot be assumed to be distributed normally, correlations between AGE, SEM, and MTI were checked by the use of Spearman's Rank Correlation with the coefficient rho (Döring & Bortz, 2016). According to the above-named literature (Gómez-Trigueros et al., 2019; Ardies et al., 2015; Potvin & Hasni, 2014b; Kubiatko et al., 2012), AGE and SEM can be expected to correlate negatively with affinity and positively with aversion of MT, therefore a corresponding one-tailed correlation test was selected. For inspection of differences in gender, a Mann–Whitney U test was used since a deviation from normality had to be assumed (Bortz & Schuster, 2010).

2.4 Results

2.4.1 Quality of the Modern Technology Attitude Index (MTAI)

To answer the first research question - How can teachers' attitudes towards MT be measured and what attributes and qualities does the corresponding instrument have? - an adapted instrument should be developed. From the first 20-item-version of the MTAI, six items were removed due to reasons of low selectivity, too high or low difficulties, or lower and multiple factor loadings.

The factor analysis revealed a three-factor solution with clearly shaped dimensions which are also convincing in terms of content and fit into the psychometrical framework. The three dimensions are referred to below as the sub-scales intimidation (INT), perceived loss of control (LOC), and perceived benefits and easement (BAE) with or through MT (see appendix A).

The INT-factor, with an eigenvalue = 2.50, accounted for 17.8% of the covariance (see table 2.2). Item loadings ranged from 0.70 to 0.91. The items defining this factor represent the affective dimension of intimidation through MT and contribute in a negative (aversion) direction to the MTAI. The second factor (LOC), with an eigenvalue = 2.07, accounted for 14.8% of the covariance. Item loadings ranged from 0.58 to 0.73. Those items depict the more cognitive dimension of control in relation to the use of MT, which also contributes negatively to the index. Items loading on the third and final factor (BAE) ought to represent the behavioral part of attitudes towards MT. They display the subject's affinity through perceived benefits and easement and therefore contribute positively to the MTAI. An eigenvalue of 1.87 and an explanation of 13.4% of the covariance, with factor loadings between 0.50 and 0.74, are achieved. The three factors together are able to explain 46% of the total variance in the sample.

The MTAI as a whole (Cronbach's α = 0.83) but also each of the three scales for itself show good internal consistencies (INT with four items, α = 0.87; LOC with five items, α = 0.79; BAE with five items, α = 0.72).

Table 2.2: Factors of MTAI sub-scales and explained variances.

Abr.	Factor	Nr. of items	Expl. var. (%)
INT	Intimidation through MT	*4*	*17.8*
LOC	Perceived loss of control with MT	*5*	*14.8*
BAE	Perceived benefits and easement with MT	*5*	*13.4*
	Total Variance	*14*	*46.0*

2.4.2 Geography Pre-Service Teacher's Attitudes on modern Technology

To address the second research question - What are the actual attitudes of pre-service Geography teachers to MT? - the geography pre-service teachers are now considered. Within the three dimensions of the MTAI, future geography teachers position themselves somewhat more positive in their attitude towards MT, as the average scores on the two aversion scales are lower (INT = 2.00; LOC = 2.69) than those on the affinity scale (BAE = 3.06). The highest agreements are found in the BAE scale, with a maximum score on the items that state that MT can eliminate a lot of tedious work for people and is responsible for many of the good things we enjoy (BAE). A minimum of agreement is particularly received by the statements that MT is difficult to understand and frustrating to work with (INT) and soon our world will completely run by MT (LOC).

Correlation testing with the pre-service geography teachers ($n = 72$) of content-related interest showed a moderate negative correlation between MTI and INT ($\rho = -0.66$), which is highly significant ($p = 9.28\times10^{-10}$). The correlations test between MTI and LOC showed no results with definite significance, while BAE shows a distinct positive correlation ($\rho = 0.26$, $p = 0.03$) with sufficient significance (see figures 2.2 and 2.3).

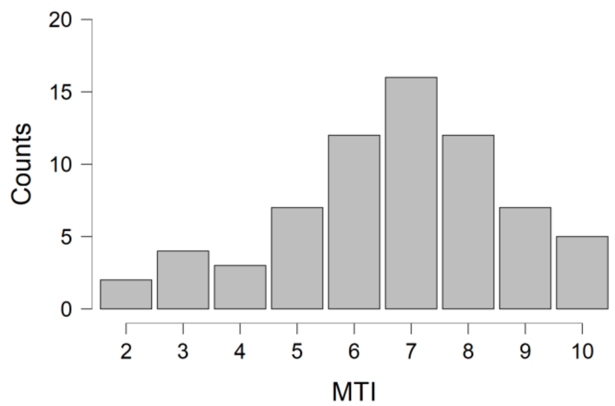

Figure 2.2 Distribution of geography pre-service teachers' interest in MT.

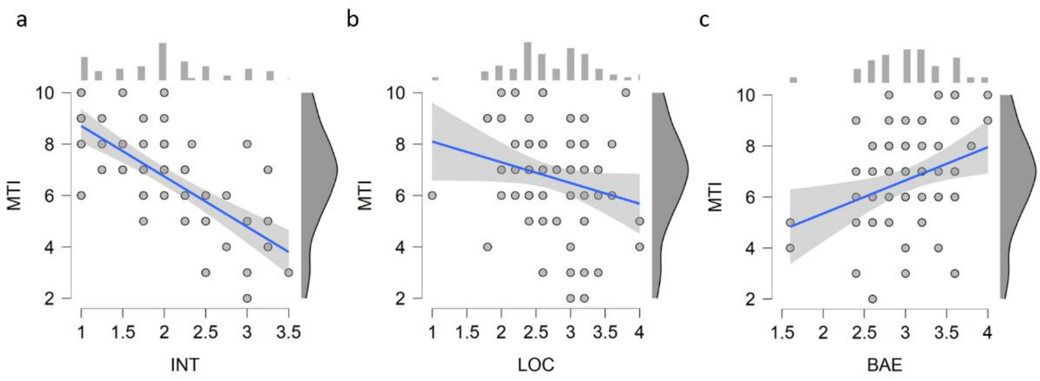

Figure 2.3 Correlations between (a) INT, (b) LOC (no significant correlation), and (c) BAE scores of geography pre-service teachers with their interest in MT.

Pre-service geography teachers do not show any significant correlations between either age (AGE) or semester (SEM) and any of the MTAI scales. The overall subject's AGE and SEM showed neither significant correlations with INT nor LOC. Only AGE correlates negatively with BAE ($\rho = -0.23$, $p = 0.03$), while SEM does not.

Differences in the gender of pre-service teachers of geography ($n_m = 31$ and $n_f = 40$) could be proven for the INT-scale (U-value = 800.00), which showed sufficient significance ($p = 0.02$) (figure 2.4). This indicates that the psychological construct for affective aversions towards MT on cognitive levels measured by this scale might be pronounced stronger with females than males.

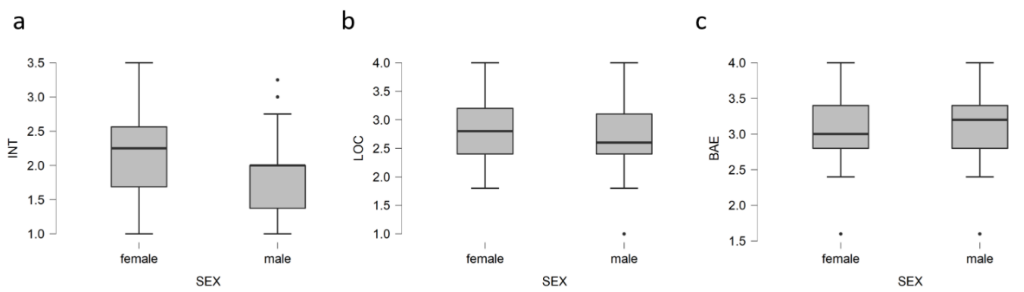

Figure 2.4 Gender distributions of geography pre-service teachers for their (a) INT, (b) LOC, and (c) BAE scores.

2.5 Discussion

2.5.1 Discussion of Research Approach

This study aimed to answer the question - How can teachers' attitudes towards MT be measured and what attributes and qualities does the corresponding instrument have? Therefore, an instrument for quantitative measuring of attitudes towards MT was developed on the basis of existing items by Nickell and Pinto (1986) and tested subsequently. The final instrument was used to measure the attitudes of pre-service geography teachers within three different sub-dimensions and to compare them with those of students from other subjects and forms of study. Even if no differences could be determined within any of these groups, some clear gender differences and influence of age and a connection between attitude and content-specific interest could be identified. The results will be discussed in the following light of the relevant literature.

2.5.2 Discussion of Sampling

The Philipps University of Marburg covers a wide range of different disciplines in the natural sciences, humanities, and social sciences so that a sufficiently wide sample could be assumed. Subjects for the study were recruited using a circular email that was sent to all students at the University of Marburg. In the geography department, there was additional verbal advertising for study participation in the lectures and courses.

Due to this type of recruitment, interested and motivated students mainly declared themselves willing to participate as test subjects. This fact could explain the low rates of participation, considering the total number of students in Marburg, and must be considered when interpreting the results.

The inequality of male and female test subjects is also an outcome of this advertising process and was not intended. When looking at our results, it should therefore be considered that the proportion of male and female participants does not represent the gender distribution of all students at the university or the department. Rather, the reason for this imbalance could be that there may be a greater willingness among women to participate in studies of this type (Lakomý et al., 2020). Nonetheless, our sampling still meets the necessary empiric requirements and is sufficient to prove the suitability of our newly developed research instrument, on the one hand, and on the other, to gain valuable insights into the attitudes of pre-service geography teachers towards MT.

2.5.3 Discussion of Instrument (MTAI)

The results show that the MTAI has several desirable properties. First of all, there is a clear separation of the underlying dimensions with relatively high and clearly differentiated factor loads on the items. The items correspond to the usual conventions in terms of selectivity, variance, and difficulty (Bühner, 2011). Compared with the original 20-item solution for computer attitudes, both the three sub-dimensions, despite their relatively small number of items, and the MTAI as an overall construct bare satisfactory internal consistency, as their Cronbach’s alpha values show.

Since there is no other suitable reference tool for cognitive, emotional, behavioral, and/or control-related measurement in attitudes towards MT, our factors cannot be clearly assigned to these psychological dimensions either (Eagly & Chaiken, 2011). Still, a division into these areas is conceivable.

Yet, the alignment of the content-specific interest compared with our three scales helps to assign these to either the affinity or the aversion spectrum. The negative correlations of interest and intimidation and perceived loss of control due to MT indicate a measured aversion in these dimensions, as well as a positive correlation of the benefits and easement scale, which indicates a dimension of MT affinity. If one considers findings according to which interest is an implicit element of attitudes or at least strongly influences it, this is an important result (Marth & Bogner, 2019; Reichhart, 2017). That means that content-specific interests are predictors of content-specific attitudes for MT.

2.5.4 Discussion of Findings

Within the three dimensions of the MTAI, future geography teachers tend to position themselves more positively in their attitude towards MT, as the average scores on the two aversion scales are lower than those on the affinity scale. This can be interpreted as a positive result since it suggests a good precondition for the successful integration of TE in future geography lessons. Interestingly, neither the group of teachers from other fields of study (bachelor, master, else) nor the group of geography students from other subjects (natural sciences or humanities and social sciences) differ significantly in their scores. According to our findings, choice of the subject such as natural sciences, human and social sciences, or geography as some kind of cross-over does not show any influences on any level of the student's MT attitudes. In previous studies, differences in social or emotional attitudes towards technology were found, depending on the subject (Stöckert & Bogner, 2020; Ceyhan& Sahin, 2018). Additionally, for example, a higher technophobia was measured among teachers in human science subjects (Rosen & Weil, 1995). However, all those studies focused on in-service teachers only, who can be expected to most likely be at least a little older, more experienced, and maybe also already shaped by their subjects (Ceyhan & Sahin, 2018; Rosen & Weil, 1995). It is conceivable that young people, as in our case as a result of technologization, which is an integral part of most of their lives, are generally less biased and more open to MT than older generations, regardless of their professional interests. The same might apply to one's chosen type of graduation. Neither the attitudes of pre-service teachers, bachelors, masters, nor any other type of study differed significantly from the others. This, too, could be a sign that technology has arrived and is being accepted as an integral component at broad levels in younger society by now, and suggests a rather unconditionally positive attitude towards TE in this part of society.

It was not surprising that the two aversion scales showed negative and affinity scale positive correlations with content-related interest. This supports the assumptions that we initially made based on existing theories of interest and motivational orientations by Reichhart (2017) and Kunter et al. (2006). Thus, subjects who indicated a strong interest in MT also had higher scores on the affinity scale and lower scores on the aversion scales.

The pre-service geography teachers' age or semester did not show significant results in terms of correlation with their MT attitudes, which could be explained due to the rather small sample size. In the overall cohort, at least age correlates negatively with perceived benefits and easement with MT. This also fits into the above explained thesis that younger people bring an inherent openness to MT. Even if the values here are not very strong either, they get along with the results of previous studies in which a decrease in positive attitudes with increasing age was reported (Potvin & Hasni, 2014b; Kubiatko, et al., 2012). A correlation with the factors INT and LOC, however, cannot be found within any of our subject groups. If there was actually no relation here, it could be concluded that the expressions of the affective and cognitive attitude dimensions to MT might be independent of age groups. Since all three dimensions cover different psychometric areas, they can also influence attitudes as individual factors and correlate (or not) individually with other parameters (Eagly & Chaiken, 2011). This is also evident in the results on gender differences.

We found that female pre-service geography teachers as well as the other female students differ from the male, particularly in the affective dimension. They show significantly higher perceived intimidation than the males. Furthermore, no differences in gender can be identified in the other two dimensions (LOC, BAE). In many other studies, different aspects and psychometric areas of attitudes towards technology were examined, and here too the results with regard to the gender differences were ambivalent (Islahi & Nasrin, 2019; Marth & Bogner, 2019; Virtanen et al, 2015; Deniz, 2007). In the long series of studies on this subject, this now is the first that suggests that the differences between male and female attitudes may only be reflected on certain levels of attitude and not in an overall view. In the case of MT, it is the emotional or affective dimension that differs, while cognitive and behavioral levels do not differ. In addition to the selected aspect of the technology, the ambivalence of previous studies could then also be explained by the choice of insufficiently differentiating measuring instruments.

In order to close the gender gap, concepts should be created in teacher training that focuses on the affective, i.e., the emotional, dimensions of technology attitudes. If fears and concerns can be dealt with rationally during the studies, those affected may be positively influenced and can later pass this attitude on to their students. One approach to creating appropriate measures might be to make use of the influence of the content-related interest on attitudes.

We suggest further use and trials of the instrument. It seems likely that the MTAI can also be applied beyond the group of student teachers without ruling out any further adjustments or improvements. It would also be quite interesting to use the instrument together with similar or different attitude measurement tools to learn more about the dimensions of attitudes towards MT.

We see that our findings are not only relevant for the development and design of training for future geography teachers but also consideration from the perspective of sustainability education. Technology itself and its effects have become an integral part of our lives. It is expedient here to consciously recognize TE as a component of all areas of modern life and especially to incorporate it into school subjects, just as it happens with education for sustainable development (UNESCO, 2020; Yli-Panula et al., 2020; Birkelbach et al. 2018). After all, TE and ESD have a lot in common from which innovative teaching-learning concepts can be derived (Yli-Panula et al., 2020; Rosman et al., 2019). Hardly any subject is better suited to accomplish this task than geography.

2.5.5 Limitations of the Study

Limitations of our study that could not be avoided but should be considered are briefly summarized below. With the choice of a bipolar four-point Likert scale, a compromise was deliberately made for this study. Whether a Likert scale should contain an even or an odd number of options or an “undecided” option is a matter of controversy (Nemoto & Beglar, 2014; Bühner, 2011). We made our decision with the aim of maximum clarity and simplicity.

Some restrictions certainly result from the sample, which was made up exclusively of students from the University of Marburg. A larger, national, or even international sample could, for organizational reasons, not be implemented. If it was, it could have produced more meaningful or detailed results under certain circumstances. In particular, a larger group of pre-service geography teachers might have enabled the identification of possible correlations between age and attitude, as it was also found in the overall sample.

Low participation rates, even within the limited range of suitable subjects, might be due to the voluntary and mostly impersonal recruitment process, which unintentionally extracted the rather motivated and interested individuals. Just as unwanted was the imbalance between male and female test subjects in our sample, which unfortunately does not represent the population and is probably, at least in part, also due to the recruiting process (Lakomý et al., 2020).

Another caveat concerns the verification of our instrument. This comes with the lack of suitable comparison scales, which would have allowed better adjustments of our instrument, and maybe even help identify more dimensions of MT attitudes (Eagly & Chaiken, 2011).

2.6 Conclusions

MT is playing an increasingly important role in our society. Responsible use of it based on a literate mindset should be the goal of TE, which, like ESD, should be an integral part of all levels of education. The subject of geography can be given particular importance due to its interdisciplinary positioning and strong application focus. That is why it is particularly the geography teachers of the future from whom we must expect an open and responsible attitude towards the role of MT in our society, in addition to the competencies to convey it along with the respective skills. With the MTAI, we created and successfully tested a practical instrument to depict teachers' attitudes towards MT within three different psychometric dimensions. With subscales for each of the dimensions, it covers a cognitive, an affective, and a behavioral range of attitudes related to MT. Next, we suggest that our instrument should be tested further in other settings and with different subject groups. We found out that the general attitudes of pre-service geography teachers towards MT are rather positive ones, and that they could partially be described by the participants' content-specific interests. A gender gap does not seem to be a fundamental phenomenon when it comes to overall MT attitudes, but it could be mainly due to the affective side of attitudes. Based on our results, better teacher training concepts can be developed in which the influence of the content-specific interest is used and the gender gap in MT attitudes can be counteracted on an affective level. In further research, the MTAI could also help evaluate the quality of new teacher training and further education programs or compare attitudes towards MT to other success factors of innovative educational concepts.

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3 Technology in Nature — mDGBL as a Successful Approach to Promote Complex Contents?

This chapter has been published as:

Bengel, Phillip T.; Peter, Carina (2023): Technology in Nature — mDGBL as a Successful Approach to Promote Complex Contents? In: Sustainability 15 (1), S. 633. DOI: 10.3390/su15010633.

Received: 24 November 2022, accepted: 27 December 2022

Abstract

The central challenges of our time mostly share a high level of complexity, which makes them unsolvable by single-perspective approaches. To offer adolescents the educational concepts that enable them to take various perspectives, comprehend, and finally deal constructively with these problems, innovative measures must be created. Additionally, the benefit of these measures must be shared equally by all learners, without being limited by their individual biographical or attitudinal characteristics. In this work, potential concepts were collected from geography education, technology education (TE), and education for sustainable development (ESD), and merged into a multi-perspective educational approach with mobile digital game-based learning (mDGBL) for the promotion of environmental and technology-related content. In the presented study, the accumulation of n = 94 Hessian students' subject-specific knowledge (SSK) was evaluated in a comparative study with a control group, along with the potential influence of gender, age, and content-related attitudes (CRA) in a longitudinal quantitative study. Firstly, in a study of this kind, in addition to the approach's short-term success, the long-term effects on subject-specific knowledge were also tested. The results prove the full success of the innovative mDGBL intervention. There were strong immediate and long-lasting effects on participants' SSK, measured right after and eight weeks after the intervention. It could be proven that, although there were partially significant gender differences in attitudes towards modern technologies, learning success was not influenced by gender, age, or any of the measured attitudinal dimensions.

Keywords: mobile learning; DGBL; multi-perspective; geography education; ESD; NEP; MTAI

3.1 Introduction

Some people think the use of modern technology and digitalization are to blame for youth's disconnection from nature. They fear that screen time is killing the green time and argue for the need for digital detox (Oswald et al., 2020; Welledits et al., 2020; Larson et al., 2019). There are indeed studies that show the growing influence of modern technologies on young people's lives, as so-called digital natives (Marston, 2019; Tully, 2003). But according to the youngsters themselves, they do not see a competitive situation between nature and technology, but much more the potential for synergies. To name one example, 71% of young people believe that nature conservation should try to make better use of the opportunities offered by digitization (Schleer et al., 2021). Considering nature and environment and modern technology as two opposing poles could be counterproductive when it comes to developing contemporary solutions for global problems (UNESCO, 2020).

As studies suggest, youth's prevailing paradigm about nature and the environment is rather positive (Kiely et al., 2021; Rideout, 2005). Therefore, there seems to be a missing link that enables largely conscious and motivated young people to interact purposefully with their natural environment. As a possible reason for their prevailing distance from nature, Brämer and Koll (2021) list the lack of access options. In this context, the authors of two independent nationwide studies on German youth conclude that need for experience-orientated educational activities is obvious and that the support of modern digital tools might bear the greatest potential for their successful implementation (Brämer & Koll, 2021; Schleer et al., 2021).

Ways still have to be found to effectively integrate new digital media into everyday school life (Herrle et al., 2020), while for modern geographers and environmental scientists, digital measurement and information technologies, as well as machine learning and data science, have long become part of their daily routine. In particular, the latest technologies have enabled the development of completely new areas within geography, such as remote sensing or digital climate and landscape modelling, which have the potential to expand the field of education with contemporary and application-related content (Meyer et al., 2019; Fargher, 2018).

The perception that, in the past, mostly ecological aspects were considered when it came to discussions about education for sustainable development (ESD) (Yli-Panula et al., 2020) prevents a consensus on our need to simultaneously protect the environment and responsibly steer technological progress (Stöckert & Bogner, 2020). Recent publications on the topic already argue that, just as is already the case with environmental science education, technology education (TE) must also be seen as an integral element of modern and successful ESD (UNESCO, 2020). Still, anchoring technological content in today's education appears to be an extensive challenge. While there has been a great effort to broadly implement environmental science education as part of ESD in most educational curricula in developed countries (Laurie et al., 2016), TE is still limited to specific educational formats or subjects. Even then, most subjects only use digital technology as educational media for pedagogical purposes or focus on its functions alone, without providing a connection to any environment or sustainability content (Yli-Panula et al., 2020; Islahi & Nasrin, 2019). Therefore, innovative didactic approaches might have the potential to start at the intersection of ESD and TE in order to provide interlinked scientific, environmental, and technological literacy.

Ultimately, it is geography that, unlike other subjects, provides a framework from the outset to teach traditional science and modern technology in combined approaches (DGfG, 2021; DeMers, 2016). Therefore, geography lessons are in the best position to implement converged ESD with TE by keeping technology not only as an educational medium but also as an object of its content that needs to be critically examined in the context of its application (DGfG, 2021; Islahi & Nasrin, 2019). This can, for example, be seen in the attempts to integrate geographical information systems (GIS) into school lessons (Fargher, 2018).

In both of these specific areas of geography education, ESD and TE, the reduction of the topic’s inherent complexity remains a central challenge (Sabelli, 2006; Sund, 2015). A promising approach to comprehending complex content is the conscious change of multiple perspectives. According to Schmayl (1995), the focus of multi-perspective approaches should be on the learner’s personal development, including examining objects, understanding their functions, and assessing their meaningful use. Furthermore, serious games or game-based learning approaches, depending on their designs, can provide frameworks that still are closely related to reality but at the same time differentiate themselves from real life’s complexity by being strictly limited in both structure and content (Prensky, 2003). Besides these benefits, the approach of digital game-based learning (DGBL) has proven to be a way to provide motivation to keep learners focused to absorb, process, and retain important content while gaming (Giannakas et al., 2018; Prensky, 2003).

Smart personal devices with wireless interfaces and built-in sensors allow any place to become a learning experience location (Giannakas et al., 2018; Huizenga et al., 2009). In the context of geography education, mobile interfaces between a real and a digital (learning) world have proven to enable location- and context-sensitive mobile learning activities (Hiller et al., 2019). Mobile digital game-based learning (mDGBL), therefore, is no longer limited in space but allows any rural, urban, or natural location to become a “modern classroom”.

Nonetheless, just because almost everyone in today’s youth has a smart device and theoretical access to extracurricular environments, this does not guarantee that the mDGBL approaches are equally suitable for everyone. Whether they are categorical gender differences or diverging individual attitudes, personal inequalities are always to be expected. It has to be assumed, therefore, that the content-related attitudes (CRA) of the individuals towards the topics treated, the locations visited, or the methods used will differ from one another and that, in addition to biographical factors, these affective attributes could affect cognitive learning success (Pratkanis et al., 2014; Eagly & Chaiken, 2011). Therefore, it should be a quality feature of an educational unit to reach everyone in its target group equally, by considering the diversity of individual prerequisites and identifying their impact on educational outcome.

In conclusion, we found it necessary to follow a new approach to creating and testing innovative educational mDGBL settings for TE and ESD in geography education. In contrast to previous research in the field, we also aim to be the first to focus on long-term learning effects and the solidity of the approach. The latter means we aim to create and evaluate an educational framework that works for a specific but still heterogeneous target group regardless of their individual requirements. In this article, we first want to discuss the theoretical and subsequently methodological components of a specific concept (the SENSO Trail) that meets the above-named requirements. We define the expected learning effects on the subject-specific knowledge of the participants and carry out an empirical comparison with a control group. In addition, we identify possible factors that could possibly jeopardize the broader applicability of the approach and test their actual influence. After a detailed presentation of our results, they are reflected in a discussion, and a conclusion is drawn.

3.2 State of Research

Mobile DGBL approaches are well suited to the context of geography and ESD in various settings, and the associated transfer of subject-specific knowledge (SSK) seems to be very successful (Janakiraman et al., 2021; Michalakis et al., 2020; Knoblich, 2020; Hiller et al., 2019; Cheng et al., 2013; Cheng & Annetta, 2012; Huizenga et al., 2009). While many studies in this field focus on immediate knowledge gain, there are still no studies examining any long-term retention of what has been learned (Janakiraman et al., 2021; Cheng & Annetta, 2012).

Cheng et al. (2013) investigated primary school students' acceptance of technology by applying DGBL to environmental education and found that their acceptance will directly be influenced by their perceived ease of use and their attitude towards the technologies used. The authors of this study assume that these parameters also influence the learning outcome, but without being able to present any evidence. Van Eck's (2006) criticism that the majority of research is limited to the efficiency of DGBL approaches is still justified today and also applies to mDGBL: it seems that scholars in the past have dwelt primarily on proving that their approaches work, rather than going a little further and answering the question of why, or rather, under what circumstances do they work and under what do they not. One sort of potential success factor - such as the chosen location, the specific setting, the structure of the intervention, or the tools, technology, and media used - could be classified as external parameters. In contrast to these setting- or application-related factors, however, there are also internal, learner-related factors that could affect the intervention. Most obvious to name are biographical factors such as age or gender (Bätz et al., 2010). But it is also conceivable that the success of the intervention could vary depending on the extent of affective (e. g., CRA) or cognitive (e. g., prior SSK) characteristics of the participants (Eagly & Chaiken, 2011). There is a direct connection between the affective attributes of a person, e. g., their attitude, and their cognitive performance, such as the accumulation of SSK (Eagly & Chaiken, 2011; Holbrook et al., 2005; Bradley et al., 1999).

Holbrook et al. (2005) suggest that the perceived importance of an object has a positive effect on the accumulation of knowledge about it. Fremerey and Bogner (2015) conducted a study with 5th to 7th graders in an extracurricular lesson on environment-related topics. They identified significant correlations between only some environmental attitudes (ecocentric) and the newly acquired knowledge, while other (anthropocentric) attitudes did not seem to correlate at all. A subsequent study even proved this connection with both dimensions for 10th graders (Schneiderhan-Opel, 2020).

In our case, this potential connection between attitudes and knowledge accumulation seems to become even more relevant, since the attitudes do not only refer to the content itself but also to the chosen setting, the tools, and the materials used (Amry, 2014). The influence of people's CRA could therefore be decisive if they are to learn something about technology-supported research of forest ecosystems while being in a real forest and actively using modern technological devices.

Attitudes might also vary between genders. This is not a rare phenomenon, as plenty of empirical evidence shows (Bengel & Peter, 2021; Brämer & Koll, 2021; Schleer et al., 2021). In studies of environment- and nature-related attitudes, it is more often females who bring more emotional connectedness to nature and pro-environmental attitudes with them, while males seem to be more reserved (Anderson & Krettenauer, 2021; Schleer et al., 2021). The gender gap in attitudes toward modern technology is discussed even more (Marth & Bogner, 2019; Potvin & Hasni, 2014). Here, males are mostly described as more tech-savvy and females as more reserved in their attitudes toward technical objects and topics (Marth & Bogner, 2019; Potvin & Hasni, 2014; Huffman et al., 2013). Bengel and Peter (2021) were recently able to distinguish the attitudes of university students toward modern technology into three different dimensions: cognitive, affective, and behavioral attitudes (Eagly & Chaiken, 2011). They found that females only showed higher perceived intimidation (affective dimension) with or through modern technology, while the cognitive and behavioral dimensions of their attitudes did not differ from males.

Not only indirectly via attitude, but also directly when it comes to the suitability of educational approaches, gender differences in the performance of participants could become apparent. Even if modern society is very interested in dissolving historically implemented gender stereotypes related to disciplines like technology and natural sciences, it must be considered that they still exist. A study presented by Dresel, Schober, and Ziegler (2007) showed that around 40% of the parents surveyed made stereotypical attributions about the natural sciences, and this had measurable positive and negative effects on their sons and daughters. Benke states that:

> *the natural sciences are part of the cultural heritage and are also very present in public discourse […]. [They] are not a gender-free zone, but […] historically male. For this reason, gender-equitable subject didactics cannot avoid dealing with gender and the stereotyping of science. (Benke, 2012, p. 217)*

Although boys are often assumed to be fonder of or more experienced with technology, computers, and digital games, it does not always affect their performance in learning. This is shown, for example, by a study by Papastergiou (2009) in which 16- to 17-year-old Greek boys and girls performed equally well in a knowledge test on computer memory after they had previously taken part in a digital learning game. The results of Bätz, Wittler, and Wilde (2010) suggest that girls, on the other hand, tend to show higher degrees of motivation and knowledge gain in extracurricular settings. Although there is proof for DGBL concepts to be suitable for the participants regardless of their gender or the level of their previous experience (Cheng et al., 2013), there is still a lack of data that would allow any statement to be made about the gender robustness of mDGBL approaches. It is therefore necessary to determine whether there are gender differences in the considered approaches and whether those have or do not have demonstrable effects on learners' performances.

The gaps in the current research outlined above are addressed in the following research questions for this study:

Q1. Does a mobile DGBL approach for ESD and TE have a sustaining influence on students' SSK?

Q2. Do affective factors such as attitude towards

Q2.1. nature and environment or

Q2.2. modern technology or

Q3. Biographical factors such as

Q3.1. age or

Q3.2. gender

have any significant effects on students' SSK acquisition during participation in the mobile DGBL approach for ESD and TE?

3.3 Material and Methods

The SENSO Trail (Science Education and Natural System Observation) is implemented in the research and educational forest of Philipps University of Marburg in Germany. SENSO Trail is an educational concept in which approaches from digital nature trails, geocaching, open-air science education, and mDGBL are combined into an innovative adventure trail. The project was funded by the Hessian State Ministry for Higher Education, Research, and the Arts, Germany, as part of the LOEWE priority project Natur4.0 – Sensing Biodiversity. In Natur4.0, natural and environmental research and modern technology are combined with approaches and perspectives from multiple disciplines on different scales (Natur 4.0, 2020; Friess et al., 2019). For example, the physiology of a tree (1) is considered on an individual small-scale level first (Sala et al., 2019); in the following step, it will be linked to the prevailing microclimates (2) on and around the tree (Friess et al., 2020); and finally, in a further change of perspective, the tree's role as a habit and its interaction with the animal world (3) is captured (Gottwald et al., 2021). To combine several of these selective insights and to upscale them into a higher-level view of the whole ecosystem, the use of machine learning methods, A.I. (4), and remote sensing (5) come into play (Egli & Höpke, 2020). As can be seen in figure 3.1, this selective consideration on varying scales within Natur4.0 was transferred into respective units of the SENSO Trail.

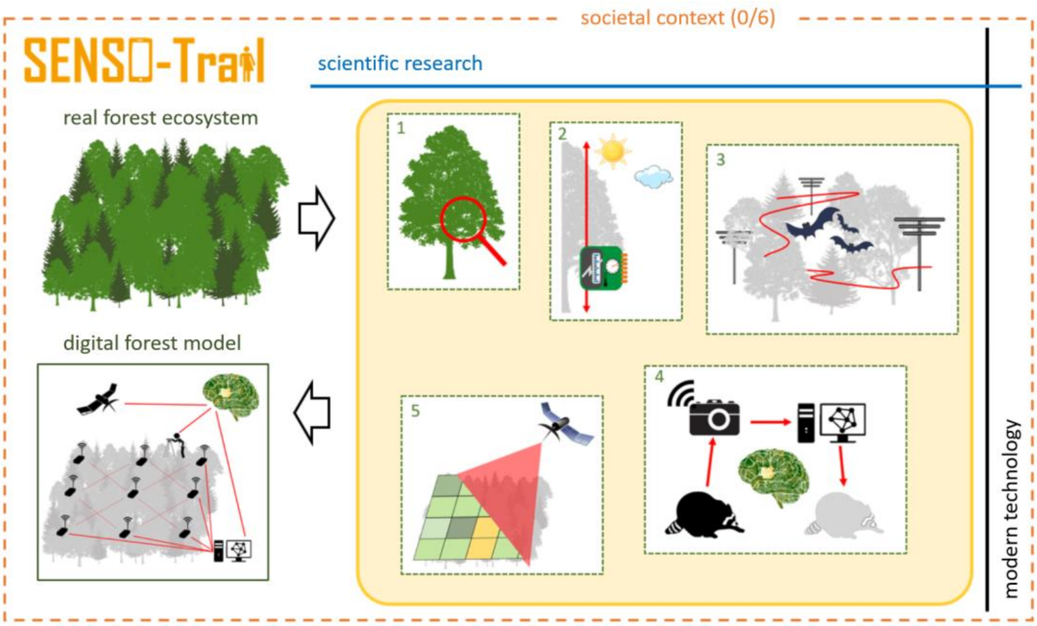

Figure 3.1 Simplified didactic concept structure of the SENSO Trail.

The trail follows a non-linear modular structure that has to be explored independently by using the SENSO app on tablets (figure 3.2). Functions and content are unlocked successively as the participants progress and are added to their individual digital portfolios. The thematic distribution into six stations breaks up Natur4.0′s content complexity in a multi-perspective approach (Schmayl, 1995). Investigation points (IPs) for each station complete the units by linking subject knowledge to the interactive use of technology and research methods. While important basic information on the relevant topic is conveyed at the actual station, this should find practical application in the IPs that are linked to each station. Here, actual data sets from Natur4.0 can actively be retrieved and reflected to keep the learning experience as close to reality as possible. In a final station (6), the content is reconnected and referred back to the societal context with a concrete application reference (the development of digital environmental models). A competitive character is deliberately integrated as a supporting game mechanism to promote learning effects (Liu et al., 2022). In that sense, the participants are credited with research points for completed stations, IPs, and collected data (Prensky, 2003).

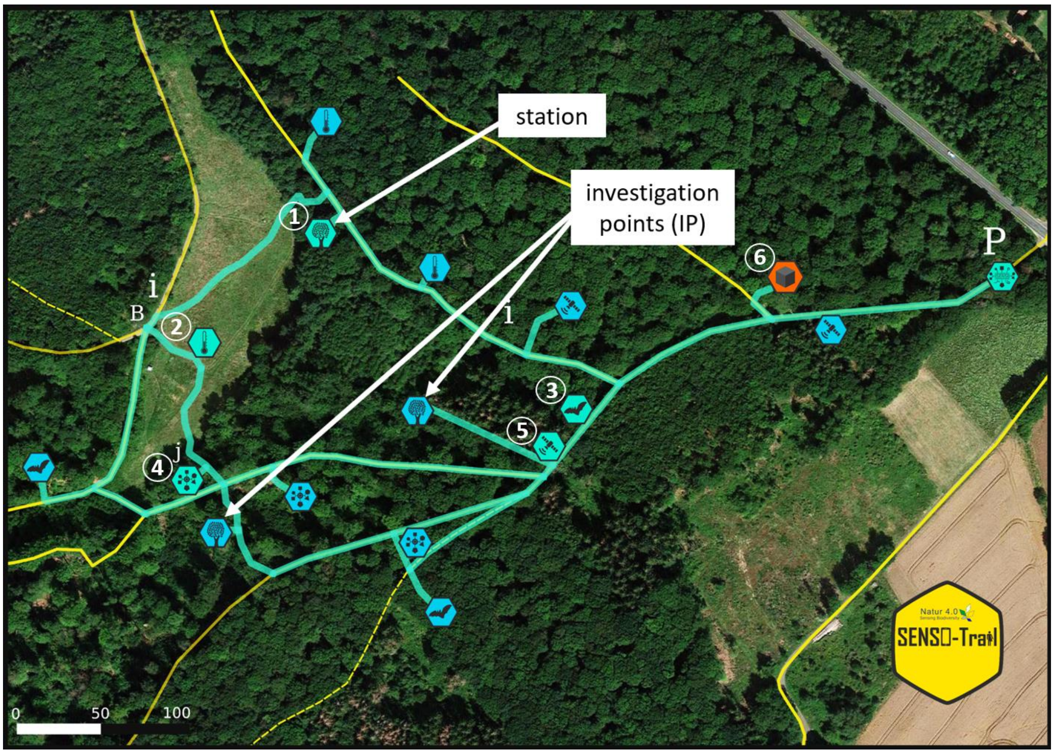

Figure 3.2 Map of the SENSO Trail area with green hexagons = stations; blue hexagons = respective investigation points; green line signature = proposed trail network.

The goals for successful participation are the expanded understanding of the biotic and abiotic environment on different scales, their mutual spatiotemporal relationships, as well as an idea of the complexity of natural systems (DGfG, 2020; Friess et al., 2019). Additionally, the promotion of awareness of scientific approaches and modern technology with their important roles in a deeper comprehension of complex causal structures is needed to identify and discuss the potential future of human–environmental interactions (DGfG, 2021, 2020; UNESCO, 2020).

Six school classes (German Gymnasium) from Hesse participated in 2021 in the presented study. In a cleaned dataset, a total of 94 subjects could be analyzed by their provided data: 43 females and 50 males with an average age of 15.62 years (min. = 14; max. = 18; SD = 0.86). A test group n = 66 (M = 5.85;

SD = 0.83) and a control group n = 28 (M = 15.07; SD = 0.66) were created through randomized assignment. In this context, it must be noted that in the follow-up examination with n = 50, a slightly lower response was achieved than was the case with the first two enquiries, which were conducted on the date of the actual intervention, directly before (pre, n = 66) and after (post, n = 66). The data were exclusively retrieved via anonymized paper-and-pencil-style questionnaires at all three times of enquiry. No additional approval from our institution's ethics committee ("Kommission Forschung und Verantwortung") was required to carry out this study apart from the declaration of consent from the participants' legal guardians.

The participants could indicate their gender as male, female, or diverse; in this study, the diverse category was not chosen by anyone and is therefore not considered in our analyses. For reasons of good scientific practice, the age parameter was also recorded and analyzed, but in contrast to gender, due to a rather narrowly defined target group and a relatively low age spread in the sample, we have no indication that significant effects are to be expected here.

Several instruments for quantifying attitudes toward nature and the environment for adults, children, and adolescents exist in the literature (Janakiraman et al., 2021; Bogner & Wiseman, 2006; Dunlap et al., 2000). While some limit themselves to certain ecocentric or anthropocentric dimensions (e. g., Bogner & Wiseman, 2006), others follow a one-dimensional approach and aim to depict the ecological paradigm of the respondents as a whole (e. g., Dunlap et al., 2000). The latter includes, as one of the best-known instruments in the field, the New Ecological Paradigm (NEP) scale. Since its development over 40 years ago, it has been applied, adapted, and refined in various contexts (Hawcroft & Milfont, 2010; Dunlap, 2008). The version of the NEP scale used in this research is an adapted variant of the 2000 scale (15 items, Cronbach's $\alpha = 0.83$) (Dunlap et al., 2000). In addition to the translation into German, item 6 of the original set was inverted as a result of pretesting. We also found that this item had lower scores in other, independent publications as well, which even strengthened the decision for our approach (Rideout, 2005).

The lack of comparable tools for measuring technology attitudes has recently been identified by Bengel and Peter (2021) and responded to with the development of the Modern Technology Attitude Index (MTAI). This instrument maintains a more general perspective on attitudes towards modern technology by measuring three main psychometric dimensions of attitudes: cognitive, affective, and conative response behavioral dimensions (Eagly & Chaiken, 2011; Ajzen, 1989), which, in this case, are intimidation (INT), loss of control (LOC), and benefits and easement (BAE). Since this instrument is still relatively young, there has only been one study so far, with pre-service geography teachers. The reported qualities (e. g., Cronbach's $\alpha = 0.83$) indicated broad suitability beyond the bounds of the initial study, which, despite the compactness of the psychometric detail with only 14 items, fully qualified for the purpose of this study (Anderson & Krettenauer, 2021).

Like the biographical variables, the 29 chosen items for measurement of attitudes (15 NEP and 14 MTAI) were only used at the first time of enquiry. Each Likert-scaled item brought four possible answers: fully agree, tend to agree, tend to disagree, and strongly disagree (Nemoto & Beglar, 2014). The means of each scale or, in the case of the MTAI, subscale, were calculated as test values for the subsequent analysis (Bühner, 2011).

Additionally, a set of test items was created to analyze the participants' potential SSK acquirements, stagnations, or even declines during the interventions and over time. Existing tests were viewed in advance but found to not fit the intended purposes, for reasons of either content orientation or scope (Huizenga et al., 2009; Kaiser & Frick, 2002). Thus, 15 test items in direct relation to the promoted content were tailored to the needs of this study. The items were formulated in the form of either true or false statements that could be marked as true, false, or do not know. In the analysis, items that were marked correctly as true or correctly as false were treated as knowing, and items marked incorrectly as true, incorrectly as false, or marked as do not know were treated as not knowing. To quantify the actual gain in SSK that might be achieved through the intervention, a variable for knowledge acquisition was created by using the score differences of pre- and post-testing.

In the intervention study presented, the immediate and long-term learning success of multi-perspective mDGBL concepts should be tested as a first step (Q1), and then potential influencing factors on the actual acquisition of knowledge should be examined (Q2/Q3). As can be seen in figure 3.3, at the first time of enquiry (TOE1), all participants were asked pseudonymized questionnaires about their biographical parameters of age and gender, and were presented with an identical knowledge test that related directly to the specific content (SSK) of the SENSO Trail. Since the test group's attitudes (CRA) towards nature and the environment (NEP) and modern technology (MTAI) as potential influence factors are of central interest for this study, they were also queried in an additional section. Corresponding parameters for the control group appeared to be less useful for this study and were omitted for reasons of efficiency.

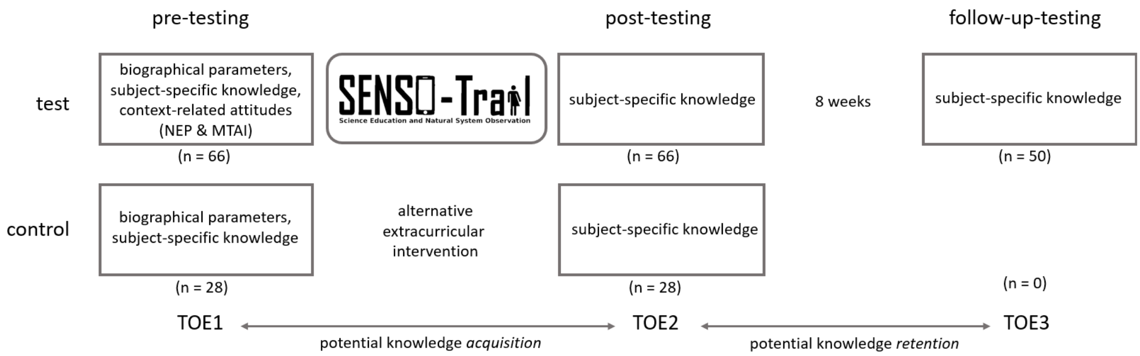

Figure 3.3 Research design.

The control group was offered an alternative extracurricular program instead. Although their intervention took place in the forest as well and was related to geography and natural sciences too, care was taken to ensure that there were no intersections with the SENSO Trail concept. At the second time of enquiry (TOE2), directly after participation, SSK was tested once more in both groups. Only for the test group, there was a third time of enquiry (TOE3) approximately eight weeks after participation. In this follow-up, the SSK was tested a third and final time to analyze the long-term effects of the intervention.

For data analysis, the free statistical software R and the additional program R-Studio, version R-4.0.2, were used for cleaning the data and the classic test theory was used for the construction of the instruments (RStudio Team, 2020). Descriptive methods, comparisons, and regression analysis were conducted with the free statistical software JASP, version 0.14.1 (Wagenmakers, 2021).

For the comparisons of the knowledge test performance within the test group over the three times of enquiry, an analysis of variance (ANOVA) with repeated measures was used together with a Greenhouse-Geisser correction for violated sphericity and a Bonferroni corrected post hoc test. Even if the development of new statistical methods and thus their variety is increasing, with ANOVA we have chosen an equally classic but reliable method to meet the needs of the statistical analysis of our data (Field, 2011). ANOVA of independent measures was performed to compare the knowledge acquisition of the test and control group to prove that possible knowledge acquisition was caused by the actual intervention and did not happen randomly. Omega squared was chosen to report effect sizes, since our sample size is rather small (Field, 2011). In a third step, multiple linear regression was used to test whether a fitting model can be created from the potential influencing factors of age, gender, or attitude (toward nature and the environment or modern technology) that can predict the acquired knowledge of the test group as a dependent variable. Additionally, another ANOVA was used to investigate potential gender differences within all the investigated variables. The level of significance was set at 0.05 (Bühner, 2011).

3.4 Results

3.4.1 Knowledge Acquisition

The repeated measures ANOVA on the test group ($n = 50$) shows significant differences ($F\ (1.55,\ 1.64) = 46.47$, $p = 1.4127\times10^{-13}$, $\omega^2 = 0.26$) between the 3 times of enquiry (TOE1 to 3). A Bonferroni-adjusted post hoc test reveals significant higher performances at TOE2 ($M_{Diff} = -0.2272$, $SE = 0.0258$, $t = -8.7932$, $p_{bonf} = 1.5036\times10^{-13}$) and TOE3 ($M_{Diff} = -0.2020$, $SE = 0.0258$, $t = -7.8198$, $p_{bonf} = 1.8408\times10^{-11}$) compared to TOE1, while there are no significant differences between TOE2 and 3 ($M_{Diff} = 0.0252$, $SE = 0.0258$, $t = 0.9734$, $p_{bonf} = 0.9983$). As can be seen in figure 3.4, in most cases the score after the intervention is higher than before and even stays on average the same level at the follow-up test (see table 3.1).

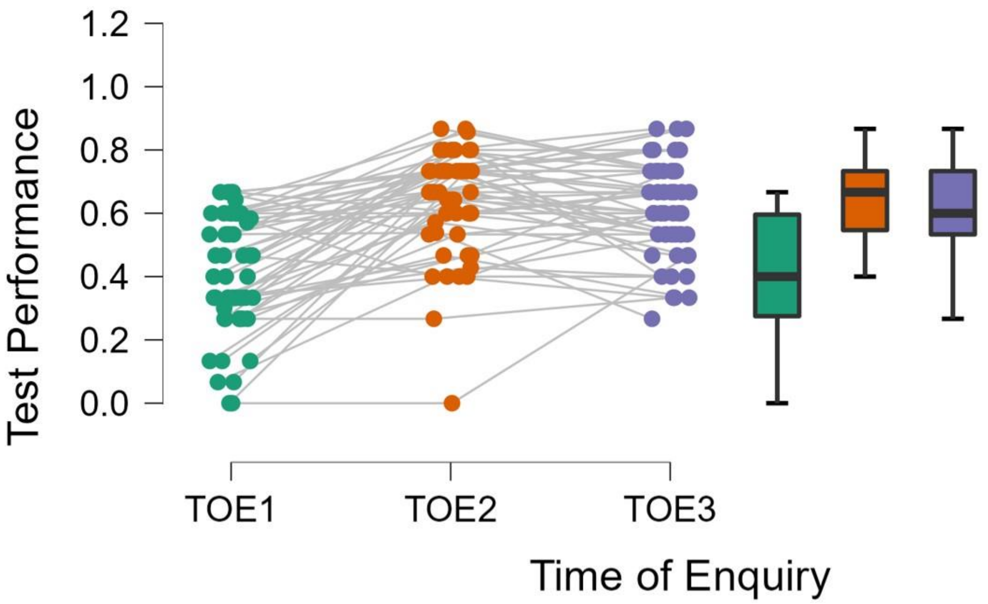

Figure 3.4. Performance on SSK of test group (n = 50) before (TOE1), right after (TOE2), and 8 weeks after (TOE3) the intervention.

Table 3.1: Mean scores of SSK (between 0 and 1) of both groups at the three times of enquiry.

Group	TOE1	TOE2	TOE3
Test (n = 50)	0.404	0.637	0.609
Control (n = 28)	0.402	0.402	-[1]

1 at TOE3 no data were gathered f0r the control group

Independent measures ANOVA showed no significant differences in prior knowledge (KN_PRE) of the tested content between the test and control groups (F (1, 92) = 0.0026, p = 0.9593, ω^2 = 0.00), as can be seen in figure 3.5. With regard to previous knowledge, the same prerequisites are given in both groups.

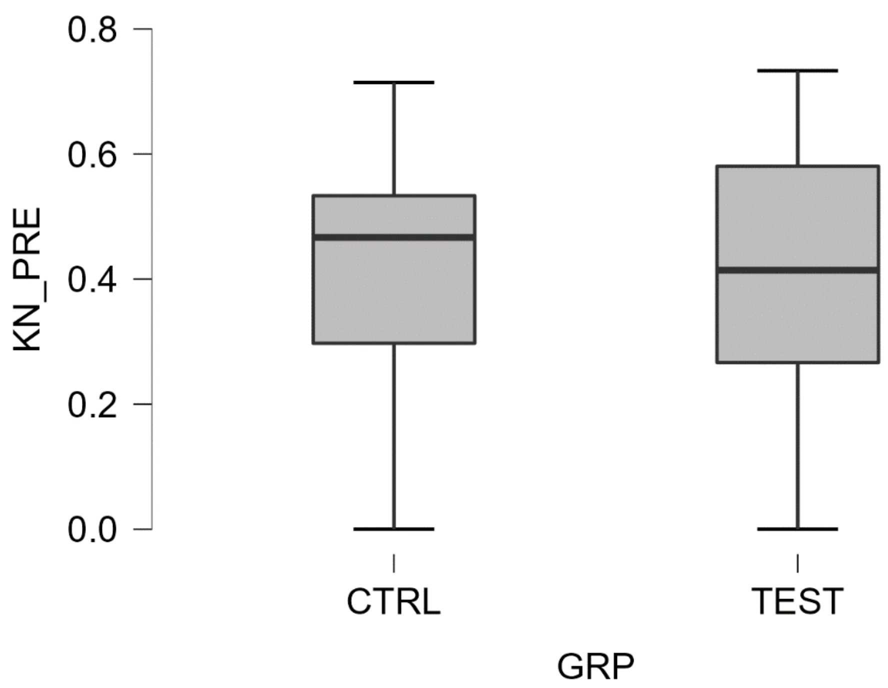

Figure 3.5 Knowledge (KN_PRE) of control (CTRL) and test (TEST) groups before intervention.

However, the knowledge acquisition (KN_ACQ) of the test group during the intervention is significantly higher ($F\,(1, 92) = 24.3107.40$, $p = 3.6182 \times 10^{-6}$, $\omega^2 = 0.20$) than in the control group (see figure 3.6). Assuming the comparability of both groups, a random effect on the KN_ACQ variable of the test group between TOE1 and TOE2 can thus be excluded.

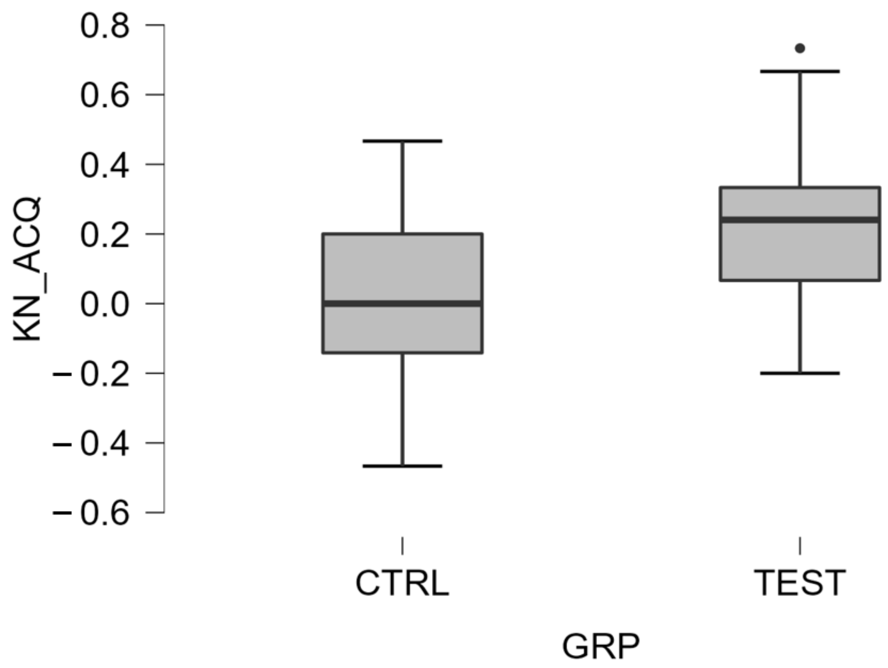

Figure 3.6 Knowledge acquisition (KN_ACQ) of control (CTRL) and test (TEST) groups during the time of intervention.

3.4.2 Descriptives of for Potential Factors

3.4.2.1 Prior Knowledge

As can be seen in figure 3.7, no significant differences in prior knowledge (KN_PRE) between the male and female participants within the test group could be found ($F(1, 64) = 1.0857$, $p = 0.3013$, $\omega^2 = 0.00$).

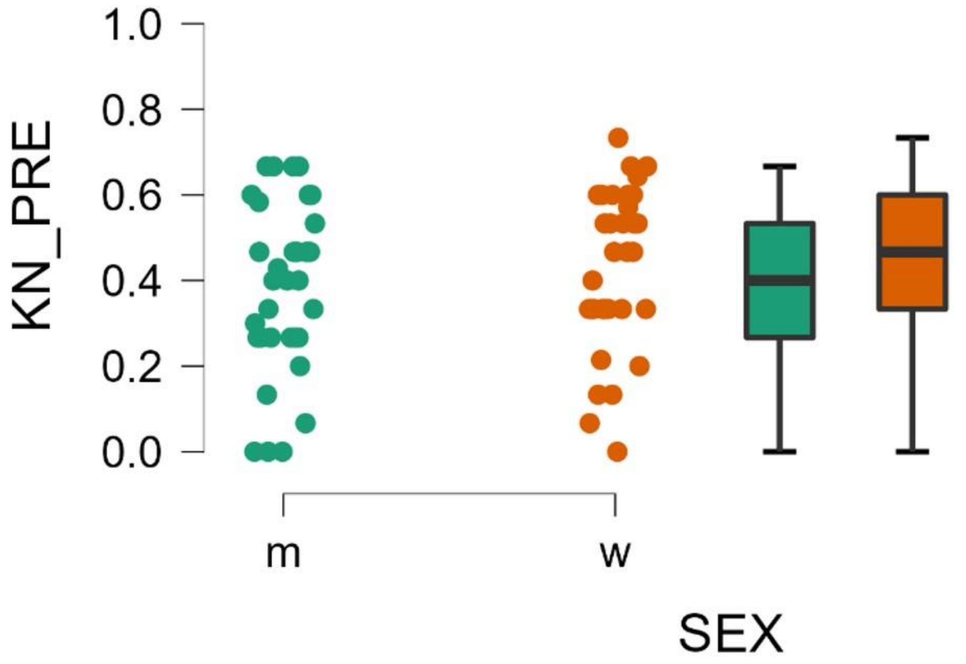

Figure 3.7 Knowledge of males (m) and females (w) before intervention.

3.4.2.2 NEP

The NEP scale's Cronbach's α was 0.78. On average, the participants showed high endorsement of the NEP with $M = 3.295$. Female participants might have gotten slightly higher scores (see Figure 3.8), but in the ANOVA no significant gender differences were found ($F(1, 64) = 3.6344$, $p = 0.0611$, $\omega^2 = 0.04$).

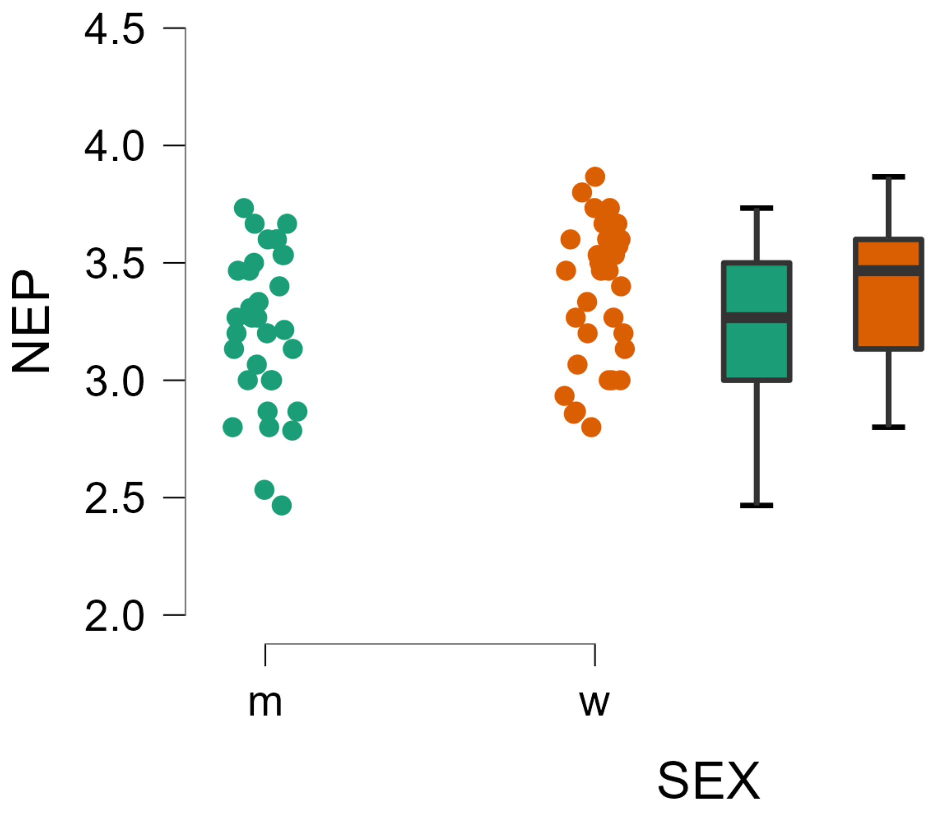

Figure 3.8 NEP scores of males (m) and females (w).

3.4.2.3 MTAI

The instrument's scales show good internal consistency (INT α = 0.81; LOC α = 0.72; BAE α = 0.83). On average, the score for intimidation was rather low, with M = 1.5417, together with the relatively high score on the benefits and easement scale (M = 3.2629) the average participant seemed to be more in favor of modern technology. Their attitude towards loss of control (M = 2.3316) on the other hand seemed rather balanced (compare figures 3.9 and 3.10).

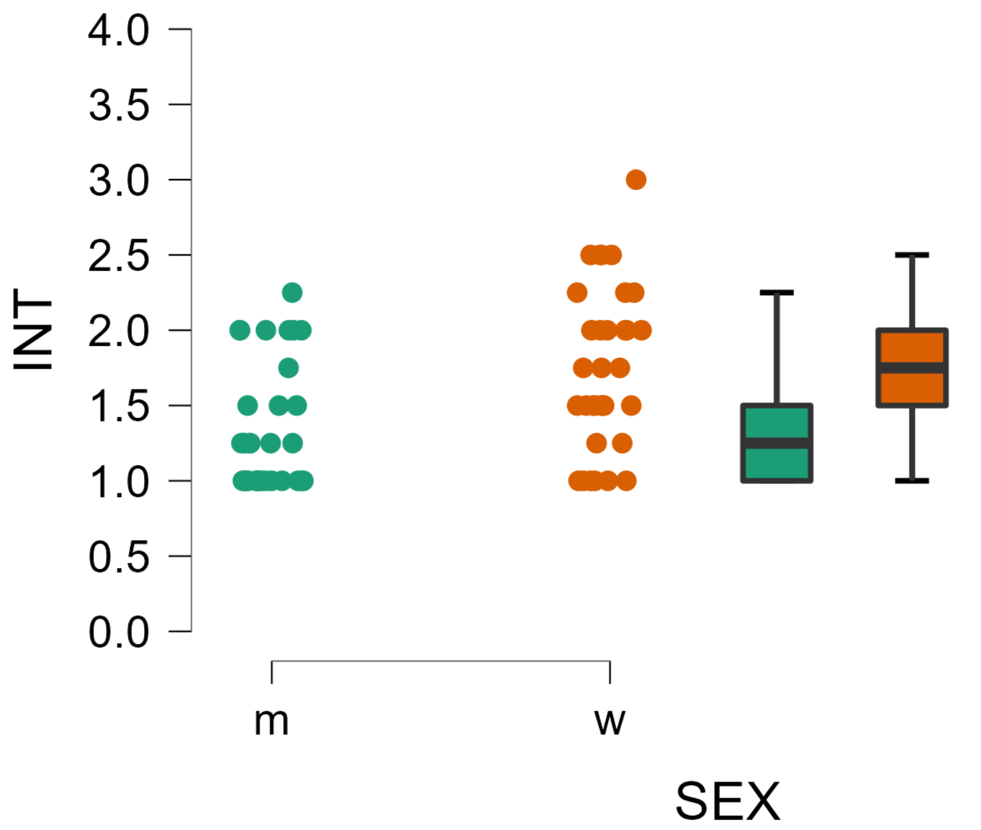

Figure 3.9 INT-scores of male (m) and female (w) participants.

Significant gender differences could only be found for the intimidation scale, where females seemed to perceive stronger intimidation (INT) than males (F (1, 64) = 11.5123, $p = 0.0012$, $\omega^2 = 0.14$), as pictured in figure 3.9. LOC (F (1, 64) = 2.8877, $p = 0.0941$, $\omega^2 = 0.03$) and BAE (F (1, 64) = 2.1974, $p = 0.1432$, $\omega^2 = 0.02$) did not differ significantly (see figure 3.10).

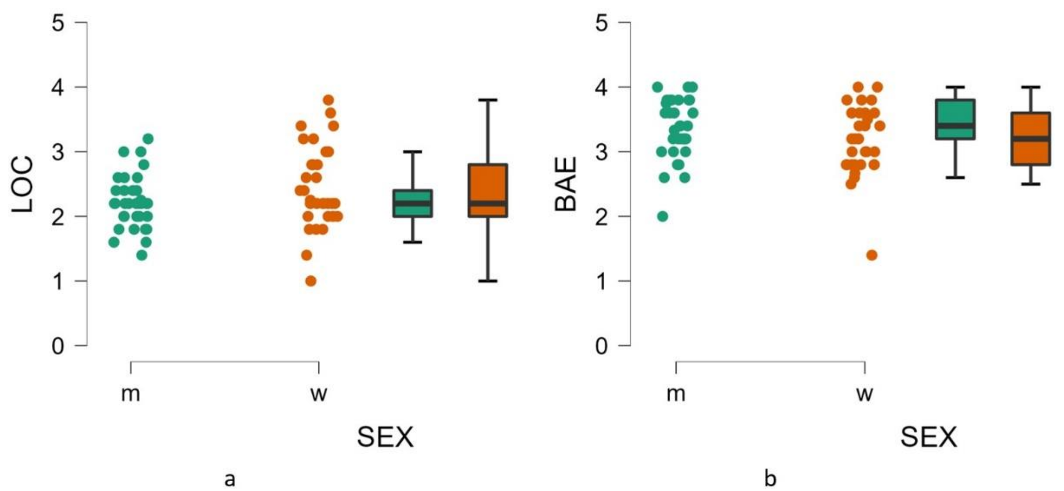

Figure 3.10. LOC (a) and BAE scores (b) of male (m) and female (w) participants.

3.4.3 Influencing Internal Factors

Multiple linear regression was used to test whether a model can be created from the potential influencing factors of gender (SEX), age (AGE), or attitude towards nature and the environment (NEP) or modern technology (INT, LOC, and BAE) that can predict the acquired knowledge of the test group (KN_ACQ). It was not possible to create a significant model by any constellation of the above-named factors as potential predictors. Conclusively, none of the tested factors seem to be significant predictors for acquired knowledge and can therefore be excluded as interference factors of educational success.

3.5 Discussion

We created and evaluated an extracurricular mDGBL education program for the transfer of complex content to test whether or not such approaches can have longer-lasting effects on students' subject-specific knowledge gain. Additionally, we asked if the intervention's general fitness might be limited by personal biographical or affective factors. Thus, we looked into the potential effects of age, gender, and content-related attitudes on the knowledge acquisition of our test candidates.

Firstly, our data showed no significant differences in the participants' prior knowledge, neither between the test and control group, nor gender-related. Further, our results show a clear gain in the test group's knowledge during participation. Direct comparison with our control group confirms this and brings the results in line with comparable studies on mobile and/or DGBL approaches (Giannakas et al., 2018). Additionally, since the participants' performance did not significantly decline over eight weeks, for the first time we have been able to prove a positive, long-term effect of this kind of educational concept.

With our second attempt, we were looking into participants' age, gender, and attitudes towards the related content to identify significant differences and analyze potential effects. The achievement of considerable alpha values despite small sample sizes on item numbers between 4 and 15 confirmed a rather good internal consistency of the NEP-Scale and MTAI, with respect to its three sub-scales. The adolescents' relatively high affection for nature and the environment, as we record it, was to be expected (Rideout, 2005). Environmental issues have an increasing presence in today's society; it is hardly possible to avoid confrontation any longer, whether you are interested in them or not (Ji et al., 2018). This might lead to a generally high level of sensitivity among young people, which has probably risen since the development of the NEP scale. Unlike the results of comparable studies, a significantly higher affection of female adolescents for nature and the environment could not be documented (Schleer et al., 2021; Marth & Bogner, 2019). This might already indicate the success of well-designed, gender-equal school and extracurricular awareness-raising measures that are now being offered to the young generations. Since a slight, albeit not significant difference can be seen in Figure 8, minor gender effects might be present, but would, for instance, only become apparent in bigger samples.

Attitudes towards modern technology were measured by the use of the MTAI in three psychometric dimensions. The perceived loss of control with or through modern technology seemed to be balanced within the test group, while the benefits and easement scale showed a rather high score on average. This could be interpreted to mean that teenagers today are generally more open to technology and feel empowered to use its advantages without being overwhelmed by it (Marston, 2019; Tully, 2003). This assumption would be confirmed by the rather low average score of the participants' perceived intimidation through modern technology. In contrast to the first two scales, there is also a significant gender difference to be found, which in the overall picture reproduces the results already reported by Bengel and Peter (2021).

Despite being able to identify this specific gender gap, neither that nor the parameter intimidation in general seem to affect the knowledge acquisition of our test group. This also applies to the other two dimensions of the MTAI. Contrary to similar studies, such as Amry's (2014), attitudes towards modern technology do not seem to influence participants' performance, although modern technology is a central theme of the intervention, both in terms of content and application. Neither could we reproduce any effects with nature and environment-related attitudes, as reported, e. g., in the studies of Fremery and Bogner (2015) or Schneidehan-Opel (2020). However, it has to be considered that, in addition to the already mentioned discrepancies in the educational formats tested and other disparities, a different measuring instrument was used in their work. Additionally, neither age nor gender as biographic parameters could be used to predict the participants' knowledge acquisition through the intervention. These are extraordinary results since at least for gender there is plenty of evidence that might lead us to expect the contrary (Benke, 2012; Bätz et al., 2010; Dresel et al., 2007).

The present study had some limitations to be mentioned. Firstly, despite the potential disadvantages of statistical analysis of rather small sample sizes, none were experienced. Of course, assumptions such as, e. g., normal distribution of residuals were thoughtfully tested ahead of the main analysis. Additionally, despite the random distribution of subjects, there was a perceivable difference between the test and control group's mean ages. This was fully acknowledged but tolerated since the later analyses showed no effect of this parameter at all. The decreasing number of participants in the follow-up enquiry can be explained by the high level of preventive or health-related leaves during the COVID-19 pandemic at the third time of enquiry. Further, it has to be acknowledged that the measurement of SSK with 15 single-choice items can only measure a limited spectrum of the actual prior or later existing knowledge. A limited scale always has the logical problem that the more knowledge a participant already brings, the less capacity is left on the scale to be acquired. This phenomenon might not apply to reality, since there are plenty of knowledge areas and levels of deeper comprehension that could be accessed by learners but are not being tested. In our setting, the areas surveyed were severely limited due to study purposes, which could ultimately possibly lead to ceiling effects (Staus et al., 2021).

Extracurricular learning environments, as well as mDGBL approaches, are extremely diverse in terms of structure, content, and space, with various learning goals for different target groups. In our approach, we limited ourselves to specific parameters, as they coincided with the concept's content and setting. The results should therefore not be generalized and applied to other cases unwarily without the necessary reflection. Programs that implement similar didactic concepts deal with other topics where the personal attributes of their target group could possibly have a demonstrable effect. Nevertheless, we can state that there are mDGBL approaches that can equally be applied to heterogeneous target groups regardless of their age, gender, or CRA and still have immediate and long-lasting effects on participants' SSK.

3.6 Conclusions

The results of this study suggest that mDGBL concepts can be used to effectively address young people with multi-perspective approaches. This applies in particular to the intersection of different disciplines in complex contexts, as shown here using the example of the merging of natural ecosystems and modern technology in applied environmental sciences. The findings further reinforce the assumption that success, even with heterogeneous groups, is not limited by certain individual characteristics. This bolsters innovative educational approaches like ours, as innovative strategies are needed in modern education if our society wants to compete with the central challenges for a sustainable future. Since the SENSO Trail was tailored to a well-defined educational situation, further research in similar and different settings will be essential to strengthen the validity of these results. Further investigation into the success factors of mDGBL and multi-perspective approaches are needed to ensure the quality and even expand the scope of application for ESD and TE in geography education and beyond. Furthermore, in addition to the personal parameters, it might also be interesting to isolate selected external factors for an investigation of their potential influences on the approach's success. An example could be a comparison of physically implemented concepts, such as the one presented here, with purely virtual variants of multi-perspective mDGBL approaches.

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4 Promoting Technological Literacy through Virtual Game-Based Field Trips

This chapter is under review for publication as:

Bengel, Phillip T.; Peter, Carina (2023): Promoting technological literacy through virtual game-based field trips. In: International Journal of Child-Computer Interaction.

Received: 30 May 2023, revised: 31 July 2023

Abstract

Virtual field trips in combination with digital game-based learning offer great potential for creating new learning environments, especially for geography education. Those approaches are not only needed to transfer knowledge but also to contribute to creating a more technologically literate society. For the future design of learning spaces and the corresponding professional development of teachers, it is indispensable to learn what the pedagogical advantages and limitations of fully computer-based virtual game-based approaches are. For this, it is necessary to know whether purely virtual concepts differ in knowledge transfer from those applied in actual field trips. When it comes to promoting technological literacy, additional relevant questions are whether there are influences on participants' attitudes toward modern technologies and whether there are implied gender effects in this regard. An empirical comparative study of a total of n = 110 German high school students was conducted to answer these questions. Key results are that actual and virtual designs using computer-supported game-based learning approaches can be equally effective in knowledge transfer. Further certain technology-averse attitudes could be identified, which were more prevalent among females than males. This gender gap could be levelled out by the effects of the virtual game-based field trip. Across genders, the levels of aversion were reduced, as well, while affirmative attitudes toward modern technology rose.

Keywords: virtual field trips; game-based learning; gender studies; technological literacy; digitalization; geography education

4.1 Introduction

Society is witnessing a self-accelerating technological shift in all areas of human development. This process takes place on average at a relatively high speed but is perceived differently by everyone for reasons of varying digital accessibility and personal inequalities (Francis et al., 2019; Nueva, 2019). Due to its fundamental complexity and the varying effects on people and the environment, it is difficult to generalise technological change as good or bad from an overarching perspective. Depending on how they are used, computers and modern technology bear great potential to either solve or aggravate our planet's global ecological, economic, and social problems. In philosophy, there are models to grasp this complex situation and its processes, in a multidimensional human-technology-environment relationship triangle, (Verbeek, 2023). The specific role of technology in this model, however, is difficult to categorise because, on the one hand, it is a social construct in which socio-technological developments are negotiated between people, institutions, and organisations. On the other hand, technology also has a more deterministic character, as in the form of artefacts, it shows clear structures and natural properties. Actor-Network Theory recognises this dichotomy and concludes that "the laws of nature and the capacities of a particular design limit the ways in which artefacts can be integrated into a sociotechnical system." (Latour, 2021, p. 147). Finally, there is the human component which plays a role in determining how the process of integrating technology into our physical and social environment happens (Torpey, 2020). This primarily means how conscious and controlled, or unconscious and uncontrolled, these processes happen (Allert & Richter, 2017).

The Covid-19 pandemic has promoted the already ongoing transition of all kinds of official, social, and cultural interactions from the actual physical world to the virtual world. Especially children and young people perceive and experience their environment and how they act socially is therefore increasingly influenced by data-based and algorithm-driven decision-making processes (Allert & Richter, 2017). Digital media such as games and mobile applications play a particularly important role in this (Edwards & Larson, 2020).

It is known, that the uncontrolled use of technology, especially in the form of digital media, can lead to unfavourable psychological outcomes (Oswald et al., 2020). Consequently, the question is what is needed to steer the technological shift in society in a direction that minimizes the risk of individuals becoming passive unthinking consumers and instead empowers people's awareness and abilities to actively use technologies for the creation of a better future. Scholars agree that the level of technological literacy in society finally dictates the circumstances of conscious control over modern technology (Su et al., 2021; Dyrenfurth & Kozak, 1991). When it comes to defining the term "technological literacy", the International Technology and Engineering Educators Association (ITEEA) stated that "in order to be a technologically literate citizen, a person should understand what technology is, how it works, how it shapes society and in turn how society shapes it." (ITEEA, 2023, p. n.a.)

Apart from technical implications, becoming technologically literate also means the development of awareness of the possible negative consequences of unreflective technology use (Dyrenfurth & Kozak, 1991). Those could for example be youth's growing disconnection from nature caused by excessive use of digital media (Edwards & Larson, 2020), gaming addictions (Liang et al., 2022), sleep disorders caused by screen exposure (Wood et al., 2013), and other issues concerning the field of cyber-wellbeing. When it comes to promoting technological literacy, Ardies et al. out that " [...] it can be assumed that students exhibiting a positive attitude towards technology could be more likely to attain technological literacy through technology education [...]" (Ardies et al., 2013, p. 8)

From the perspective of most pedagogical systems we know, it is the task of education to prepare people for reality and to promote an open and unbiased attitude (Banks & Williams, 2022). Thus, the promotion of a critical, open attitude towards technology can be seen as an educational goal in terms of technological literacy, while promoting or tolerating an anti-technology attitude that contradicts the goals of this social mandate.

When it comes to attitudes toward modern technology, it is often stated that males have a generally more technology-positive attitude than females (Cai et al., 2017; Niiranen, 2016). Even if such stereotypical debates in other fields have rightly calmed down, the gender issue in the field of technology is still alive and constantly fuelled by new findings that cannot be disregarded in this context. However, some studies claim that there are no differences between genders (Islahi & Nasrin, 2019), as well as those that identify specific differences focusing only on certain dimensions of technology-related attitudes (Svenningsson et al., 2022).

To overcome the passive stance of people and inequalities that may exist concrete educational approaches need to be developed (Huff et al., 2012). Plenty of positive examples of the use of technology can be found in geographic sciences (e. g. geospatial information systems (GIS), remote sensing, or earth data resp. spatial data modelling), where technological achievements are used to address challenges, such as climate change, environmental degradation, and digitalization, and the analysis of human-environment systems with regard to technological impacts is becoming increasingly important (Ash et al., 2018). However, modern technologies also have a strong geographical aspect themselves that may only become clear at a second glance. At the latest since artificial environments were created by digital technologies, virtual realities (VR) have also become interesting for geography as a spatial science (Kraak et al., 2021; Brendel & Mohring, 2020).

Even though the educational mission on modern technology is certainly a cross-curricular one, there is a great deal of potential for implementation in the subject of geography. Many current examples show that modern technology is not only integrated in terms of content but also as a holistic approach to geographic education, e. g. spatial and environmental modelling (Su et al., 2021; Edwards & Larson, 2020). Through adapted application-oriented concepts, children learn about technological tools and the impacts of their use on themselves, society, and their environments by applying them in real, or at least realistic, spatial settings (Brand & Fischer, 2013). In the form of mobile devices, computer technology is used in field exercises for digital mapping or to support extracurricular formats, such as city rallies, adventures, and scavenger hunts, along with mobile apps for geographic positioning (GPS) and digital media (Huizenga et al., 2009).

Contemporary computer technology allows the creation of new digitally supplemented or purely virtual learning environments. With the introduction of technologically supported field trips, it became possible to create completely new references to spaces, objects, structures, and processes, either in real location-based settings or just by bringing the corresponding space as a whole, virtually, into the classroom (Roelofsen & Carter-White, 2022). These new possibilities in extracurricular learning with technology can be highly supportive, especially when it comes to communicating complex geographical topics regarding environmental or technological sustainability education to children (Ho et al., 2022; Edwards & Larson, 2020). One example would be to integrate remote sensing data of a specific area, allowing learners to change spatial perspective via the digital interface on the one hand, and being introduced to the technology behind remote sensing on the other.

Respective applications also support the comprehensive process by promoting individually accessible content in multimedia formats framed by attractive features, such as storytelling, chat options, and automatic location reverences via GPS or augmented reality (AR). A prominent feature of modern technology applications in the context of education is digital game-based learning (DGBL) (Prensky, 2003). In many cases, so-called serious games provide a reality-orientated outset, which, on the one hand, allows one to approach objects or phenomena closely enough to impart relevant information about them. On the other hand, since a game could also be interpreted as an interactive model of actual, historical, or fictional realities, it has to be strictly limited in space, structure, process, and content. Ultimately, this allows a targeted reduction of real life's complexity and, thus, supports the process of comprehension (Prensky, 2003). This unique constellation of closeness to reality and limitation of complexity allows the creation of a pedagogical strategy with the motivational character to maintain people's focus to receive, process, and apply selected content (Camacho-Sánchez et al., 2022). In addition, games usually offer the opportunity for some form of interaction, which can strengthen social and subject-related competencies in addition to pure knowledge transfer. As a study from Portugal indicated, adolescents in particular might prefer playful elements to a purely story-based format in mobile applications, (Cesário & Nisi, 2022). There are various educational concepts for geography and other subjects where DGBL is used successfully as a mobile feature for actual interactive field trips (Giannakas et al., 2018; Huizenga et al., 2009), as well as for virtual e-learning experiences (Ho et al., 2022).

Accordingly, it is no surprise that virtual field trips (VFTs) in particular are becoming more and more attractive in many educational areas (Alsaqqaf, 2022). The subject of geography occupies a special position here since, from a geographic perspective, virtual spaces not only represent a new kind of educational setting but also form their own spatiotemporal objects of scientific interest (Mercer et al., 2022). Here, too, human-environment systems are of great importance (DGfG, 2020). For example, it can be assumed that, just like in the actual world, the environment, even if it is a purely virtual one, has cognitive or affective effects on the visitor (Nikolaou et al., 2022; Robledo & Prudente, 2022; Relph, 1976). When it comes to the design of VFTs, according to Klippel et al. (2019), three different categories, depending on the technical effort and the degree of visitor interaction, can be distinguished. Basic VFTs are accessible as a single-user experience and represent nothing more than a digital copy of an actual physical field trip (AFT). The next more advanced VFT level allows a change in perspective so that, for example, a bird's eye view can be taken. At the highest level, multi-visitor communication and interaction are enabled. Moreover, the reality shown is adjusted so that, for example, processes can be simulated, and certain changes over time can be visualized on demand. Admittedly, the creation and application of third-level VFTs require much higher levels of technical ability than most educators have, and, therefore, they are still scarce in educational practice (Klippel et al., 2020). While immersion is an elementary component of most definitions and conceptual models developed for VR in general (Kardong-Edgren et al., 2019; Latta & Oberg, 1994), there is currently no consensus on this for the definition of VFTs. This means that the experience of a field trip in virtual space can vary in its degree of immersion depending on the technical interface and spatial design used, but no clear boundaries can be drawn as to when one can actually speak of VFT. In educational practice, it remains a question of technical, financial, human, and temporal effort whether one chooses immersive virtual reality (iVR), for example with head-mounted devices, or the technically simpler variant that is accessible with basic desktop computers (Klippel et al., 2020). The latter also has a different physical and mental impact on participants. More immersive concepts can provide a more realistic experience, depending on the quality of the equipment

(Cheng & Tsai, 2019). However, they also harbour an increased potential for addiction, and might lead to so-called simulator sickness for some people (Ciążyńska et al., 2022).

In addition, despite all the impressive possibilities that VFTs offer, also, none of them allows the sensational experience of touching an object. Further, it is also possible to integrate some of the above-named VFT features into the actual field. Think, for instance, about AR applications on mobile devices (ARaction, 2022). These combine some of the best virtual reality (VR) features as mixed reality approaches at the actual site. However, some arguments also exist in favor of purely virtual implemented field trips, and these have been collected and discussed by scholars in previous studies. An obvious one is that there is no distance to be covered, so even hard-to-reach sites of interest can be accessed fast and easily (Bruch et al., 2011). As VFTs can be organized regardless of their locations, high costs and logistical problems are avoided, and the ecological footprint in terms of traveling is reduced. Moreover, they are made more accessible to students with disabilities (Klippel et al., 2019). Further, VFTs are a relatively new alternative experience and might, therefore be more interesting for young users (Çaliskan, 2011). VFTs have no physical limits, which allow travel through space and time and to places that would otherwise be difficult or dangerous to access (Bruch et al., 2011). In addition to the many other options for shaping the 3D environments according to educational needs, VFTs foster a change of perspective with regard to the provided scalability, which requires learners to think spatially (Salsabila et al., 2022).

AFTs are already often combined with ludic elements or serious games through corresponding mobile applications (Giannakas et al., 2018; Huizenga et al., 2009). If you consider that both VFTs and digital games are mostly created in a virtual space, it is not surprising that the DGBL approach is also often integrated here in practice (Araujo-Junio & Bodzin, 2022). However, despite the large number of studies that have recently been published around these two concepts, VFTs, and DGBL have hardly been investigated together (Alsaqqaf, 2022).

4.2 Theoretical Background

In the present study, we are particularly interested in the application of interactive DGBL features in VFTs and their effects on the acquisition of subject-specific knowledge, compared to AFTs with similar features. Further, possible effects of a game-based VFT on participants' attitudes toward technology with regard to their technological literacy will be investigated.

The independent attainment of the status of a technically literate person who can confidently navigate actual and virtual technology-based contexts is often hindered by several factors. Certainly, some people are content with their status as passive users and show no further interest in gaining more insight into, understanding of, and control over such technology (Gram-Hanssen, 2008). Others are sceptics with rational apprehensions that appear partly justified by potential negative impacts on the people or environment resulting from the abuse or disproportionate use of modern technology (Welledits et al., 2020). Some, however, are influenced by attitudinal barriers, such as irrational fears and aversions, which might be based on a lack of knowledge and the distorted image of modern technology that prevails in society (Khasawneh, 2022). These favor the perceived loss of control of the sceptics or their feelings of being overwhelmed by the complexity and intimidated when dealing with new technologies. With the promotion of technological literacy as a higher goal, several influencing factors have to be taken into consideration. The ITEEA (2023), for instance, identifies knowledge and skills in terms of how to use, manage, and understand the crucial benefits and risks of current and future technology. Ardies et al. (2013) also state that the attitudinal dimensions related to technology correlate with a person's technological literacy. Consequently, we are dealing here with an interplay of knowledge, practical skills, or behaviors, and content-related attitudes. The influence of knowledge (e. g., conceptual knowledge and subject-specific knowledge) on a person's attitude is just as well-known in psychology, as both knowledge and attitude influence a person's behavior (Eagly & Chaiken, 2011). From this basis, it can be concluded that for an educational process that is intended to contribute to technological literacy, effective knowledge transfer is the cornerstone on which attitudinal changes and behavioral adjustments (Maio & Haddock, 2009) can be built and ultimately empower effective, conscious technology-related actions (Nikolaou et al., 2022; Ardies et al., 2013).

4.2.1 Knowledge Acquisition

> *In changing situations of knowledge acquisition and use, the new interactive technologies redefine – in ways not yet determined – what it means to know and understand and what it means to become literate or an educated citizen. (Lave & Wenger-Trayner, 2011, p. 12)*

Effectiveness in the sense of the knowledge acquisition of both mobile and e-learning approaches for field trips (La García de Vega, 2022), as well as for DGBL approaches (Wang et al., 2023; Camacho-Sánchez et al., 2022) has already been demonstrated not only in geography lessons (Roelofsen & Carter-White, 2022), but also in various areas of actual extracurricular education (e. g., Knoblich, 2020). Still, when it comes to the educational qualities of VFTs, opinions vary.

With reference to education for sustainable development (ESD), Siegmund et al. (2013) argue that the importance of an original occurrence in a real situation cannot be simulated or even replaced by a virtual representation on a computer. The scholars emphasize that pre-eminently on a sensual level, being in a virtual forest landscape and experiencing a forest “live” are fundamentally different. The arguments of the situated learning theory seem similar here, which particularly emphasize the advantages of places and communities for formal and informal learning. It is interesting to note, however, that in this theory virtual places, are not excluded but even explicitly explored by some scholars in the field (Baker et al., 2008). So, it is not surprising that some studies already exist, especially several recent ones, that attest to the use of VFTs as an effective didactic tool. Cheng and Tsai (2019) for instance, report enhanced students’ motivation in VFTs and highlight the important role of experienced realism and perceived spatial presence. Salsabila et al. (2022) even provide evidence that the spatial intelligence of participants is significantly influenced by VFT and improves their problem-solving abilities. And then there are growing numbers of studies, which present evidence of improved knowledge, changed attitudes, and influenced awareness through VFT participation (Al-Mugheed et al., 2022; Gram-Hanssen, 2008).

However, the number of studies that directly compare VFTs with AFTs is rather small. Even so, they do not produce a consistent picture either in terms of the research methods or the results. Kingston et al. (2012), for instance, compared their newly developed VFT format in geography with the “old” program for the topic of hydrology, which, in contrast to the VFT, did not have interactive elements or make use of any modern technology. Thus, it is not surprising that positive results in favor of VFTs were observed. Friess et al. (2016), in another example, tested a rather passive VFT concept that consisted of videos and no interaction and resulted in less enjoyment and acquired knowledge of participants compared to staff-led AFTs. However, of course, cases also exist where VFTs and AFTs were designed more comparably, and these studies paint a more consistent picture. The research of Stumpf et al. (2008) and Ruberto et al. (2017) attests VFTs’ and AFTs’ equal effectiveness, while Klippel et al. (2020, 2019), Zhao et al. (2020), and Firomumwe (2021) report clear advantages of VFTs compared to AFTs in both geoscience and geographic educational frameworks. Some findings even provide evidence that effective VFTs are not necessarily limited to immersive setups, such as head-mounted devices, but can also make use of simpler technological solutions, such as desktop VR (Zhao et al., 2020). Even though creators of both AFTs and VFTs often make use of technological features and gaming elements to catch and hold participants’ attention and to motivate and support the acquisition of knowledge, no comparative studies can be found in which these DGBL components have been explicitly considered.

4.2.2 VFTs and DGBL

DGBL, however, offers great pedagogical potential for actual and virtual settings, as studies have shown. Almost two decades ago, Virvou et al. (2005) provided the first evidence, that games help to improve and retain learners’ knowledge, by comparing a VR game for primary school geography students to educational software lacking the gaming aspect. Others followed as summarized in Merchant et al.’s (2014) meta-study on the effectiveness of VR-based instruction. Their results confirm that gaming elements in simulations or virtual worlds show higher learning gains. A different example is the work of Ho et al. (2022), which compared virtual and non-virtual versions of one and the same board game to improve students' knowledge of and attitudes toward sustainable development, and even though both approaches were successful, the digital variant performed better in both areas. Next to better knowledge gain and higher motivation, current studies also suggest that game-based VR interventions can have significant effects on content-related attitudes (Agbo et al., 2022).

Supporting arguments for computers and technology in the form of mobile applications, digital games, and VR as part of modern education are sufficiently available. As their use and design possibilities rapidly evolve in both actual and virtual settings, the question, of which setting the pedagogical value is actually higher, might become increasingly important in the future. The urgent relevance of this question arises from mundane factors such as organization, effort, and costs. On the other hand, it might also hold profound implications for the future development of teachers' competencies or the infrastructure and equipment situation in schools. Only with a direct empirical comparison could clear statements be made about the advantages and disadvantages of the use of one or the other variant. Since most pedagogical approaches focus on imparting subject-specific knowledge, their success should also be the determining parameter in a corresponding comparison. Despite all the upcoming research in this area, to the best of our knowledge, to date, no studies exist that specifically compare the effectiveness in terms of knowledge transfer of an AFT and a VFT containing the same DGBL approach. One reason why this type of comparative study still does not exist may be because of the challenge of comparing two rather complex but still identical concepts in disparate settings, as some of the examples above have already shown (Friess et al., 2016; Kingston et al., 2012). For reasons of good empirical practice, the comparability of the two variants must be assumed in any case. Only when the central parameters provided, such as the group of subjects as well as the intervention's content, structure, methods, and media used, are approximately the same in both variants is a sensible comparison possible (Bühner, 2011). In our study, we want to create the named conditions for such an approach and, thus, answer the following research question:

RQ 1 How does a game-based VFT compare to its actual physically implemented counterpart when it comes to imparting subject-specific knowledge?

4.2.3 Attitudinal Change

Recent studies show, that the use of modern educational technologies can positively impact the learner's enjoyment and perceived ease of use (Cárdenas-Sainz et al., 2022). Therefore, in addition to the pure knowledge acquisition through DGBL and VFT, it seems worthwhile to consider potential effects on other pedagogical dimensions. Robledo and Prudente (2022) for instance, conducted a VFT study with senior high school students in Manila and found significant effects on their environmental awareness and changes in their environmental attitudes. A recent literature review on this topic revealed that most of the scholars examined with regard to the field of the educational use of virtual settings reported positive effects of virtual interventions on attitudinal factors, such as emotions and empathy (Pirker & Dengel, 2021). DGBL approaches are also known to have targeted effects on participants' mindsets, as a study with 13 to 18-year-olds from the United Arab Emirates and India shows, which reported an influence on the social-emotional competencies of the adolescents participating in the game (Mukund et al., 2022). Meanwhile, there is also increasing evidence in this area for the positive effects of combined approaches of VR and DGBL. In addition to studies that focus on attitudes toward the didactic concept itself (Araujo-Junior & Bodzin, 2022), some studies examine changes in the attitudes related to the actual content. Reference has already been made to the study by Ho et al. (2022), in which the use of a virtual game approach showed an impact not only on the subjects' knowledge about, but also on their attitudes toward sustainable development issues. Another example is the work of Agbo et al. (2022), in which attitudes toward computational thinking concepts were increased with the help of a VR game-based app. One area where we do not find many examples of content-related attitudes and game-based virtual interventions, although it is a much-discussed issue in many other areas, particularly when it comes to attitudes to technology, is the issue of gender differences.

4.2.4 Gender Differences

Recent studies show that females are attributed to a different approach to gaming than males, who are predominantly associated with the field (Kelly et al., 2023). In contrast, results show that females learn more and are more motivated on field trips than males (Bätz et al., 2010). When it comes to the technology-related differences in attitudes between females and males, controversial studies have constantly been presented in recent decades, in which either gender differences (Alfadda & Mahdi, 2021; Marth & Bogner, 2019), or equality (Svenningsson et al., 2022, Islahi & Nasrin, 2019) has been emphasized. Well-known, old-fashioned stereotypes of tech-savvy boys and tech-shy girls are often underpinned or attacked by the respective publications. This makes it clear that the gender aspect has a certain relevance when it comes to promoting technological literacy, which should take place for all members of our society, regardless of gender (Pérez Sedeño, 2021). However, in the meantime, two things seem to have become clear, at least, which show that the problem is more complex than initially thought: First, in most studies, several features in addition to gender have contributed to the variation in effect sizes. This seems obvious if you think about the variety of study designs and preconditions of different target groups (Alfadda & Mahdi, 2021). Second, in particular, a more recent study from Svenningson et al. (2022), but also the meta-analysis of 50 articles from the past two decades by Cai et al. (2017), clearly show that gender differences, if they appear, are expressed differently in distinguishable psychometric dimensions. Here, the cognitive, affective, and behavioural attitude dimensions are mentioned more frequently (Svenningsson et al., 2022).

Recent studies by Bengel and Peter (2022, 2021) show a clear gender difference in the affective dimension, both among university students and adolescents in high school from the 9th to 12th grades. This is explicitly represented by perceived intimidation, where significantly higher scores were observed for female respondents in both cases. Since there is evidence that students' technophobia impacts their technological acceptance (Khasawneh, 2022), a reduction in perceived intimidation is of the essence if closing the gender gap and promoting technological acceptance and literacy are the goals. To do so, the authors recommended deliberately addressing this affective dimension in concepts of technological education. Svenningson et al. (2022) name interest as another representative of the affective attitude and also describe this dimension as one of the most important influencing factors and as significantly related to the other two components. Among females, a strong relationship between cognitive and behavioural levels is also reported. Thus, the authors' recommendations for technology education are aimed at stimulating interest through engaging tasks, on the one hand, and conveying a broader conception of technology to females in particular, on the other.

Given that the above-mentioned findings and recommendations can successfully be implemented in a game-based VFT concept, it is essential to observe the latter's possible effects on technology-related attitudes and even examine potential contributions to the reduction of the much-described gender gap. This brings us to the following three research questions to also be answered by this study:

RQ 2 Are there significant effects on content-related attitudes as a result of participating in the game-based VFT?

RQ 3.1 Are there significant gender differences in technology-related attitudes among observed participants?

RQ 3.2 And if so, do these change as a result of participation in the game-based VFT?

4.3 Methods

4.3.1 Concept Description

The SENSO Trail (Science Education and Natural Systems Observation) are an extracurricular educational program for secondary school students funded by the Hessian State Ministry for Higher Education, Research and the Arts, Germany, and it was developed as part of the LOEWE priority project Natur4.0 – Sensing Biodiversity. It applies modern technologies and digital media to teach subject-specific knowledge and scientific methods of innovative environmental monitoring in geography education. This happens interactively and through using games based on authentic examples of forest ecosystems. The goal of successful participation would be an understanding of the complex biotic and abiotic environments and their mutual spatiotemporal relationships, together with an awareness of scientific procedures for the examination of the underlying complex causal structures. Additionally, modern technology is promoted as a key element, both to obtain relevant information (for example, spatial and environmental data through sensors and measuring stations in the forest) and to better understand this information (through the didactic elements of the educational application). Together a picture of the synergic effects of a human-technology-environment relation triangle is drawn and used to identify and discuss the potential of its current and future interactions.

The content and structure of both concepts, VFT and AFT, are identical and consist of seven stations (information transfer), ten examination points (interaction), and several small quizzes (knowledge feedback and retention) on different ecological, geographical, and technological sub-topics. The story-based game structure is provided by the app and does not differ for both variants. The area has a modular structure and resembles an open-world game concept in which new areas are opened up as progress is made. By retrieving research data at each station, unlocking new areas of the forest, and answering quiz questions correctly, participants earn research points that are added up to an overall score and can later be compared with other participants. Central media for information transfer, coordination, and instruction in both variants are auditory and visual sequences (voice messages, images, and animations), which are made available via the app, along with a personal research portfolio with a scoreboard and an interactive digital map of the area with additional informative features.

The same educational concept has been implemented through two variants. The crucial difference between the two variants is the setting. The first is an actual physical adventure trail in the research and teaching forest of the Philipps-University Marburg (figure 4.1).

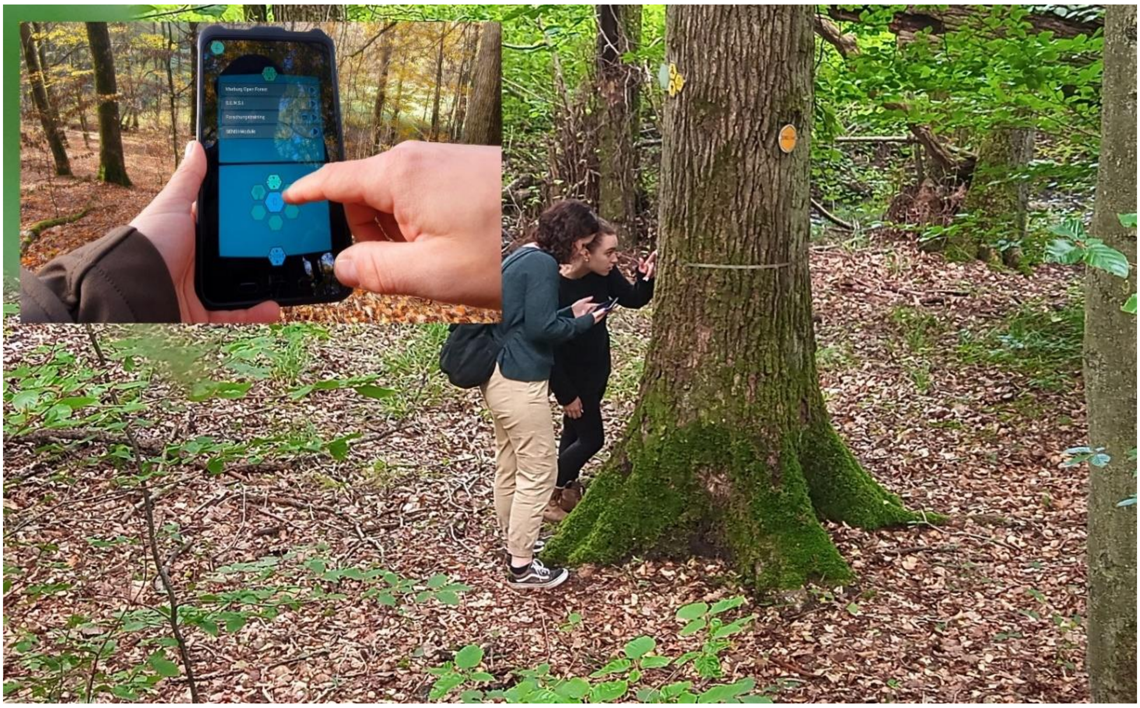

Figure 4.1 AFT participants examining a research station in the forest (large image) and photo of the SENSO app in use (small image).

Here, participation is mainly self-controlled and coordinated by using the associated app on a mobile device. Second, the SENSO Trail360 is designed as a purely virtual tour that can be visited and experienced indoors regardless of one's location. It is accessible on a desktop computer as a modular 3D tour through the simulated forest, consisting of 17 high-resolution 360° images with an integrated version of the app as the central control unit (figure 4.2).

Figure 4.2 Test group participating in the VFT (small image) and a screenshot of the virtual forest with embedded SENSO app (large image).

4.3.2 Survey

Altogether, a total of n = 110 (53 females, 56 males, 1 diverse) students from five German gymnasiums participated in the study between June 2021 and July 2022. The participants were students in mixed-gender classes from the 9th to the 12th grade (m = 10.3) with an average age of 16.4 years. In the first step, n = 66 (33 females, 33 males, 0 diverse) participated in the AFT, and then n = 44 (20 females, 23 males, 1 diverse) joined the VFT the year after. All the schools were contacted and encouraged to participate at the same time. The division of the participating classes into the VFT and AFT was randomly based on the time of registration and the availability of the schools and teachers. All the surveys were conducted on the participation dates, directly before and after the respective interventions. All procedures were performed in compliance with relevant laws and institutional guidelines and were approved by the appropriate institutional committee ("Kommission Forschung und Verantwortung") of the Philipps-University.

Depending on how they identified themselves, participants indicated their gender as m, f, or d; the diverse category was only chosen once and has, therefore, been disregarded in the gender comparisons for statistical reasons. Since, depending on the class level, different levels of knowledge and maturity of the students are to be expected, this was also recorded to ensure comparability of the test (VFT) and control (AFT) groups due to the relatively wide range of four class levels.

In our survey, subject-specific knowledge is the central measure of the success of the interventions. Specifically, this refers to environmental science knowledge and methods, which have strong links to geography and (mostly through a concrete application reference) to modern technology. A review of existing knowledge tests to measure the participants' subject-specific knowledge acquirements, stagnations, or even declines during the interventions was unsatisfactory for scope and content reasons (Huizenga et al., 2009; Kaiser & Frick, 2002). Finally, 15 directly content-related test items were created to meet the needs of this study. The content of our test is directly related to the geographical and technological aspects of the various stations in the forest. The items are statements that could be checked as true, false, or do not know. Items that were correctly checked as true or false were treated as "knowing," and items incorrectly checked as true or false or checked as do not know were treated as "not knowing." See the two examples a (= false statement) and b (= true statement) beyond.

a. A virtual environment model is an exact copy of a certain area of the real world.

◯ *true* ◯ *false* ◯ *don't know*

b. *Nowadays, scientists use self-piloting camera drones, lasers on airplanes and artificial intelligence to study nature and the environment.*

◯ *true* ◯ *false* ◯ *don't know*

The same subject-specific knowledge scale was used for the VFT and the AFT. During the analysis, a variable for knowledge acquisition was created by using the score differences between the pre- (SSK_1) and post-testing (SSK_2) to quantify the actual gain that could have been achieved through the respective interventions.

The Modern Technology Attitude Index (MTAI) was recently developed and has proven to be a suitable tool for measuring and differentiating between attitude dimensions. Its development was the response to an identified lack of instruments that were qualified for such operations in terms of scope and precision (Bengel & Peter, 2021; Ankiewicz, 2019). The MTAI consists of 14 items measuring the three main psychometric dimensions of attitudes: the cognitive, affective, and conative response behavioral dimensions (Eagly & Chaiken, 2011). Further, these dimensions can be categorized based on two technology-aversion scales, intimidation (INT) and loss of control (LOC), and third, a technology-affirmation scale with benefits and easement (BAE). Originally applied to observe pre-service teachers' attitudes, the latest studies show a broader scope of use, including secondary school students (Bengel & Peter, 2021). The tool was, therefore, chosen to identify potential changes within our test group in the virtual setting. The 14 items of the MTAI were rated on a Likert scale with four possible answers: (1) strongly disagree, (2) tend to disagree, (3) tend to agree, and (4) fully agree (Nemoto & Beglar, 2014). For the subsequent analysis, the means of the three subscales were calculated as test values (Bühner, 2011). In contrast to the biographical parameters, the attitudes were also queried again directly after the VFT intervention using the same instrument to observe potential changes (see Table 4.1 and figure 4.3).

Table 4.1: Surveyed parameters of the VFT and AFT groups at the first (pre) and second (post) times of inquiry.

Group	Parameters	Pre-testing	Post-testing
VFT (n = 44)	Biographical parameters	•	
	Subject-specific knowledge	•	•
	Content-related attitudes (MTAI)	•	•
AFT (n = 66)	Biographical parameters	•	
	Subject-specific knowledge	•	•

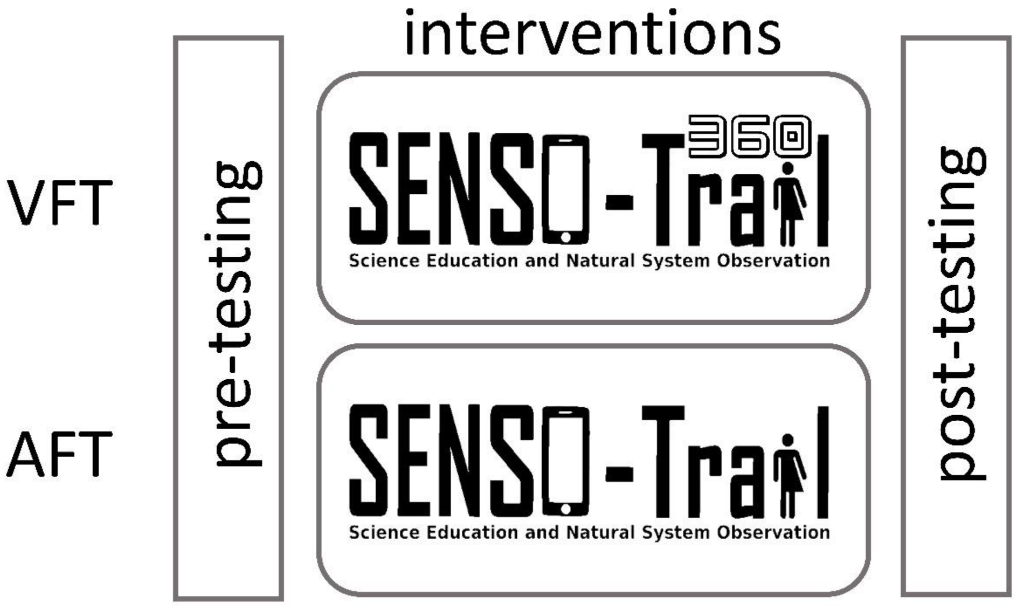

Figure 4.3 Research design.

4.3.3 Data Analysis

For the descriptive methods and comparisons, the free statistical software JASP (version 0.14.1) was used (Wagenmakers, 2021). The data presented in this study are openly available via the research data repository of Phillips-University: https://data.uni-marburg.de/handle/dataumr/226 (accessed on February 21, 2023).

For the identification of potential disparities in the students' grades and the comparison of the prior and acquired subject-specific knowledge scores in both groups, a Student's t-test for independent values was performed. The same procedure was used to compare males' and females' subject-specific knowledge and content-related attitudes scores within the VFT group. For cases of violated normality or equality of variances, either Welch's t or Mann-Whitney tests were used instead. A paired Student's t-test and a respective Wilcoxon signed-rank test were performed for cases with violated normality to analyze all the participants' pre- and post-subject-specific knowledge scores and the indoor group's attitudes pre- and post-scores. The level of significance was set at 0.05 (Bühner, 2011).

4.4 Results

4.4.1 Prerequisites

Before examining the VFT (n = 44) and AFT (n = 66), possible differences in their attributes, such as grade and subject-specific previous knowledge (SSK_1), had to be determined to ensure comparability. The t-test showed no significant differences in the average grades of both groups. However, there is a significant difference in terms of SSK_1. This, as can be seen in figure 4.4, was revealed by a difference of 0.081 in the means ($t_{Welch} = 2.471$, $p = 0.015$), meaning that such knowledge was slightly higher in the VFT group than in the AFT group.

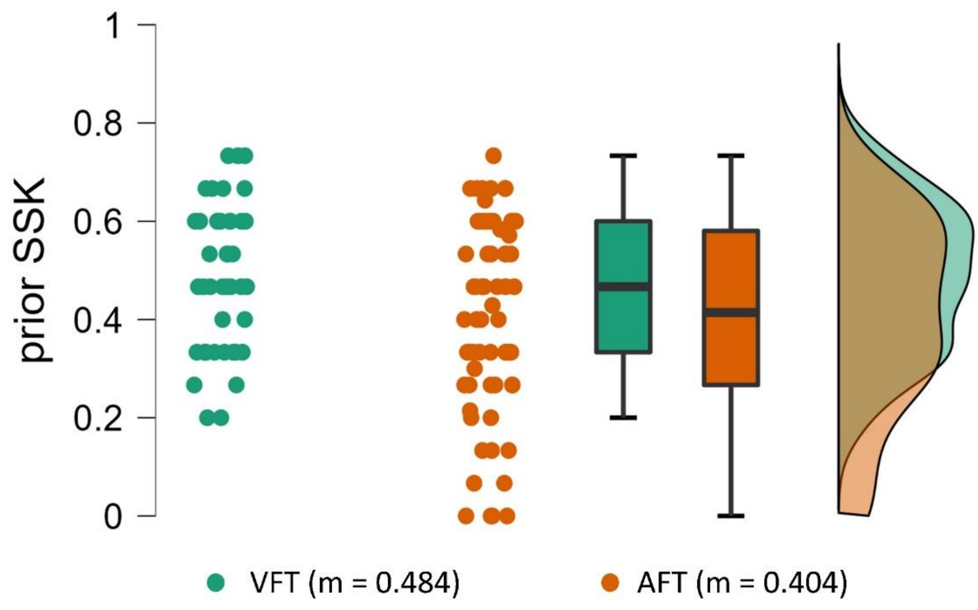

Figure 4.4 Prior subject-specific knowledge scores in the AFT and VFT with means (m).

4.4.2 Acquired Subject-Specific Knowledge

In a second step, the acquired subject-specific knowledge of both groups, which can be seen as the difference between the SSK_2 and SSK_1 scores in figure 4.5, was compared in another t-test. Figure 4.6 shows how the mean values did not differ significantly, with a variance of 0.001 ($t_{Welch} = 0.030$, $p = 0.976$).

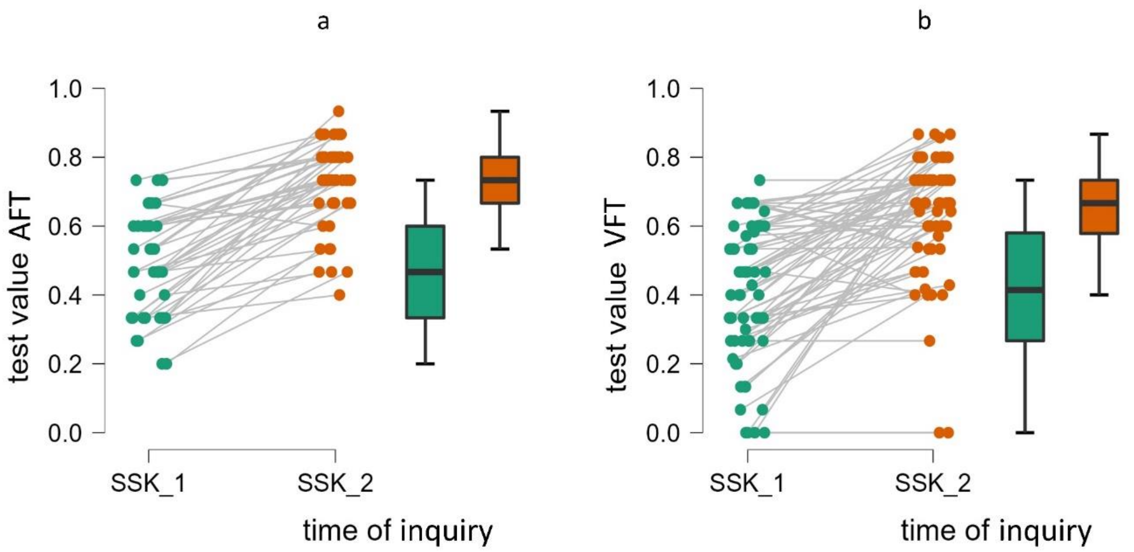

Figure 4.5 Subject-specific knowledge gains of the AFT (a) and VFT (b) between the first and second times of inquiry.

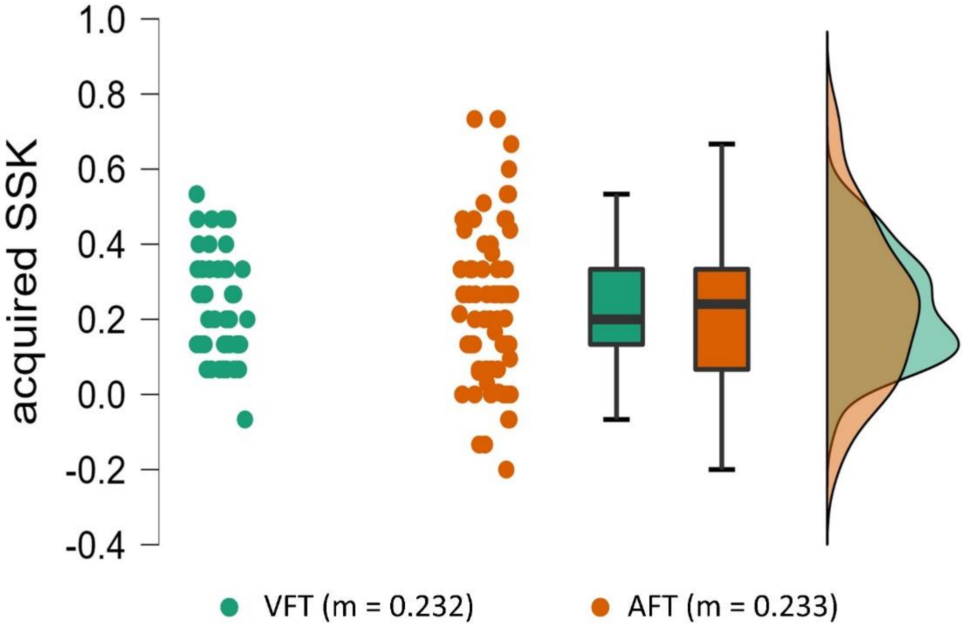

Figure 4.6 Acquired subject-specific knowledge in the AFT and VFT with means (m).

4.4.3 Attitudinal Changes

In the next section of our research, we wanted to analyze content-related attitudes. The goals were to observe whether or not there are significant changes in attitudes towards technology as a result of participation in the virtual experience and, subsequently, identify potential gender effects.

A comparison of the whole test group's (n = 44) pre- and post-values on the affective dimension of intimidation (INT) did not show any significant effects. The result was different for the other two scales. Here a Wilcoxon signed-rank test indicated that the mean post-test ranks of the perceived loss of control (LOC) were significantly lower than the mean pre-test ranks (z = 3.319, p = 0.001; see figure 4.7).

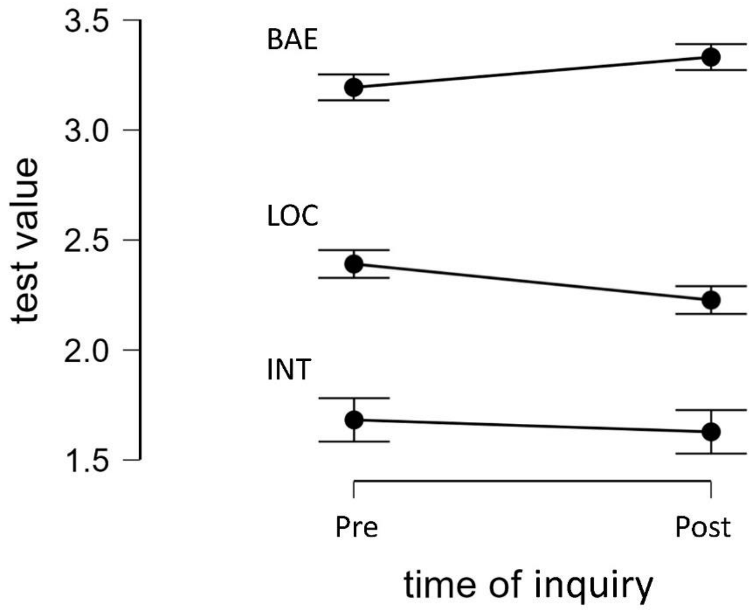

Figure 4.7 Content-related attitudes development of the VFT participants between the first and second times of inquiry.

For the dimension of perceived benefits and easement (BAE), the Wilcoxon signed-rank test indicated that the mean post-test ranks were significantly higher than the mean pre-test ranks (z = -2.665, p = 0.008; see figure 4.7).

4.4.4 Gender Analysis

Next, further t-tests were used to analyze gender-specific differences. These were conducted for subject-specific knowledge and the three dimensions of attitudes before and after the interventions.

A gender comparison of subject-specific knowledge before and after the interventions shows a significant increase in the knowledge of both groups, as mentioned above. Further, there is no significant gender difference in either the initial situation before the interventions or at the second time of inquiry after them.

Other results are observed when it comes to content-related attitudes. At the first time of the inquiry, females showed a significantly higher score on the INT scale than males ($U = 322.5000$, $p = 0.022$). At the second point in time, the score for females had dropped from an average of 1.90 to 1.78 and was, thus, close enough to the nearly unchanged value for males that a statistical difference ($U = 274.0000$, $p = 0.276$) could no longer be proven (see figure 4.8).

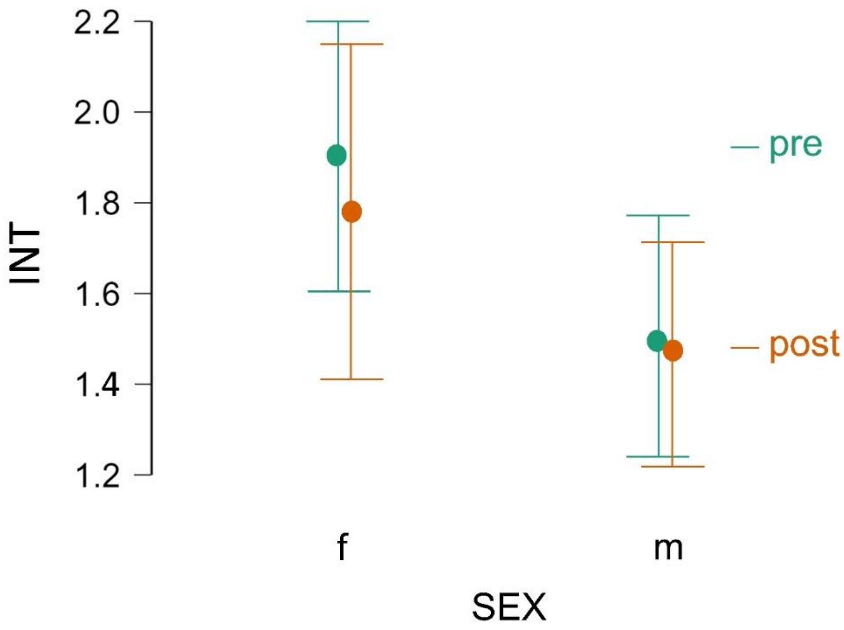

Figure 4.8 INT pre- and post-scores of the female and male VFT participants.

The same effect can be reported for the second aversive dimension measured with the LOC scale. Although there was a cross-gender decline in the test values, the gender difference was also only significant at the first point in time ($t_{Student} = 2.396$, $p = 0.021$), while it was no longer significant at the second point ($t_{Student} = 1.238$, $p = 0.223$) due to a greater decline in the number of females (see figure 4.9).

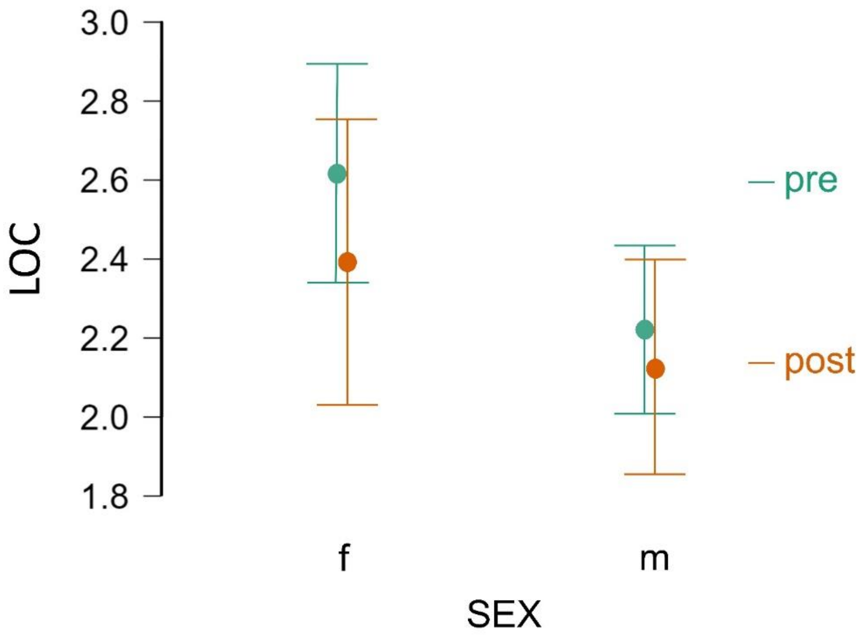

Figure 4.9 LOC pre- and post-scores of the female and male VFT participants.

Regarding the affirmative scale for benefits and easement (BAE), there were no significant gender-specific differences.

4.5 Discussion

4.5.1 Discussion of the Results

In the first step of our research, we wanted to investigate how a fully computerized game-based VFT compares to its AFT counterpart in terms of imparting subject-specific knowledge. Observing the pre-conditions of comparability, despite no measurable differences in grades, we identified significantly lower levels of prior knowledge within the AFT group. However, the positive differences in the acquired knowledge between both times of inquiry among both groups did not differ at all, and, in fact, they were nearly identical. This leads to the conclusion that regardless of the prerequisites, both concept variants work similarly well and confirm earlier assumptions in this regard (Ruberto et al., 2017; Prensky, 2003).

The fact that despite the considerable differences in the settings of both variants students' knowledge acquirements were almost identical can be interpreted in two ways. First, it could be that the aspect of the spatial environment no longer has a subjective influence, since young people of this generation already act as naturally in virtual contexts as they do in real ones. Therefore, it might be that the virtual or actual setting parameters do not really matter as long as the core educational concept remains the same. The second attempt at an explanation seems to be more likely but rather complex at the same time. It includes the assumption that various external influencing factors had an effect in both settings but canceled each other out in the aggregate. Thus, it is easy to imagine that the AFT group experienced many opportunities for distraction due to the open setting in an actual forest, while the participation that took place in a computer room, which is relatively similar to a classroom, was more focused in this regard. At the same time, of course, the experience of actually being in the forest could have left a more authentic and, therefore, positive impression on the learners, as already described by Siegmund et al. (2013), and, thus, have had a positive effect on the learning process. This scenario is only one example of the many ways in which parameters that were not recorded might have had positive or negative effects on the learners' performances but could compensate each other for the bottom line. The positive effects reported in studies of VFTs in geography or serious games in VR may also exist in this case, but they do not seem to outweigh those of actual physical experiences (Ho et al., 2022; Firomumwe, 2021).

For computer-supported geography lessons, this means that VFTs are an attractive alternative to AFTs, at least when it comes to the pure acquisition of subject knowledge. VFTs offer some organizational advantages over AFTs; for example, they are often cheaper, less time-consuming, and more accessible than their counterparts (Klippel et al., 2019). However, in geography education, other competencies are important in addition to subject knowledge. Regarding many of them, it is still unclear whether they might not be better promoted by AFTs, in which application-oriented encounters with real objects and phenomena, which are usually highly valued in geography education, are possible (Friess et al., 2016; Siegmund et al., 2013). In addition, the educational use of computers and modern technology must continue to be treated with caution, given the potential negative physical and mental impacts on learners (Wang et al., 2023; Wood et al., 2013). Anyway, for certain geographical competencies, there is already evidence of the advantage of VFTs, e. g., in the promotion of spatial orientation (Salsabila et al., 2022). At any rate, spatial perception in virtual worlds will be a major issue to be addressed by geography as a science of human-environment relations, but also as a subject of education. In this context, Relph's (1976) concept of representative inwardness could also be interesting, with which he describes a perception that arises when one deals with a place in one's imagination. Although we must leave it to subsequent studies to further illuminate this topic, our investigations of the influences of the game-featured virtual learning worlds on visitors' attitudes may represent another valuable contribution to the role of computers in education.

Other than to be expected from the results of Pirker and Dengel's (2021) literature review there was no general effect on the affective dimension of the participants' attitudes in this study since the perceived intimidation related to modern technology did not change significantly. It is noteworthy that in this context the behavioral (loss of control) and cognitive dimensions (benefits and easement) did show demonstrably changes in favor of affirmative modern technology attitudes. The latter fits with the findings of Cárdenas-Sainz and Baron-Estrada (2022), who in their recent study were able to demonstrate effects on perceived ease of use through the use of modern educational technology. It can thus be concluded that at least one of the MTAI's aversive scales, together with its affirmative scale, indicates a change toward more positive attitudes in relation to modern technology which might have been promoted through the effects of the DGBL-featured VFT intervention. From the perspective of technological literacy promotion, this is a valuable finding that shows that the pedagogical use of appropriate concepts based on computer technology itself is suitable for positively influencing attitudes towards these very devices and their purposes.

At last, the gender-specific differences in attitudes and the respective changes in this study are particularly interesting. At first glance, it already becomes clear that it was a sensible decision to assess attitudes toward modern technology in several dimensions, as earlier studies suggested (Cai et al., 2017). As expected from the previous studies by Bengel and Peter (2022, 2021) and Svenningsson et al. (2022), here too, among the females a significantly higher score was initially found in the affective dimension, which was represented by the aversive subscale for intimidation. Interestingly, there were also differences at the cognitive level, which was represented by the perceived loss of control. The female participants, therefore, showed significantly higher values on both aversion scales than their male counterparts. After participation, however, no clear differences between female and male participants could be detected on either scale. Despite the different gender associations with gaming as e. g. described by Kelly et al. (2023), the game-based approach combined with a virtual experience seems to have a positive impact on female participants, when it comes to a reduction of aversive attitudes towards technology. It is worth noting two things concerning this: First, despite clear attitudinal differences between genders and attitudinal changes over time, none of these facts seems to affect the learning success of either of the genders. This is in line with current results, according to which content-related attitudes do not influence the acquisition of subject-specific knowledge in respective interventions (Bengel & Peter, 2022; Pirker & Dengel, 2021). Second, our results suggest that the DGBL-featured VFT could support a positive development toward closing attitudinal gender gaps within modern technology. These findings are not only a valuable contribution to the development of gender-responsive education. Even more, they support the development of similar computer-based game-featured approaches that effectively reduce the gender gap and equally promote technological literacy on an attitudinal level.

4.5.2 Discussion of the Limitations

The imbalance in terms of the sizes of the two groups can be explained by the fact that, during a pandemic, such as the one transpiring when this study was conducted, it is far easier to recruit school classes for an open-air activity than one in computer rooms. Based on these results, it would perhaps be going too far to assume that interventions such as those described here provide a general solution for closing gender gaps. Nevertheless, the corresponding effects cannot be dismissed out of hand, and the presented approaches could make a positive contribution. We have to admit that this study is a comparison deliberately reduced to a few relevant factors. Other constellations of indoor and outdoor educational approaches and the manifold possibilities offered by digital technologies and game-based learning, such as augmented or mixed reality, could not be included. The same applies to other potential influencing factors and pre-conditions of the participants. Interest, motivation, previous technological experience, perceived self-efficacy, socio-economic background, and additional geographical competencies are just a few variables that follow-up studies or other scholars in this field might want to investigate further.

It should be noted as well that due to the lack of respective instruments, we were not able to survey technological literacy in its complex entirety (Dyrenfurth & Kozak, 1991) However, with parameters of subject-specific knowledge and content-related attitudes, we did measure variables that have a proven effect on this construct (Ardies et al., 2013). By promoting these attributes, we can therefore assume that technological literacy is directly promoted.

4.6 Conclusion

The present study allows us to add results for the positive effects of DGBL (e. g., Camacho-Sánchez et al., 2022) and VFT concepts (e. g., Robledo & Prudente, 2022) as a combined approach. In summary, we can confirm that game-based VFTs and game-based AFTs can equally effectively convey subject-specific knowledge (Robledo & Prudente, 2022; Klippel et al., 2019). Even if the attitudes towards modern technology itself do not seem to have an effect on knowledge acquisition in VFTs, these interventions seem able to promote affirmative attitudes towards modern technologies in general and reduce aversions. Unlike in comparable studies (Araujo-Junior & Bodzin, 2022; Robledo & Prudente, 2022), the content reference of the attitudes establishes a direct link to the modern technology used. The resulting effect is particularly pronounced among females. A gender gap represented by higher intimidation levels among females, was measured before the intervention and could be equalized during the participation. Through targeted knowledge transfer, but also through thte positive effects on the participants' attitudes toward modern technology, this pedagogical approach represents a valuable contribution to the promotion of technological literacy. The findings do not lead us to make a conclusive recommendation for the use of computers and modern technology in either virtual or actual settings. Rather, they show an overarching potential of DGBL-featured and virtually implemented approaches on computers that should be promoted, further developed, and further investigated in their individual but overlapping areas. The exploration of human-(technology-)environment relations in virtual spaces opens up a new aspect of geographical education with unknown potential. If VFTs, as examined in this study, contribute to the promotion of technological literacy through knowledge transfer and positive effects on attitude, it is likely that other approaches will also succeed. While game-based learning was a crucial part of a successful approach in our case, it's not clear that other pedagogical approaches work just as well. However, what became clear is that there does not seem to be a need for targeted “technology education” as such. Positive results can also be achieved if elements of technology education are combined in a transdisciplinary manner (in our case with geographical content) and the technology itself is part of the materials used in the form of computers or apps. These findings open up a broad field for different approaches that could contribute to the promotion of technological literacy. Through the targeted and conscious use of new technologies, modern learning environments could be created, not only for innovative geography lessons but also for the general promotion of technological literacy in society regardless of gender or virtual and real spatial boundaries.

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5 Summary

This dissertation is based on three studies investigating innovative didactic approaches based on modern technologies in extracurricular geography teaching. Besides the conception and evaluation of contemporary educational approaches, the central motive is to contribute to promoting a technologically literate society.

In the first study, the Modern Technology Attitude Index (MTAI) was developed and validated based on a quantitative data set using factor analysis to measure the attitudes of geography teachers toward modern technology in the educational context. The results show that modern technology's perceived benefits and easements are strongly correlated with respondents' subject-specific interest, while gender differences were found in affective attitudes. In the following studies, the instrument was applied with other quantitative measurement tools to adolescent students of Hessian Gymnasiums (high schools) to investigate the effects of technology-supported educational approaches for school field trips. A central role played a multi-perspective approach, together with mobile digital game-based learning (mDGBL), for teaching environmental and technology-related content in a forest ecosystem. The multi-perspective approach aims to reduce the complexity of learning objects in geography education by changing spatial and thematic perspectives. The integration of digital game-based learning supports this process through the fictional plot of a game, which is close to reality but simultaneously limited in complexity by its structural and spatial boundaries. The first intervention led to a significant and long-term improvement in students' subject-specific knowledge compared to a control group. Knowledge acquisition was unaffected by content-related attitudes, prior knowledge, gender, and age of the participants. The following study investigated the potential of virtual field trips in combination with the above approaches. Here, a comparison showed that virtual game-based formats could impart knowledge just as effective as comparable field trips conducted in actual physical settings. Furthermore, the results confirmed the assumption from the previous two studies that certain technophobic attitudinal characteristics are more pronounced in female participants than in males. However, participation in the game-based virtual excursion seemed to eliminate this

difference and reduce aversive attitudes toward modern technologies as well as promote a positive one in both genders.

Overall, the studies highlight the positive impact of technology-enhanced approaches on acquiring subject knowledge and cognitive and behavioral attitudes. At the same time, they reveal gender differences in affective attitudes and suggest approaches to address them. In conclusion, the findings provide valuable insights into digital and technology-enhanced learning possibilities and their potential for innovative extracurricular education. They could thus contribute to the further development of geography education regarding human-technology-environment systems and thus successfully contribute to a more technologically literate society.

5.1 Conclusion

This work aims to explore subject-specific knowledge and technology-related attitudes as crucial indicators for evaluating educational approaches and to develop and apply valid instruments to measure them. Further, it demonstrates how cutting-edge strategies like digital game-based learning, virtual field trips, and mobile technology integration in geography education could efficiently disseminate this subject-specific knowledge and foster positive attitudes toward technology. Gender differences, even if they do not seem to have a demonstrable impact on the knowledge transfer of the educational approach, do play a role and could be effectively addressed with specific measures. The three phases of this dissertation are now considered from a coherent overall perspective, and conclusions reflected on the research aims of this work are drawn.

A central goal of this thesis is the exploration of content-related attitudes of both educators and learners and their significance for the evaluation of educational concepts. The development of a relatively short yet widely and reliably applicable instrument for measuring technology attitudes has provided an elementary basis for this work. Finally, the MTAI adds up to a range of high-quality but disparate instruments available to researchers in this area (e. g., Mart & Bogner, 2019, Wolters, 1989; Shulman, 1986). It has been applied in all three phases of this project. In the initial phase, it provided a valuable first indication that the majority of the pre-service geography teachers tested did not only show interest in, but also, in correlation to that, had relatively positive attitudes toward modern technology. For the educational process that is necessary to create a technology-ready society, this can be seen as a positive prerequisite. Teachers' attitudes toward educational contents and concepts are expected to substantially influence their instructional practices and students' learning experiences (Reichart, 2017; Westerback, 1982). Thus, teacher convictions are a vital aspect of their professionalism (Kunter et al., 2011).

Although educational goals today go far beyond mere knowledge transfer (e. g., DGfG, 2020), it still plays a central role in most pedagogical practices. For this reason, the acquisition of subject-specific knowledge was chosen as the central measure of educational success for the concepts tested in this work (Liu et al., 2014). Geography lessons often deal with complex inter- and transdisciplinary issues, such as the application of modern environmental sciences in forest ecosystems, in the demonstrated case. Those topics often require a comprehensive spatial understanding of systems, their structures, functions, and processes (Mehren et al., 2016; Peter & Nauss, 2020). The challenge of modern and even more extracurricular teaching approaches to provide a sustained knowledge of these topics has been successfully met by the SENSO Trail concept (Neeb, 2012). For a targeted assessment of this subject-specific knowledge, survey instruments were developed that are thematically matched to the content and sufficiently sensitive in their measurement accuracy (see examples in 4.3.2). The second study showed that multi-perspective, mobile digital game-based approaches in an extracurricular context, such as the SENSO Trail, can be very successful when it comes to imparting complex subject-specific knowledge that persists. With a view to the future of innovative educational design in geography lessons, this indicates a clear potential of the approaches tested here.

In the subsequent third study, a comparison was made between the actual, physically implemented concept and an identical but purely virtually implemented variant, the SENSO Trail360. It is interesting to note that the two versions did not differ in the success parameters measured. These results allow conclusions for the future of extracurricular education. From a knowledge transfer perspective, in the case of a field trip, teachers and learners have the free choice to opt for an actual or virtual visit to a learning site. However, there will be other parameters where the two versions differ. Cost, infrastructure, accessibility, and safety (Klippel et al., 2019), or the sensory qualities of an experience and social aspects (Siegmund et al., 2013), may also be relevant in the individual decision. Based on the presented results, however, it can be assumed that the didactic toolbox from which educators can draw will expand in the future to include additional, and promising technologically supported options.

Based on the assumption that content-related attitudes can have an influence on the learning process (Holbrook et al., 2005), attitudes toward nature and the environment were also recorded (Dunlap et al., 2000), in addition to the technical attitudes measured with the MTAI. In the second study, these, together with other personal factors such as age, grade, or gender, should be examined for a potential impact on the knowledge acquisition during the interventions. The fact that none of the measured variables seemed to have any impact on learning success suggests, on the one hand, the robustness of the concepts tested. On the other hand, other individual and external factors were not considered, which might have proven to be effective influencing factors in further investigations.

However, the more detailed analysis of technology-related attitudes in the first study suggested that, even if not correlated to knowledge acquisition, there may be gender-related differences in participants' attitudes toward technology. It even suggested that these may be limited to certain psychometric domains (Ajzen, 1989). The two following studies supported this assumption. In the last study presented, it was finally possible to demonstrate a compensatory effect of the examined educational measure on the gender difference, and an aversion-reducing and affinity-strengthening effect in the overall cohort, with the help of the MTAI. Three main conclusions can be drawn here. First, even among the so-called digital natives of a technology-driven society, affective gender differences in technology attitudes can occur (Marston, 2019). Secondly, the successful implementation of technology-enhanced extracurricular learning approaches is possible without being influenced by these differences; and thirdly, under certain circumstances, they may even help to level out these inequalities and promote a generally receptive attitude towards technology.

Moreover, learners' content-related attitudes toward technology are expected to significantly influence their technological literacy (Ardies et al., 2013). Encouraging a positive affinity and reducing aversions for technology empowers learners to embrace technological advancements, fostering a technologically literate society prepared for the challenges of the modern world. Thus, educators' and learners' attitudes have to be considered when it comes to educational concepts and shaping an environment conducive to meaningful and compelling learning experiences (Pratkanis et al., 2014; Maio & Haddock, 2009).

5.2 Outlook

This research provides valuable insights into the effectiveness and applicability of selected technology-based learning strategies. It explicitly shows the added value that digital media can offer in extracurricular education, and discusses the respective conditions. Some of the findings may be of interest for the development of technology-enhanced teaching strategies, for the training of teachers and curriculum developers, as well as for further research in the field of future-ready extracurricular geography education.

Especially in geography, where extracurricular experiences are essential, the technological options do not yet seem to have been exhausted. On the contrary, new possibilities will continue to arise with technological progress. At the same time, research interest in developing and critically evaluating these possibilities might be growing. For example, this work focused on actual and virtual learning settings separately, but in some areas of the modern educational world, this separation no longer exists. Thanks to AR and XR technologies, supplemented or mixed realities create completely new educational spaces, which should also be designed and examined by competent educators and researchers. Thus, in the future technology-supported, educational approaches to modern geography teaching can be designed in different settings and with different didactic approaches, depending on the target group, learning objective and individual situation. This work only deals with a certain spectrum of these possibilities, the elements of which have been deliberately selected and brought together for extracurricular geographic education based on their didactic popularity, social presence, or potentially adopted application-related qualities. Still, this work could be a cornerstone for further research, providing a valid measurement tool, a review of theoretical foundations, conceptual experience, and quantitative research results.

The emergence of new spaces, virtual, actual or mixed, their structures, effects, and perceptions, as well as their technological implications, should be of particular interest to contemporary geography. On the one hand, this science, like no other, has a spatial focus and the typical working methods of its profession are strongly influenced by technology. On the other hand, also from the perspective of education, which is the focus here. It has been shown, that in geography teaching technology-supported didactic approaches can promote a more open attitude toward modern technology. Further it has been demonstrated, that the approaches can be used in a gender-sensitive manner and could, therefore, address inequalities. Together with other goals of effective educational approaches, this potential for comparable concepts should be further investigated. If corresponding implications for teacher training would be derived from this, and the basis for practical teaching developed, future geography education could also make a significant contribution to the promotion of a technologically literate society.

In conclusion, it could be said that for innovative and future-ready approaches in extracurricular geography teaching, great importance is attached to the targeted integration of technology. Further technological innovations are expected to be developed in future and their didactic implications should be considered with mindful interest.

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6 Zusammenfassung

Diese Dissertation basiert auf drei Studien, die sich im Kern mit der Untersuchung innovativer didaktischer Ansätze, basierend auf modernen Technologien im außerschulischen Geographieunterricht beschäftigen. Zentrale Motivation ist, neben der Konzeption und Evaluation zeitgemäßer Bildungsansätze, dadurch auch einen Beitrag für die Förderung einer technologisch aufgeschlosseneren Gesellschaft zu leisten.

In der ersten Studie wurde der Modern Technology Attitude Index (MTAI) auf der Grundlage eines quantitativen Datensatzes mit Hilfe einer Faktorenanalyse entwickelt und validiert, um anschließend die Einstellung angehender Geographielehrkräfte zur modernen Technologie im Bildungskontext zu messen. Die Ergebnisse zeigen, dass die wahrgenommenen Vorteile und Erleichterungen durch moderne Technologie stark mit dem fachspezifischen Interesse der Befragten korreliert, während bei den affektiven Einstellungen geschlechtsspezifische Unterschiede festgestellt wurden. In den Folgestudien wurde das Instrument zusammen mit anderen quantitativen Messwerkzeugen an jugendlichen Schülerinnen und Schülern Hessischer Gymnasien angewendet, um damit die Effekte technologie-gestützter Bildungsansätze für Schul-Exkursionen zu untersuchen. Dabei spielte ein multiperspektivischer Ansatz, zusammen mit mobilem digitalem spielbasiertem Lernen (mDGBL) zur Vermittlung von umwelt- und technologiebezogenen Inhalten im Ökosystem Wald, eine zentrale Rolle. Der multiperspektivische Ansatz zielt darauf ab, die Komplexität der Lerngegenstände im Geographieunterricht durch den Wechsel räumlicher und fachlicher Perspektiven zu reduzieren. Die Integration von digitalem spielbasiertem Lernen unterstützt diesen Prozess durch die fiktive Handlung eines Spiels, dass einerseits nah an der Realität angelehnt, aber zugleich durch seine strukturellen und räumlichen Grenzen in der Komplexität limitiert ist. Die erste Intervention führte zu einer signifikanten und langfristigen Verbesserung des fachspezifischen Wissens der Schülerinnen und Schüler im Vergleich zu einer Kontrollgruppe. Der Kenntniserwerb blieb dabei unbeeinflusst von inhaltsbezogenen Einstellungen, fachlichen Vorkenntnissen, Geschlecht und Alter der Teilnehmenden. Die darauffolgende Studie untersuchte das Potenzial von virtuellen Exkursionen in Kombination mit den oben genannten Ansätzen. Hier zeigte ein Vergleich, dass virtuelle spiel-basierte Formate, ebenso effektiv bei der Wissensvermittlung sein können, wie vergleichbare, im Realraum durchgeführte Exkursionen. Darüber hinaus bestärkten die Ergebnisse, eine, aus den vorherigen Studien hervorgegangene Annahme, dass bestimmte technophobe Einstellungsmerkmale bei weiblichen Teilnehmenden stärker ausgeprägt sind als bei Männlichen. Die Teilnahme an der spielbasierten virtuellen Exkursion schien diesen Unterschied jedoch auszugleichen und bei beiden Geschlechtern, aversive Einstellungen gegenüber modernen Technologien zu verringern und eine positive Einstellung zu fördern.

Insgesamt heben die Studien die positiven Auswirkungen technologiebasierter Ansätze auf den Erwerb fachspezifischer Kenntnisse, sowie kognitive und verhaltensbezogene Einstellungen hervor. Sie decken gleichzeitig geschlechtsspezifische Unterschiede bei affektiven Einstellungen auf und weisen auf Ansätze hin diese zu adressieren. Zusammenfassend bieten die Ergebnisse wertvolle Einblicke in Möglichkeiten des digitalen und technologie-gestützten Lernens und seine Potenziale für innovative außerschulischer Bildung. Sie könnten damit zur Weiterentwicklung des Geographieunterrichts in der Betrachtung von Mensch-Technik-Umwelt Systemen und damit erfolgreich zu einer technologisch aufgeschlosseneren Gesellschaft beitragen.

Appendix

A MTAI item examples

Table A: Modern Technology Attitude Index (MTAI) with one item example (in German) for each of the three sub-scales.

Nr.	Sub-scale	Text
1	INT	*Moderne Technik ist mir unangenehm, weil ich sie nicht verstehe.*
2	LOC	*Bald wird unsere Welt vollständig von Technik beherrscht.*
3	BAE	*Moderne Technik ist für viele der guten Dinge verantwortlich die wir genießen.*

B Questionnaire excerpts

(1st time of inquiry, main study)

Hallo und vielen Dank,

dass Du unsere Studie unterstützt!

Worum es geht:
In unserer Forschung beschäftigen wir uns mit der Prüfung neuer Lehr-Lern-Formate, die z.B. an digitalen oder realen Lernorten stattfinden. Dabei interessiert uns von welchen Voraussetzungen und Einflussfaktoren der Erfolg solcher Bildungsangebote abhängt. In diesem Fall geht es dabei besonders um Themen aus Natur und Umwelt und moderne Technik.
Deine Teilnahme an unserer Studie ist absolut freiwillig und kann von Dir ohne eine Angabe von Gründen verweigert oder zu jedem Zeitpunkt abgebrochen werden. Dir würden daraus keinerlei Nachteile entstehen.
Dennoch freuen wir uns sehr, wenn Du mitmachst und damit aktiv einen wichtigen Teil zu unserer Forschung beiträgst!
Alle erhobenen Daten werden auch absolut anonym behandelt, ausschließlich zu Studienzwecken verwendet und anschließend gelöscht.

Dein persönlicher Code:

Damit wir deine Daten später vergleichen können ohne wissen zu müssen zu welcher Person sie gehören erstellt sich jede*r Teilnehmende einen einzigartigen Code.
Befolge dazu bitte die folgenden Schritte:

1. Trage hier den **aktuellen Monat** (als Zahl) ein
2. Trage hier den **ersten** Buchstaben des Vornamens deiner Mutter ein
3. Trage hier den **letzten** Buchstaben deines Nachnamens ein
4. Trage hier dein **Geburtsjahr** ein
5. Trage hier deine **Jahrgangstufe** ein
6. Trage hier ein „W" ein, wenn du **weiblich**, ein „M" wenn du **männlich** bist. (Wenn du dich keiner der beiden Kategorien zugehörig fühlst, darfst du ein D eintragen)

1	2	3	4	5	6

Beispiel:
Sophie Müller nimmt im **Juli** (**7**. Monat) an der Befragung teil, ihre Mutter heißt **E**mma, der letzte Buchstabe ihres Nachnamens ist ein **R**, sie ist **2006** geboren und geht in die **8.** Klasse, außerdem ist sie **w**eiblich

1	2	3	4	5	6
7	E	R	2006	8	W

Einverständniserklärung

Die Richtlinien guter ethischer Forschung sehen vor, dass sich die Teilnehmenden an empirischen Studien (bzw. ihre gesetzlichen Vertreter) explizit und nachvollziehbar mit der Teilnahme einverstanden erklären.

Worum es geht.
Ziel der Studie ist es eine neuentwickeltes, virtuelles Lern-Erlebnis-Konzept (SENSO-Trail360) zu testen. Das Konzept baut auf verschiede Elemente auf, die bspw. Inhalte zu moderner Technik und natürlicher Umwelt aus wissenschaftlicher Sicht betrachten und in einem Gamedesign verbinden. Deine Antworten werden uns dabei helfen Schwachstellen und Stärken zu erkennen und das Angebot noch zu verbessern. Darum ist es wichtig, dass du den Fragebogen bis zum Ende ausfüllst!
Vielen Dank!

Freiwilligkeit.
Deine Teilnahme an dieser Untersuchung ist freiwillig. Es steht dir zu jedem Zeitpunkt dieser Studie frei, deine Teilnahme abzubrechen, ohne dass dir daraus Nachteile entstehen.

Anonymität.
Deine Daten sind selbstverständlich vertraulich, werden pseudonymisiert erhoben und nur in anonymisierter Form ausgewertet und nicht an Andere weitergegeben. Angaben wie Alter oder Geschlecht lassen keinen eindeutigen Schluss auf deine Person zu.

Datenschutz.
Personenbezogene Daten werden noch vor Ort pseudonymisiert (nach Art. 25 DSGVO) erfasst und anschließend (nach Art. 17 DSGVO), für Dritte unzugänglich in gesicherten Räumlichkeiten der Philipps-Universität aufbewahrt. Für die Auswertung werden die Daten anonymisiert und ausschließlich in anonymisierter Form für den angegebenen Zweck (vgl. „Zweckbindung“ Art. 5 DSGVO) verwendet. Nach Abschluss der Forschungsarbeit, spätestens aber zum 31.12.2024 werden alle Daten gemäß Art. 17 DSGVO vollständig gelöscht (Aufbewahrungs- und Löschkonzept kann auf Wunsch eingesehen werden).

Fragen.
Falls du noch Fragen zu dieser Studie haben solltest, findest du unten eine Mailadresse des Studienleiters an die du schreiben kannst. Du kannst auch jederzeit eine/n Studienbetreuer/in ansprechen und deine Fragen stellen. der ein

Studienleiter und Durchführender Wissenschaftler: Phillip Bengel, M.Sc

◯ **Hiermit bestätige ich, dass ich die Einverständniserklärung gelesen und verstanden habe und (im Fall von Minderjährigen) das Einverständnis eines/r Erziehungsberechtigten eingeholt habe.**

1. Schultyp
Bitte gib deinen Schultyp an.

Ich bin Schüler/in an ...

◯ einer Hauptschule
◯ einer Mittelstufenschule
◯ einer Realschule
◯ einem Gymnasium
◯ einer Förderschule
◯ kooperativen Gesamtschule
◯ integrierten Gesamtschule
◯ andere
◯ ich bin kein/e Schüler/in

[this part has been deleted for reasons of publication by the author]

2. Umwelt
Hier möchten wir nun etwas über deine Einstellung zur **Umwelt** erfahren.
Bitte bewerte jede Aussage aus deiner persönlichen Sicht und gib an, ob sie für dich *voll zutrifft, eher zutrifft, eher nicht zutrifft* oder *überhaupt nicht zutrifft*.

Bitte immer <u>nur eine Antwort</u> auswählen!!!

[This part (NEP-Scale by Dunlap et al., 2000) has been removed by the author for reasons of publication.]

Du hast schon über zwei Drittel geschafft, weiter geht‵s …Endspurt ->

3. Moderne Technik

Mit dem Begriff ***moderne Technik*** sind Software und Hardware von Hightech-Geräten gemeint, deren technologischer Stand nicht älter als 15 Jahre ist. Dazu zählen z. B. Smartphones, Computer, Tablets, Wearables, Drohnen, Smart-TV, etc., aber auch technische Instrumente die in der Industrie, Wirtschaft und Forschung verwendet werden.

Beurteile die Aussagen aus deiner persönlichen Sicht.

[This part has been removed by the author for reasons of publication. Find examples in appendix A]

4. Wissensfragen

Hinweis:
Wundere dich nicht, wenn die folgenden Fragen etwas speziell und zum Teil auch schwierig erscheinen.

Die Fragen dienen dazu den Wissensstand unterschiedlicher Menschen zu Natur und Technik abzufragen. Es ist also keine Schande, wenn du eine falsche Antwort auswählst, oder einmal eine Frage gar nicht beantworten kannst (wähle dann einfach die Option **"weiß ich nicht"**, das **ist besser als zu raten!**).

[This part has been removed by the author for reasons of publication. Find item examples 4.3.2]

Du hast es geschafft! Vielen Dank 😊

…und jetzt viel Spaß in unserem Forschungswald!

(2nd time of inquiry, main study)

Vielen Dank, dass du noch einmal mitmachst.

Die erneute Befragung (teilweise mit denselben Fragen) ist **besonders wichtig** für unsere Studie. Durch sie werden später Unterschiede zwischen den Erhebungszeitpunkten untersucht - um zu sehen welchen Effekt die Teilnahme an unserem Konzept bei den Teilnehmenden hatte.
Beantworte die Fragen bitte wieder konzentriert und gewissenhaft und vergiss nicht deinen Kenn-Code auf der ersten Seite einzutragen!

Dein persönlicher Code:

Damit wir deine Daten später vergleichen können ohne wissen zu müssen zu welcher Person sie gehören erstellt sich jede*r Teilnehmende einen einzigartigen Code.
Befolge dazu bitte die folgenden Schritte:

1. Trage hier den **aktuellen Monat** (als Zahl) ein
2. Trage hier den **ersten** Buchstaben des Vornamens deiner Mutter ein
3. Trage hier den **letzten** Buchstaben deines Nachnamens ein
4. Trage hier dein **Geburtsjahr** ein
5. Trage hier deine **Jahrgangstufe** ein
6. Trage hier ein „W“ ein, wenn du **weiblich**, ein „M“ wenn du **männlich** bist. (Wenn du dich keiner der beiden Kategorien zugehörig fühlst, darfst du ein D eintragen)

1	2	3	4	5	6

Beispiel:
Sophie Müller nimmt im **Juli** (**7**. Monat) an der Befragung teil, ihre Mutter heißt **E**mma, der letzte Buchstabe ihres Nachnamens ist ein **R**, sie ist **2006** geboren und geht in die **8.** Klasse, außerdem ist sie **w**eiblich

1	2	3	4	5	6
7	E	R	2006	8	W

Wissensfragen

[This part has been removed by the author for reasons of publication. Find item examples in 4.3.2]

Herzlichen Dank für deine Teilnahme!!!

(3rd time of inquiry, main study)

Vielen Dank, dass du noch ein letztes Mal mitmachst.

Wir wissen drei Fragebögen sind viel. Trotzdem möchten wir dich noch **ein aller-letztes Mal** bitten **noch 5 Minuten** konzentriert und gewissenhaft mitzumachen und vergiss nicht wieder deinen Kenn-Code hier einzutragen!

Dein persönlicher Code:

Damit wir deine Daten später vergleichen können ohne wissen zu müssen zu welcher Person sie gehören erstellt sich jede*r Teilnehmende einen einzigartigen Code.
Befolge dazu bitte die folgenden Schritte:

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1	2	3	4	5	6

Beispiel:
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1	2	3	4	5	6
7	E	R	2006	8	W

Wissensfragen

[This part has been removed by the author for reasons of publication. Find item examples in 4.3.2]

Herzlichen Dank für deine Teilnahme!!!

(1st time of inquiry, follow-up study)

Hallo und vielen Dank,

dass Du unsere Studie unterstützt!

Dein persönlicher Code:

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3. Trage hier den **zweiten** Buchstaben des Vornamens **deiner Mutter** ein
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1	2	3	4	5	6	7

<u>Beispiel:</u>

Sophie Mülle**r** nimmt im **Februar** an einem **Mi**ttwoch an der Veranstaltung teil. Ihre Mutter heißt E**m**ma, ihr Nachname endet auf **R**, sie ist **2006** geboren, geht in die **10**. Klasse und sie ist **W**eiblich

1	2	3	4	5	6	7
2	Mi	M	R	2006	10	W

Einverständniserklärung

Die Richtlinien guter ethischer Forschung sehen vor, dass sich die Teilnehmenden an empirischen Studien (bzw. ihre gesetzlichen Vertreter) explizit und nachvollziehbar mit der Teilnahme einverstanden erklären.

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Darum ist es wichtig, dass du den Fragebogen bis zum Ende ausfüllst!
Vielen Dank!

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Personenbezogene Daten werden noch vor Ort pseudonymisiert (nach Art. 25 DSGVO) erfasst und anschließend (nach Art. 17 DSGVO), für Dritte unzugänglich in gesicherten Räumlichkeiten der Philipps-Universität aufbewahrt. Für die Auswertung werden die Daten anonymisiert und ausschließlich in anonymisierter Form für den angegebenen Zweck (vgl. „Zweckbindung“ Art. 5 DSGVO) verwendet. Nach Abschluss der Forschungsarbeit, spätestens aber zum 31.12.2024 werden alle Daten gemäß Art. 17 DSGVO vollständig gelöscht (Aufbewahrungs- und Löschkonzept kann auf Wunsch eingesehen werden).

Fragen.
Falls du noch Fragen zu dieser Studie haben solltest, findest du unten eine Mailadresse des Studienleiters an die du schreiben kannst. Du kannst auch jederzeit eine/n Studienbetreuer/in ansprechen und deine Fragen stellen. der ein

Studienleiter und Durchführender Wissenschaftler: Phillip Bengel, M.Sc

○ **Hiermit bestätige ich, dass ich die Einverständniserklärung gelesen und verstanden habe und (im Fall von Minderjährigen) das Einverständnis eines/r Erziehungsberechtigten eingeholt habe.**

Wissensfragen

Hinweis:
Wundere dich nicht, wenn die folgenden Fragen etwas speziell und zum Teil auch schwierig erscheinen.
Diese 15 Fragen dienen dazu, das Vorwissen abzufragen. Es ist also keine Schande hier noch nichts oder nur wenig zu wissen.
Wähle in dem Fall einfach die Option "weiß ich nicht", das ist besser als zu raten!

[This part has been removed by the author for reasons of publication. Find item examples in 4.3.2]

Einstellungsfragen

Mit dem Begriff ***moderne Technik*** sind Software und Hardware von Hightech-Geräten gemeint, deren technologischer Stand nicht älter als 15 Jahre ist. Dazu zählen z. B. Smartphones, Computer, Tablets, Wearables, Drohnen, Smart-TV, etc., aber auch technische Instrumente die in der Industrie, Wirtschaft und Forschung verwendet werden.

Bitte bewerte jede Aussage aus deiner persönlichen Sicht und gib an, ob sie für dich

++ voll zutrifft

+ eher zutrifft

- eher nicht zutrifft oder

- - überhaupt nicht zutrifft

[This part has been removed by the author for reasons of publication. Find item examples in appendix A]

Du hast es geschafft! Vielen Dank :)
…und jetzt viel Spaß auf dem SENSO-Trail360!

(2nd time of inquiry, follow-up study)

Fragebogen II

Vielen Dank, dass du noch mal mitmachst.
Die erneute Befragung (teilweise mit denselben Fragen) ist **besonders wichtig** für unsere Studie. Durch sie werden später Unterschiede zwischen den Erhebungszeitpunkten untersucht - um zu sehen welchen Effekt die Teilnahme an unserem Konzept bei den Teilnehmenden hatte.
Beantworte die Fragen bitte wieder konzentriert und vollständig und vergiss nicht deinen Kenn-Code auf der ersten Seite einzutragen!

Dein persönlicher Code:

Damit wir deine Daten später vergleichen können ohne wissen zu müssen zu welcher Person sie gehören erstellt sich jede*r Teilnehmende einen einzigartigen Code.
Befolge dazu bitte die folgenden Schritte:

1. Trage hier den **aktuellen Monat** (als Zahl) ein
2. Trage hier den **Wochentag** ein, an dem du am *SENSO-Trail360* teilgenommen hast
3. Trage hier den **zweiten** Buchstaben des Vornamens **deiner Mutter** ein
4. Trage hier den **letzten** Buchstaben deines **Nachnamens** ein
5. Trage hier dein **Geburtsjahr** ein
6. Trage hier deine **Jahrgangstufe** ein
7. Trage hier ein „W“ ein, wenn du **weiblich**, ein „M“ wenn du **männlich** bist. (Wenn du dich keiner der beiden Kategorien zugehörig fühlst, darfst du ein D eintragen)

1	2	3	4	5	6	7

Beispiel:

Sophie Müller nimmt im Februar an einem Mittwoch an der Veranstaltung teil. Ihre Mutter heißt Emma, ihr Nachname endet auf R, sie ist 2006 geboren, geht in die 10. Klasse und sie ist weiblich

1	2	3	4	5	6	7
2	Mi	M	R	2006	10	W

Wissensfragen

[This part has been removed by the author for reasons of publication. Find item examples in 4.3.2]

Einstellungsfragen

Bitte bewerte im nächsten Abschnitt wieder jede Aussage aus deiner persönlichen Sicht und gib an, ob sie für dich

++ voll zutrifft

+ eher zutrifft

\- ***eher nicht zutrifft*** oder

- - ***überhaupt nicht zutrifft***

Bitte immer nur eine Antwort auswählen!!!

[This part has been removed by the author for reasons of publication. Find item examples in appendix A]

Es ist geschafft, super!!!

Und Herzlichen Dank für deine Teilnahme :)