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Digital media to enhance learning in informal learning contexts

With a focus on knowledge acquisition, motivational and cognitive aspects especially in the STEM field

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Dedicated to my beloved daughter Marie

“Any day spent with you is my favorite day.
So, today is my new favorite day.”
Winnie the Pooh

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Abstract

Digital media have a high potential for supporting learning processes in both formal and institutional informal learning places. The present dissertation examines learning with digital media once in an institutional informal context as a systematic literature review and once as an applied example in a formal setting, but in an informal learning context.

In order to get a first overview of the research on the use of digital media in institutional informal learning places as well as connecting points for further research, a systematic literature review (Article A) was conducted on the basis of 26 studies in the first step. Qualitative content analysis was used to examine the identified studies on the general characteristics of digital media and their functions in institutional informal learning places, as well as on the measured outcomes regarding informal learning with digital media in institutional informal learning places. The results show that portable and stationary digital media are used somewhat equally frequently and often include augmented reality. However, the range of possible functions is not yet fully exploited in the conceptualization. It has been shown that digital media are able to enhance motivational and cognitive learning processes, especially in knowledge acquisition and interest as well as in collaboration and social interaction.

Connecting to the findings from the systematic literature review, the second step was an empirical study examining an exemplary use of digital media in a formal setting but in an informal learning context (Article B) with a special focus on how to support learning. In the study, 62 university students used different types of double-content worked examples (WE) integrated into a digital learning environment to learn the steps of scientific observation as part of a course on water body structure mapping. The aim was to find out to what extent WE can support the acquisition of a basic scientific method competence - scientific observation. For this purpose, the acquisition of factual and applied knowledge about scientific observation, motivational aspects and cognitive load were investigated. The results showed that WE promoted knowledge application, as students in the experimental groups were able to perform the steps of scientific observation more accurately. No advantage was shown by faded WE over non-faded WE. Descriptive results also revealed higher motivation and lower extraneous cognitive load in the experimental groups, although none of these differences were statistically significant. Our results add to the existing evidence that WE can be useful for developing science literacy.

Zusammenfassung

Digitale Medien besitzen ein großes Potenzial zur Unterstützung von Lernprozessen sowohl in formalen als auch in institutionellen informellen Lernorten. Die vorliegende Dissertation untersucht das Lernen mit digitalen Medien einmal in einem institutionellen informellen Kontext als systematisches Literaturreview und einmal als angewandtes Beispiel in einem formalen Setting, aber informellen Lernkontext. Um einen ersten Überblick über die Forschung zum Einsatz von digitalen Medien an institutionellen informellen Lernorten sowie Anknüpfungspunkte für weitere Forschung zu erhalten, wurde in einem ersten Schritt ein systematisches Literaturreview (Artikel A) anhand von 26 Studien erstellt. Mittels der qualitativen Inhaltsanalyse wurden die ermittelten Studien zu den allgemeinen Merkmalen der digitalen Medien und deren Funktionen sowie zu den gemessenen Ergebnissen in Bezug auf das informelle Lernen mit digitalen Medien in institutionellen informellen Lernorten untersucht. Die Ergebnisse zeigen, dass portable und stationäre digitale Medien etwa gleich häufig eingesetzt werden und oft Augmented Reality beinhalten. Die Bandbreite an möglichen Funktionen wird jedoch bei der Konzipierung noch nicht vollständig ausgeschöpft. Es hat sich gezeigt, dass digitale Medien in der Lage sind motivationale und kognitive Lernprozesse zu fördern, vor allem beim Wissenserwerb und beim Interesse sowie bei der Zusammenarbeit und sozialen Interaktion. Anknüpfend an die Erkenntnisse aus dem systematischen Literaturreview wurde als zweiter Schritt eine empirische Studie durchgeführt, die einen beispielhaften Einsatz von digitalen Medien an einem zwar formalen Lernort, aber in einem informellen Lernkontext untersucht (Artikel B), wobei der Forschungsschwerpunkt auf der Unterstützung des Lernens lag. In der Studie nutzten 62 Universitätsstudierende verschiedene Arten von double-content Worked Examples (WE), die in eine digitale Lernumgebung eingebettet waren, um die Schritte der wissenschaftlichen Beobachtung im Rahmen eines Kurses über die Gewässerkartierung zu erlernen. Ziel war es herauszufinden, inwieweit WE den Erwerb einer grundlegenden wissenschaftlichen Methodenkompetenz - der wissenschaftlichen Beobachtung - unterstützen können. Hierfür wurde der Erwerb von Fakten- und Anwendungswissen über wissenschaftliche Beobachtung, motivationale Aspekte und kognitive Belastung untersucht. Die Ergebnisse zeigten, dass WE die Wissensanwendung fördert, da die Studierenden der Versuchsgruppen die einzelnen Schritte der wissenschaftlichen Beobachtung genauer durchzuführen konnten. Keinen Vorteil zeigten faded WE gegenüber non-faded WE. Die deskriptiven Ergebnisse ergaben zudem eine höhere Motivation und eine geringere kognitive Fremdbelastung in den Versuchsgruppen, wobei keiner dieser Unterschiede statistisch signifikant war. Unsere Ergebnisse ergänzen die bestehenden Belege dafür, dass WE für den Aufbau naturwissenschaftlicher Kompetenzen nützlich sein können.

Included Publications

The present dissertation was written cumulatively and includes two English-language journal articles published in international peer-reviewed journals. The author of this dissertation is first author of both articles (Article A: 75 %, Article B: 70 %) and was primarily responsible for developing and designing the study, collecting and analyzing the data and writing the two publications.

Article A was submitted to the open-access journal Computers and Education Open in June 2021 and was accepted for publication in December 2021. The supervisor Prof. Doris Lewalter (10 %) and the co-author Dr. Stephanie Moser (15 %), supported the writing process by providing professional comments and proofreading the article.

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Contents

1 Introduction

The definition of what characterizes a learning place has been constantly changing for many decades. The term "learning place" was first defined by the German Education Council in 1974 (Deutscher Bildungsrat, 1974). At that time, a place of learning was defined as an educational institution that is recognized within the public education system and systematically organizes learning programs. Although this term already implies a plurality of learning places, informal learning and explicit orientation towards the target group are not considered. From the 1990s onwards, an extension of the learning place concept took place with the inclusion of informal learning. In the following decades, the combination of learning places and the decentralized connection of institutions and learning places came more and more into focus (Tippelt & Reich-Claassen, 2010). Currently, in addition to formal educational institutions such as schools or universities, extracurricular and informal learning places are in the focus of the educational debate, as these learning places have a great potential for, among other things, science education (Leibniz-bildungspotenziale@dipf.de, 2023).

These learning places include the institutional informal learning places, such as museums, nature parks or botanical gardens (Schwan et al., 2014). The institutional informal learning places are characterized by the fact that they are visited individually or in groups by people of different ages and backgrounds for a variety of reasons, such as the need for education or entertainment. These learning places offer learners the opportunity to gain experiences that are sometimes not possible in a formal setting (Lin & Schunn, 2016). The authenticity of the place, for example, in zoos or aquariums allows learners to observe animals in their habitat or look at objects presented in museums in reality rather than just on pictures or videos. However, these learning experiences are characterized by often being spontaneous and uncoordinated, making the learning process mostly self-directed (Rogers, 2014) and often leading to knowledge gains based on random discoveries (Lewalter & Neubauer, 2019).

This leads necessarily to the question of how learning can be supported in these informal learning places in order to ensure learning success. Digital media seem to be appropriate for this purpose, as they contain various functions with which learning can be structured and supported. For example, information can be presented in a variety of ways, such as visually and auditorily or by mixing virtual and real environments (Ibáñez & Delgado-Kloos, 2018; Mantiri, 2014). Through the functions of adaptivity and interactivity it is also possible to make concrete reference to the learner's level of knowledge and provide a tool for active learning (Bannert & Reimann, 2009; Gerard et al., 2015; Niegemann & Heidig, 2019).

Institutional informal learning places such as museums often relate thematically to the natural sciences. With regard to the learning content to be taught at these informal learning places, they can offer the opportunity to acquire basic or general knowledge on domain-specific topics or more universal scientific methods (Lunetta et al., 2007). Due to their functions, digital media can provide appropriate support for teaching such learning content.

In addition, a specific instructional scaffold called worked examples (WE) have proven to be particularly helpful in acquiring the cognitive schemata that often have to be learned in the natural sciences (Renkl, 2014). WE follow a specific structure in that they demonstrate all the steps required to solve a task or problem. They consist of a problem statement, the solution steps and the solution itself. By focusing on the problem and solution steps while working on the task, the learner should be able to develop more generalized solutions or schemata. The learning-irrelevant, cognitive load is low with WE solutions (Sweller et al., 1998). This is because the use of WE, also in their digital form, can avoid consuming more cognitive resources than necessary to learn successive actions (Renkl, 2017). The benefit of using WE in science is well established by studies (Barbieri et al., 2021; Booth et al., 2015). However, only a few studies specifically address the impact of WE on the acquisition of basic science competencies involving heuristic problem-solving processes (Hefter et al., 2014; Koenen et al., 2017; Schworm & Renkl, 2007).

The overall aim of this dissertation is to show how (mobile) digital media are used in informal learning contexts and to what extent the media can support the informal learning in terms of cognitive and motivational aspects. As this is still a rather new field of research with just older and non-systematically analyzed literature reviews (Hawkey, 2004; Sefton-Green, 2004), the first step was to review the current status quo of the research field by conducting a systematic literature review in order to get a first impression of how (mobile) digital media are used to support informal learning with a focus on institutional informal learning places (Article A). Here, the focus of the evaluation was on the general characteristics, learning-relevant functions and learning outcomes for the digital media examined in institutional informal learning places. The term institutional informal learning places was chosen for the study because the focus should be explicitly on informal learning in specific institutions. In the systematic literature review, the focus is on the use of digital media during the individual informal learning process of visitors in the sense of a freely selectable learning activity in the respective setting.

After attempting to answer the overall goal by means of qualitative research, the second step was to develop a mobile digital learning environment based on the findings of the literature review. In addition, the self-developed learning environment should be designed to be motivating and not cognitively overloaded and providing factual knowledge and applied knowledge (Article B).

Specifically, the study examined the effects of different forms of digitally presented WE (no WE vs. non-faded WE vs. faded WE) using learning videos on students' cognitive and motivational outcomes. The WE are heuristic double-content We, which include two learning domains (learning domain and exemplifying domain). The insights gained from this research provide a practical extension of the findings from Article A in order to give hands-on recommendations for this research field. Furthermore, the combined perspective of factual and applied knowledge as well as motivational and cognitive aspects provides another value of the study. Both articles have been published in peer-reviewed international journals.

At the beginning of the thesis, chapter 2 provides an overview of different learning places with a special focus on institutional informal learning places. In chapter 3, the use of digital media to support informal learning in these learning places is presented. How specific learning support in the form of digital worked examples can look like, is explained in chapter 4. Following the theoretical part, chapter 5 presents the two studies with their specific research questions. In Chapter 6, Study I is presented with regard to the research design and the results. Chapter 7 presents Study II, including the research design and results, as well as a description of the digital learning environment. The chapter 8 contains the overall interpretation and discussion of the results as well as the practical implications. At the end, the limitations of the studies are mentioned and recommendations for future research are given. The thesis closes with the conclusion.

2 Different forms of learning (places)

2.1 Differentiation of the learning forms

In Study I, the focus was on the investigation of learning in institutional informal learning places in order to examine the use of digital media during the individual informal learning process of visitors, in the sense of a freely selectable learning activity in the respective setting. However, it is important to understand and differentiate between the different forms of learning in other learning places, as they each encompass different learning contexts and methods. Knowledge of these different learning contexts and methods can help to develop effective learning strategies.

A general distinction is made between the three forms of formal, non-formal and informal learning (Lewalter & Neubauer, 2019). Formal learning traditionally takes place in educational or training institutions and occurs under pedagogical guidance. Learning in such educational institutions is structured in terms of learning content, learning objective, learning time and learning method. The content to be taught is based on the curriculum and learning leads to formal certification. From the learner's perspective, formal learning is mandatory, goal-orientated and intentional. In contrast, non-formal learning is typically not offered by an educational or training institution, but takes place at specific locations, such as in-house training. Also, in this case learning is systematically structured in terms of learning objectives, learning time or learning support, but does not lead to certification. From the learner's perspective, non-formal learning is voluntary, goal-orientated and intentional. Informal learning, on the other hand, often takes place in everyday life in a non-staged setting. It is not structured in terms of learning objectives, learning time or learning support and does not lead to certification. In contrast to non-formal learning, informal learning can be intentional from the learner's perspective, but does not have to be (European Commission, 2002; Lewalter & Neubauer, 2019).

2.1.1 Institutional informal learning places

Institutional informal learning places such as museums, zoos, aquariums or science centers represent a specific learning setting that enables learners to learn independently and, in an action-oriented way. They differ from formal educational settings such as schools in that learners can have a variety of experiences there that are not possible in formal settings (Lin & Schunn, 2016). Another characteristic of these learning places is that they are visited by a very heterogeneous audience in terms of age and preconditions (Schwan et al., 2014) and when visiting the places as a group or individually, the goals and intentions of the visit can be very different (Falk, 2009). These learning places are often visited because of the need for entertainment, education, aesthetic appreciation, recreation, social exchange or because of the place itself (Schwan et al., 2014).

In these learning places, information are often presented through real and authentic objects such as artifacts or live animals and supplemented by hands-on activities and narratives in this setting (Schwan et al., 2014). This type of learning place often consists of a large room that has many focal points of attention and presents information simultaneously throughout the room.

2.1.2 Informal learning in institutional informal learning places

As shown in 2.1.1, there are different types of institutional informal learning places in which learning takes place in a very specific way. Learning in institutional informal learning places is lifelong and self-directed learning, which usually takes place without direct guidance (Schugurensky, 2000). This means that it is not structured in terms of learning goals, learning time or learning support. Instead, learning is problem-solving orientated, whereby the learning material is predominantly viewed holistically (Eshach, 2007; Lewalter & Neubauer, 2020). On the one hand, this means that learners initiate and plan the informal learning process themselves and carry it out purposefully and intentionally. However, this does not necessarily have to be the case. The learning process in institutional informal learning places can be self-initiated, but not purposeful and casually (Lewalter & Neubauer, 2019). The learning outcomes achieved in this manner are primarily based on experiential knowledge, which means that informal learning does not lead to certification (Rogers, 2014). It has also been shown that informal learning activities can enhance scientific thinking skills (Gerber et al., 2001). The experiences gained through informal learning foster learning and interest in such a way that it can lead to ongoing engagement in science activities (Morris et al., 2019).

3 Digital media and informal learning (places)

3.1 Digital media and the focus on informal learning

Due to rapid technological progress, digital media can be found in many areas of life. Especially for the younger generation, digital media have become an integral part of life (Mantiri, 2014). This is accompanied by the diverse use of digital media, whereby the support of learning processes plays a major role. (Mobile) digital media can be defined as electronic devices on which information can be saved and transferred in digital form. In addition to stationary digital media such as tabletops or computer, mobile web-based media such as smartphones or tablets are primarily used to support learning in order to access (learning) information independently of time and place. The retrieved (learning) information can then be presented in different ways via digital media, for example, as texts, images, sounds, videos, animations or a combination of these elements (Mantiri, 2014). This creates the opportunity for digital learning material to be designed in such a way that it can be used by learners according to their own preferences, prior knowledge or learning pace. In terms of "ubiquitous learning", mobile digital media thus offer the opportunity to design learning processes in a flexible and self-directed way (Moser, 2017).

However, it must be considered here that, especially in self-directed learning environments as is often the case in informal learning places, the use of digital information in itself does not automatically lead to an enhancement of the learning process. For this reason, further supportive measures are necessary to guide the learning process in order to really support learning processes using digital information (Bannert & Reimann, 2009; Lin et al., 2017; Moser et al., 2017). On a cognitive and motivational level, these can be, n, design features that enable interactivity and adaptivity (Bannert & Reimann, 2009; Gerard et al., 2015; Niegemann & Heidig, 2019). Studies have already shown that digital media appear to have a positive influence on the learning process for learner´s subject knowledge (Chien, 2012), motivation (Lin et al., 2017) and media literacy (Ungerer, 2016). The use of digital media to support learning can be especially appropriate in institutional informal learning places (Schwan et al., 2018). Here, digital media offer an exciting, interactive and educational experience and thus combine leisure entertainment and education (Schwan, 2015). In museums, for example, information is prepared with the help of digital media in order to explore exhibits in a self-directed manner instead of passively viewing objects (Schwan, 2015). New digital applications such as AR options can be implemented here, for example, which combine the physical and virtual worlds of the learners by expanding the real world of the learners with additional virtual information on a display (Ibáñez & Delgado-Kloos, 2018).

This results in two roles for digital media: In one case, digital media can be used to complement the learning experience by presenting a complex principle using animation on a screen. Secondly, the digital medium itself can provide authentic insights, for example, when learners actively use the medium to acquire new knowledge on their own. Digital media are usually found in museums in their complementary role (Kampschulte et al., 2019).

3.2 Functions and use of digital media in institutional informal learning places

Digital media offer the advantage that they can provide various functions, adapted to the respective learning situation. Three didactically relevant functions in teaching-learning processes can be considered as follows (Ojstersek & Kerres, 2010): 1) Digital media as knowledge tools for the presentation of information, in order to present difficult-to-understand facts more clearly through different presentations. 2) Digital media for communication and cooperation to support collaboration and communication in synchronous and asynchronous form between individuals and groups. 3) Digital media for controlling the learning process by using digital learning programs to enable the presentation of learning content in the ongoing learning process or self-directed processing of learning content.

An extension to five functions of digital media is made by Petko (2014): 1) Digital media have here the function as information and presentation means, in order to represent learning contents understandably as well as to present the information in different way (text, audio, video). 2) Digital media can be used to make learning tasks more diverse, for example, by linking various multimedia materials with reality. 3) Digital media as a tool and work equipment offer the possibility to support the work by word processing and presentation programs. 4) Digital media for learning support and communication can promote interaction, for example, through chats, forums, audio and video conferences. 5) Finally, digital media for test evaluation offer the possibility of conducting exams more efficiently, evaluating them automatically and reporting back.

Based on Petko's five functions, Kampschulte et al. (2019) analyzed the functions of the media used in 120 informal learning places. In fact, the results show that digital media are primarily used as "information and presentation tools" in informal learning places. In second and third place are media for "designing learning tasks" and as "tools and work equipment". The media are rarely used for "learning guidance and communication" and are only used for "examination and assessment" at one of the learning places.

4 Learning support through digital worked examples

4.1 The use of digitally presented worked examples to enhance learning

Especially in the fields of STEM education (science, technology, engineering and mathematic), it is often necessary to learn certain laws or principles. This often concerns the acquisition of domain-specific topics such as the application of a mathematical multiplication rule or more general scientific methods such as conducting the steps of a scientific observation (Lunetta et al., 2007). Digital media can be used here to support STEM learning, such as through the use of digitally presented WE (Booth et al., 2015; Renkl, 2014). The digitally presented WE enables the content to be presented in different ways, for example, via video, audio, text or images or in a combination of different formats. This is beneficial because it allows the content to be adapted to the needs of the learners, so that it can be used individually according to their own prior knowledge or learning speed (Mayer, 2001). WE are designed to consist of a problem statement, the solution steps, and the solution itself (Atkinson et al., 2000; Renkl, 2014; Renkl et al., 2002). This information can be provided to learners in a timely, motivating, and engaging manner using digital media to make learning effective and on-demand (Mayer, 2001).

Studies show that digitally presented WE leads to higher learner satisfaction, positive attitudes and content knowledge (Dart et al., 2020). The use of digital WE can demonstrate positive effects on self-directed learning in terms of learning location, learning time, and learning speed (Kay & Edwards, 2012). The addition of self-explanatory prompts to digital WE have been shown to be superior to learning methods such as hypertext learning and observational learning (Berthold et al., 2009). The successful use of WE are significantly dependent on the influence on the cognitive load during learning, which is based on the assumption of the Cognitive Load Theory (Sweller, 2006).

The Cognitive Load Theory analyses the cognitive load when acquiring knowledge. The basic idea of the theory is that the cognitive capacity of the human working memory is limited, so that learning is hindered if a learning task requires too much capacity. The extent of the cognitive load during learning depends on how complex the learning content is and how the learning materials are designed (Skulmowski & Man Xu, 2021; Sweller, 2006). If the cognitive load is too high for the capacity of the working memory, this leads to cognitive overload, which has a negative impact on learning success. A differentiation is made between three forms of cognitive load (Sweller, 2006). Intrinsic cognitive load is caused by the complexity and difficulty of the task itself. The more complex and difficult a task is, the higher the intrinsic cognitive load can be. The extraneous cognitive load is due to the design and presentation of the learning material and the learning environment. A high extraneous cognitive load can lead to reduced performance on a task.

Germane cognitive load refers to the mental effort required to understand and learn new concepts and information. Germane cognitive load is important to the learning process as it helps to ensure that information can be effectively processed and remembered (Sweller, 2010). Here, studies show that the use of WE can lead to a decrease in extraneous load, while leading to an increase in germane load (Paas et al., 2003; Renkl, 2014). Regarding intrinsic load, it is still not conclusive whether WE have an influence on this (Gerjets et al., 2004).

Furthermore, WE have been shown to be particularly effective with novices in terms of learning gain (Bokosmaty et al., 2015; Sweller et al., 1998; Van Gog et al., 2011), but can lose this advantage as knowledge gain progresses due to the expertise reversal effect. The expertise reversal effect means that the effectiveness of the instructional material is strongly dependent on the learner's level of knowledge. While inexperienced learners may benefit from more guidance, experienced learners may have a load on their working memory, because some or all of the instructions may be redundant for them (Kalyuga et al., 2003). This phenomenon can be prevented with so-called scaffolding learning, in which so-called faded WE are used to gradually fade out solution steps as learners' knowledge and expertise grow (Renkl, 2014). Here, faded WE, in contrast to non-faded WE have been shown to improve near knowledge transfer while reducing errors (Renkl et al., 2000).

In terms of learning motivation, the reduction of intrinsic and extraneous cognitive load through WE show a positive impact (Van Harsel et al., 2019). In particular, positive effects have been demonstrated on interest (Gupta, 2019; Van Gog & Paas, 2006) and with regard to learner satisfaction and emotions (Um et al., 2012). Again, fading and non-fading WE have different effects on learners. Fading WE are more motivating for more experienced learners, while non-fading WE can be particularly motivating for learners without prior knowledge (Paas et al., 2005). In addition, it can be further assumed that learning environments that use WE may have an impact on learners' situational interest and basic needs. This assumption is based on the fact that learning environments are influenced by motivational aspects in the learning process, such as situational interest (Lewalter & Knogler, 2014), motivationally relevant experiences, such as basic needs, or by motivational attributes of the learning process, such as self-determined motivation (Deci & Ryan, 2012).

Situational interest is a content-related motivational quality that develops in a current learning situation and is linked to it (Lewalter & Willems, 2009). It is based on the situational characteristics of the learning environment, the individually perceived interest of the learning material and the emotional experience during the learning process. Situational interest is divided into two phases, the catch phase ("triggered interest") and the hold phase ("maintained interest") (Neubauer, 2015). The catch phase refers to the first occurrence of situational interest, where one's own attention is drawn to an object and interest is awakened.

In the following hold phase, interest in the learning situation should be maintained, for example, by the learner seeing the learning object as personally relevant and therefore wanting to become more involved with it (Lewalter & Willems, 2009; Neubauer, 2015). There is a close connection here to the value-based component of basic scientific literacy, which emphasizes the appreciation of science and scientific research, as well as the willingness to engage with it. This confirms the appropriateness of situational interest as a motivational indicator for measuring basic scientific literacy (Neubauer, 2015). Learning environments that foster autonomy, competence and social integration in the sense of basic needs can contribute to the development of situational interest in particular (Lewalter & Willems, 2009). The need for autonomy is expressed in a person's efforts to experience themselves as acting independently, for example, by defining the goals and procedures of their own actions for themselves. The experience of competence refers to a person's need to experience themselves as capable of acting in the face of challenges in learning and work situations and to be able to manage tasks under their own power. The need for social integration is based on a person's general desire for social contact and is expressed in the effort to achieve social acceptance in the relevant peer group.

Furthermore, with regard to WE, a distinction can be made between algorithmic and heuristic WE as well as WE with one and two contents (Koenen et al., 2017; Reiss et al., 2008; Renkl, 2017). As the focus of the present study is on heuristic WE with two contents, only these are described below. According to Koenen et al. (2017), heuristic WE used in STEM fields, mainly include basic scientific working methods, such as conducting experiments. Double-content WE include two learning domains relevant to the learning process (Renkl et al., 2009). Here, the first learning domain contains the process or concept to be learned, in this study the method of scientific observation. The second exemplifying domain contains the specific content on which the process or concept from the learning domain is learnt. In this study, this is the mapping of a water body structure.

4.2 Scientific observation as a learning object

As mentioned above, learning in science is often about the acquisition of fundamental principles related to, for example, universal scientific methods (Lunetta et al., 2007). An example is learning the steps of scientific observation, which is fundamental to all scientific activities and disciplines (Kohlhauf et al., 2011). In contrast to unspecific everyday observation, which merely involves the noticing and description of certain characteristics (Chinn & Malhotra, 2001), scientific observation is a complex activity for the method of knowledge acquisition. It is defined as theory-based, systematic and selective observation of concrete systems and processes without basic manipulation (Wellnitz & Mayer, 2013).

Similar to experimentation, scientific observation is also about developing an understanding of the criteria for appropriate experimental design in relation to the development, measurement and evaluation of outcomes (Brownell et al, 2014; Dasgupta, Anderson & Pelaez, 2014; Deane et al, 2014; Sirum & Humburg, 2011).

In detail, scientific observation consists of the six steps of 1) formulating the research question(s), 2) deriving the null hypothesis and alternative hypothesis, 3) planning the research design, 4) conducting the observation, 5) analyzing the data and 6) answering the research question(s) (Wellnitz & Mayer, 2013).

The WE described in the chapter 4.1 are shown here to be suitable to support the learning of scientific observation (Booth et al., 2015; Renkl, 2014). This didactic support on a cognitive level by means of digitally presented WE is important so that observation can be carried out in a clear and structured manner (Eberbach & Crowley, 2009; Ford, 2005). This is because, especially in informal learning contexts, scientific observation often takes place in a spontaneous and uncoordinated manner and knowledge gain is due to random discoveries (Jensen, 2014).

5 The present research

Against the background of the growing importance use of digital media in school and university educational contexts, this dissertation contributes to providing on the one hand, an up to date and systematic overview of the research field of the use of digital media in institutional informal learning places to support informal learning and on the other hand to analyses the effectiveness of a self-developed digital learning environment in relation to double-content WE in an informal learning context. The results of the studies presented in the two articles of the dissertation contribute to finding out how digital media should be designed in highly self-regulated educational contexts in order to be as motivating and cognitively less loaded as possible, as well as to contribute to maximizing knowledge acquisition.

Article A (Digital Media in Institutional Informal Learning Places: A Systematic Literature Review) Learning contexts and educational contexts are becoming increasingly diverse. In addition to the classic formal learning places such as school or university, institutional informal learning places such as museums, botanical gardens or zoos become more and more important (Schwan et al., 2014). However, learning in precisely such learning places is often confronted with the difficulties that the learning process here often takes place spontaneously and uncoordinated (Rogers, 2014). For this reason, it is important to provide support, for example, through the use of digital media. Because of their different functions, such as the possibility to present information in a variety of ways, they have a high potential to structure informal learning. The use of digital media to support learning in institutional informal learning contexts is a field of educational research with rather older and not systematically examined literature reviews. And even in the more recent literature, mainly application-specific analyses can be found, for example, review articles on AR applications. To address this research gap, an updated, comprehensive, and systematic literature review was conducted to investigate research findings related to the use of digital media in institutional informal learning places. The research focused primarily on the general characteristics, learning-relevant functions and learning outcomes of using digital media in this educational context.

This led to the following three research questions:

RQ1: What are the general characteristics of the examined digital media in institutional informal learning places?

RQ2: What are the functions of the examined digital media in institutional informal learning places that are relevant for learning?

RQ3: What learning outcomes were measured as they relate to informal learning with digital media in institutional informal learning places in the examined studies?

Article B (Learning Scientific Observation with Worked Examples in a Digital Learning Environment) Based on the findings the systematic literature review, the aim of Study II was to develop and analysis a digital learning environment and to test the practical application in an informal learning context with regard to knowledge acquisition, motivation and cognitive load. While knowledge acquisition and motivation were already investigated aspects in the systematic literature review, the cognitive load was not investigated in detail. However, especially with the use of WE, the cognitive load is an important aspect to be investigated, as WE can support the development of cognitive schemas during learning in order to avoid an overload of cognitive resources during learning (Renkl et al., 2004; Renkl, 2017). Previous studies showed that faded WE performed better compared to non-faded WE in terms of knowledge acquisition and cognitive overload (Renkl et al., 2000). The study was designed in the context of a university water body structure mapping workshop in which during a field trip several river sections of a small Bavarian river were mapped. Three different types of double-content WE (no WE, faded WE, non-faded WE) in the form of learning videos were investigated to what extent they can support the acquisition of a basic scientific methodological competence - conducting scientific observations. So, the focus is on learning scientific observation (learning domain) through river structure mapping (exemplifying domain), which takes place with the support of digital media in a formal (university) setting but in an informal learning context (field trip in nature).

This led to the following three research questions:

RQ1: To what extent exist differences between the three conditions (no WE, faded WE, non-faded WE) with regard to learners' competence acquisition (acquisition of factual knowledge about the scientific observation method (quantitative data) and practical application of the scientific observation method (quantified qualitative data))?

RQ2: To what extent exist differences between the three conditions with regard to learners' motivation (situational interest and basic needs)?

RQ3: To what extent exist differences between the three conditions with regard to cognitive load?

It is assumed that (Hypothesis 1), the integration of WE (faded and non-faded) leads to significantly higher competence acquisition (factual and applied knowledge), significantly higher motivation and significantly lower extraneous cognitive load as well as higher germane cognitive load during the learning process compared to a learning environment without WE. No differences between the conditions are expected regarding intrinsic cognitive load. Further, it is assumed (Hypothesis 2) that the integration of faded WE leads to significantly higher competence acquisition, significantly higher motivation and lower extraneous cognitive load as well as higher germane cognitive load during the learning processes compared to non-faded WE. No differences between the conditions are expected with regard to intrinsic cognitive load.

6 Study I: Digital media in institutional informal learning places: A systematic literature review

6.1 Qualitative data analysis in the context of a systematic literature review

For the systematic literature review as Study I, a literature search was conducted between November 2020 and February 2021 according to PRISMA guidelines (Higgins et al., 2019; Siddaway et al., 2019). After determining inclusion and exclusion criteria, established online research databases on education (Scopus and FIS (include ERIC, EBSCOhost ebooks and BASE)) were searched for studies. Search terms covered the three main topics of the research questions were used for this purpose: Media, Informal Learning and Institutional Informal Learning Places. The search of the databases yielded a total of 125 hits, 52 from the FIS database and 73 from Scopus. Four duplicates were removed from these hits. Subsequently, the titles and abstracts of the remaining 121 hits were reviewed, resulting in the exclusion of 92 hits. The remaining 29 hits were now reviewed in detail and another 19 hits were excluded. A total of 10 matching studies were thus identified. In the next step, a backward as well as a forward search was performed on the 10 studies and the excluded literature reviews to find additional relevant studies. Through these procedures, additional 16 studies were found. In total, the systematic literature review thus examined 26 studies. These 26 studies are marked with an asterisk in the references list. A more detailed description of the literature search including the exact search syntax can be found in the article in chapter 3.1. The studies were evaluated using the method of qualitative content analysis (Aspers & Corte, 2019; Mayring, 2015). For this purpose, corresponding categories were formed for each of the three research questions in order to group the studies according to their common characteristics.

The first category examined the hardware and software to determine the general characteristics of digital media. The category "hardware" included the subcategory "device" (medium used) and the subcategories "mobile medium" and "stationary medium". The category "Software" included the subcategories "Accessibility", "Name of the software used" and "Digital format". The second category examined six didactic functions and one sub-function following Kerres (2000) and Petko (2014) to determine the general media functions. Here the categories "information" (only availability of information), "task” (giving an instruction to work), the subcategory "processed task" (processing the task in the real or the virtual world), "documentation and processing" (creating photos, audio recordings or notes) "cooperation or collaboration" (instruction to work together to process a task), "communication" (possibility to contact other users), "evaluation and feedback" (receiving feedback) were examined. The third category examined the measured learning outcomes. For this, the five categories "research approach," "data collection," "cognitive outcomes," "motivational outcomes," and "outcomes related to collaboration and social interaction" were examined.

The coding of the 26 studies was done manually separately according to their characteristics and then classified according to the established categories. To check the coding, eight manuscripts were then randomly selected and cross-coded by an external coder. A total of 208 cases were analyzed, with 17 cases not matching. The analysis revealed a high to very high degree of agreement (Cohen's $\kappa = 0.763$ to Cohen's $\kappa = 0.910$). It can be assumed that the category system is clearly formulated and that the units of analysis can be correctly assigned. With regard to the 17 differently coded cases, both coders exchanged views and adapted the coding guide on the basis of consensus.

6.2 Empirical findings

Before the results are presented, structured according to the research questions, a short overview of the studies analyzed is given in order to be able to better classify the further results. The studies analyzed are predominantly from the natural sciences (biology and physics) and rarely from the fields of art, history or music. The institutional informal learning places found in the articles are primarily museums, especially natural science museums. Since 2016, significantly more studies have been published and the institutional informal learning places have become more heterogeneous and, in addition to well-known learning places such as science and nature centers, summer camps and nature parks have been found (Zimmermann et al., 2014; Zimmermann et al., 2016; Fränkel et al, 2020; Knoblich, 2020). With regard to the duration of the visit, it was revealed that visitors spend an average of 30 to 60 minutes at the learning place and the visit mainly takes place in groups of two or three.

With regard to the first research question, which examines the characteristics of digital media, the results showed that stationary digital media are used approximately as frequently as mobile digital media. However, since 2018 mobile digital media such as smartphones or tablets have been increasingly used, although the use of smartphones is very rare in contrast to tablets. One explanation for this could be that, due to rapid technological progress, smartphones are now better equipped and can be used to play complex applications (Khaddage et al., 2016). Most visitors now bring their own smartphones with them so to use according to the "bring your own device (BYOD)" approach. Applications are developed specifically for the studies with approximately the same frequency as using existing applications. However, self-developed applications have been increasingly implemented since 2018. AR visualizations have become quite common in recent years, but they differ significantly in terms of complexity. While complex AR visualizations such as 2D and 3D avatars have been used since 2019 (Moorhouse et al., 2019; Hammady et al., 2020), AR was mostly used as dynamic visualizations or instructional labels in previous studies (Yoon, et al., 2012a; Yoon, et al., 2012b; Wang et al., 2012).

With regard to the second research question, which examines the functions of digital media, the evaluation showed that the most frequently used function is the provision of information and tasks. This corresponds to the findings of Kampschulte et al. (2019), where media are used in particular for information and presentation purposes as well as for the design of learning tasks. In the studies analyzed, the tasks are mainly completed in the virtual world, with different levels of complexity. In addition to short work instructions ("try to complete the cycle", Yoon et al., 2012b), there are also detailed instructions on how to explore the museum (Clayphan et al., 2018). Both in this evaluation and in the study by Kampschulte et al. (2019), the documentation and editing function comes in third place, which mostly includes tools for taking photos or saving notes. The existence of a communication function in the media tool, for example, in the form of chats or emails, is very rare both in the present study (Evans et al., 2014; Zimmermann et al., 2014) and in the study of Kampschulte et al. (2019). Overall, an increase in the number of digital media functions can be seen from 2018 onwards.

With regard to the third research question, it has been shown that qualitative or mixed-methods are primarily used for data collection. One reason for this could be the relatively new field of research, where the focus is on obtaining comprehensive results (Mohajan, 2019). Aspects such as engagement or social interaction can be measured more accurately through qualitative data collection, for example, by means of observation (Apers & Corte, 2019). Quantitative research is less common and is mainly used to evaluate the acquisition of knowledge. Most studies use a research design without a control group to investigate different conditions in the media tool. Also, the use of media is rarely tested against no use of media, if then in relation to the acquisition of knowledge. Especially at the beginning of media research, the investigation of the effectiveness of digital media with learning without digital media was prioritized, even if a specific analysis of the conditions was often neglected (Ammad-ud-din et al., 2014).

With regard to the measured outcomes, the results show that the outcomes can be divided into three categories: cognitive outcomes, motivational outcomes and outcomes relating to collaboration and interaction. With regard to the cognitive outcomes, the analysis found that mainly content knowledge and conceptual knowledge were measured. Other cognitive outcomes measured, but very rarely found, were cognitive understanding, preferred learning style, cognitive theorizing skills, media literacy, procedural knowledge and digital competence. Only positive cognitive outcomes related to the use of digital media were reported in all studies analyzed. With regard to the motivational outcomes the analysis showed that different motivation qualities, interest, and visitor engagement are measured. Regarding motivation, different aspects are assessed: general motivation, intrinsic motivation, internal motivation and external motivation. In addition, interest is partly stated more specifically: situational interest, general interest and science interest.

In all studies reviewed, only positive motivational outcomes are reported. With regard to visitor engagement, the studies analyzed showed that interactive tabletops have a positive impact on visitor engagement. One study (Dieck et al., 2016) reported negative effects on visitor engagement and social acceptance of visitors due to the use of wearable AR applications. In terms of collaboration and interaction, the studies analyzed showed that social interaction, collaboration and family conversations were measured. In all studies analyzed, collaboration and interaction were evaluated positively. A more detailed description of the results including the qualitative analysis can be found in the article in chapter 4.

Overall, the results show that institutional informal learning places have become more and more diverse in recent years and that, in addition to museums, galleries or nature parks are increasingly coming into focus. It also shows that the design of digital media tools is becoming more and more complex, for example through the increased use of 3D animations, and that portable digital media are preferred. Not nearly all the functions that digital media can provide are currently used, but mostly the provision of information and tasks. Furthermore, the results suggest that digital media promote and support motivational and cognitive informal learning processes, especially in knowledge acquisition and interest as well as collaboration and social interaction.

In summary, this study has broadened research on the still very new field of educational research on the use of digital media in institutional informal learning places by systematically correlating the individual studies for the first time in a systematic literature review. The study thus provides important insights for media-based educational research. The overarching conclusion of the study is that digital media at institutional informal learning places offer appropriate support possibilities to enhance informal learning.

7 Study II: Learning scientific observation with worked examples in a digital learning environment

7.1 Mixed method approach to assess scientific observation competence of university students

In Study II, 62 science students and doctoral students from a German university participated (age M = 24.03 years; SD = 4.20; 36 females; 26 male). The participants had different levels of prior knowledge of scientific observation (N=37, intermediate level knowledge) and water body structure mapping (N=7, intermediate level knowledge). N=25 had no experience in both. Two participants were excluded retrospectively due to lack of posttest. The study was conducted as a field experiment with a 1-factorial, quasi-experimental, comparative research design (pretest and posttest) where participants were randomly assigned to one of three conditions. Two online questionnaires (pretest and posttest) were used to collect the data. The pretest included socio-demographic questions, questions about the course of study, number of semesters and questions about prior knowledge about scientific observation. Also, the independent preparation based on the learning materials for the water body structure mapping was questioned (Bayerisches Landesamt für Umwelt, 2019; Walker et al. 2007). Furthermore, the pretest included a factual knowledge test on scientific observation and questions for calculation the self-determination index. The factual knowledge test for the quantitative assessment of scientific observation competence consisted of 12 single-choice questions. The questions are based on Wahser (2008, adapted from Koenen, 2014) and are adapted to scientific observation. For the calculation of the self-determination index (SDI-index), Thomas and Müller's (2011) scale for self-determination was used in the pretest.

In the posttest, the same knowledge test was used for comparison. In addition, questions were asked about basic needs, situational interest, measures of cognitive load and questions about the usefulness of the WE. The basic needs were measured with the scale by Willems and Lewalter (2011). Situational interest was measured with the scale by Lewalter and Knogler (2014; Knogler et al., 2015; Lewalter, 2020). The intrinsic cognitive load and the extraneous cognitive load were measured with the scales from Klepsch et al. (2017). The germane cognitive load was measured with the scale from Leppink et al. (2013). The usefulness of the WE were measured with the scale from Renkl (2001) and with the scale from Wachsmuth (2020). All scales used in the study are proven instruments for measuring the results that fulfil the quality criteria of objectivity, reliability and validity. Furthermore, applied knowledge in the form of answers written by the participants in the digital learning environment (Chapter 7.2) was evaluated by using a self-developed coding scheme. A detailed description of the coding scheme can be found in the article in chapter 3.4.1.

Using the coding scheme, 600 cases to be coded (60 participants with 10 responses each) were identified and coded by the first author. Of these cases, 240 cases (24 participants, 8 from each course) were randomly selected and cross-coded by an external coder for verification. The assessment agreed in 206 of the coded cases. The cases where the raters disagreed were discussed together and a solution was found. A Cohen's $\kappa = 0.858$ results from this, indicating a high to very high level of agreement. This suggests that the category system is clearly formulated and that the individual units of analysis could be correctly categorized.

To answer the research questions analyses were conducted using SPSS version 28. Descriptive statistics (means, standard deviation) were calculated for the variables. Using ANOVA, there were no significant differences in the variable’s prior knowledge and SDI index between the three groups, which is why they were excluded as covariates. A single factorial analysis of variance (ANOVA) with repeated measures was used to compare the three groups (no WE vs. non-faded WE vs. faded WE) in terms of the increase in factual knowledge about the scientific observation method from the pretest to the posttest. Furthermore, a multivariate analysis (MANOVA) was calculated with the three groups (no WE vs. non-faded WE vs. faded WE) as the fixed factor and the dependent variables practical application of the scientific observation method, situational interest, basic needs, and cognitive load. Bonferroni-adjusted post-hoc analyses were calculated to determine differences in applied knowledge among the three groups.

7.2 Development of a digital learning environment with digitally presented WE for learning scientific observation

When developing the digital learning environment, the focus was on acquiring the competence of scientific observation. With the help of the digital learning environment the six steps of scientific observation, the formulation of research questions and hypotheses, the planning and implementation as well as the analysis and interpretation of the data, were explained to the students so that they are able to conduct a scientific observation independently at the end of the digital learning environment. In order to be able to learn the concept of scientific observation, a second learning domain is needed, through which the concept is learned (Koenen, 2014; Renkl et al., 2009). The second learning domain focused on the mapping of a water body structure, which was to be used to practice scientific observation. Learning how to conduct a water body structure mapping thus represents the second learning aim, which should be taught using the digital learning environment, but was not evaluated as part of the study.

The Moodle software was used for the technical realization of the digital learning environment. A specific layout was designed, which is structured like a book in which it is not possible to turn back. This is important insofar as the participants do not have the possibility to revisit information in order to keep the conditions comparable as well as distinguishable. The learning videos that were added to the learning environment were recorded with Power Point, set to audio and converted into a video file. The structure of the learning environment is described below, more detailed information on the scripts for the learning environment and the videos can be found in the article and in the appendix A and appendix B.

The digital learning environment started with a short welcome and an introduction to the course navigation followed by the pretest. A short hypothetical scenario was then described, which was the framework for the course. Participants were told that they were employees of an urban planning office who were tasked with analyzing the ecomorphological condition of a small river near a Bavarian town. The river consists of five sections, each of which has to be mapped separately. After this hypothetical framing, the mapping for the first section began. At the beginning of each section, a research question and corresponding hypotheses on the ecomorphological condition of the river section had to be formulated and written down. Afterwards, data on the river section was collected using a paper-based mapping sheet and afterward the data was then analyzed. At the end, the research question and hypotheses were answered according to the evaluation. This structure was maintained for the mapping of all five sections.

As already mentioned, the digital learning environment was designed with Moodle. In Moodle there were three courses that were identical in structure and design, the only difference was the implementation of the WE in the form of videos. The students were randomly assigned to one of the three courses, so that each course consisted of 20 participants. The course that served as the control group did not include WE videos to support the scientific observation method. The course contained only short written work constructions. The course with the non-faded WE included three videos for each of the five sections. Each of the three videos showed two steps of scientific observation, so that all six steps of scientific observation are explained in one section. The first video on research questions and hypotheses explained what constitutes scientifically based research questions and hypotheses. A practical example was given with explanations and tips on how to formulate research questions and hypotheses. The second video explained the two steps of planning and implementation. A practical example was given with explanations and tips for planning and implementing the scientific observation. The third video explained how to analyze and interpret the collected data. For this purpose, a practical example was given with explanations and tips on how to analyze and interpret data. After these three videos for mapping the first water body section, the mapping of the next section with the same structure began.

The course with the faded WE has the same number of videos as the course with the non-faded WE. Here, the information in the videos is gradually reduced. In the first section, all three videos are available in complete form. In the second section the information have been reduced by omitting the tip in all three videos. In the third section the tip and the practical example have been omitted. In the fourth and fifth sections there were only the written work instructions without videos.

7.3 Empirical findings

In the following, the results of the study on the use of WE to support scientific observation of students are explained according to the research questions.

The first research question related to the students' increase in knowledge. The results indicated that there were no significant differences in the factual knowledge test results between all three groups, and specifically between the two experimental groups. These findings contradict existing literature, which suggests that WE have a positive impact on knowledge acquisition (Renkl, 2014). Furthermore, research suggests that faded WE are more effective for knowledge acquisition and transfer compared to non-faded examples (Renkl, 2014; Renkl et al., 2000).
However, the study results revealed major significant differences when analyzing applied knowledge. Here, the increase in applied knowledge when conducting scientific observation steps was significantly lower for the participants in the control group than for the participants in the two experimental groups. The group that had the non-faded WE in the digital learning environment performed better than the group with the faded WE. Since no significant differences were found between the two experimental groups, it can be assumed that both faded and non-faded WE are appropriate for teaching applied knowledge about scientific observation in the learning domain (Koenen, 2014). But here too, the results of the study are different from the existing literature. According to this, the faded version results in the highest knowledge transfer (Renkl et al., 2000). Nevertheless, the results of Renkl (2014) and Hesser and Gregory (2015) were confirmed, according to which the faded version of the WE are also appropriate for supporting learning, even if the non-faded WE performed best.

The second research question examined the participants' motivation in relation to situational interest and basic needs. The results showed no significant differences across all three groups or between the two experimental groups. When evaluating the descriptive results, a slightly higher level of motivation (situational interest and basic needs) was found in the two experimental groups compared to the control group. The descriptive results confirm the existing literature to the effect that WE lead to higher motivation relevant to learning (Paas et al., 2005; Van Harsel et al., 2019). Further data analysis showed that both test groups consider the benefits of WE to be high and rate WE positively.

The third research question examined the cognitive load. The results showed that the cognitive load does not differ significantly between all three groups. However, the differences in extraneous cognitive load were only just non-significant. The descriptive data analysis indicated that the control group had the highest extraneous and the lowest germane cognitive load. The group with the faded WE had the lowest extraneous cognitive load and a similar germane cognitive load to the non-faded WE group. Here too, the differences were only just above the significance level. The results on a descriptive level are consistent with the results of the existing literature. According to both Renkl (2014) and Paas et al. (2003), WE can help to reduce extraneous cognitive load and, in turn, lead to an increase in germane cognitive load.

With regard to the two hypotheses, the results of the data analysis only partially confirmed the first hypothesis. It was confirmed that the integration of faded as well as non-faded WE leads to a higher acquisition of applied knowledge compared to the control group without WE. An increase in factual knowledge was not found, however. Only at the descriptive level was a higher motivation and a different cognitive load measured. The second hypothesis could not be completely confirmed. No significant differences were found between the two WE conditions with regard to acquisition of factual and applied knowledge, motivation and lower extraneous cognitive load as well as higher germane cognitive load. The hypothesis was only confirmed with regard to the intrinsic cognitive load, as no differences were found here either. This could be due to the high complexity of the study topic (water body structure mapping). The topic is particularly difficult for beginners to handle, so learners could benefit from continuous support in the form of non-faded WE. A more detailed description of the results including statistical parameters can be found in the article in chapter 4.

In summary, the results of Study II suggest that WE are appropriate in supporting the application of scientific observation steps. Since no general advantage of faded WE over non-faded WE was shown, it is important to take into consideration both faded and non-faded WE. This information can be used to develop targeted interventions to support scientific observation competence.

8 General discussion and conclusion

8.1 Interpretation of empirical findings

The overall goal of this dissertation was to show how (mobile) digital media are used in informal learning contexts to support learning and to investigate cognitive and motivational effects. As there was no systematic overview of this relatively new field of research at the time of the study, in Study I the current state of research was analyzed by conducting a systematic literature review along the PRISMA guidelines in order to gain an initial overview of the use of (mobile) digital media to support informal learning with a focus on institutional informal learning places. The main aim here was to provide an overview of the general characteristics of (mobile) digital media in institutional informal learning places, their learning-relevant functions and the learning outcomes by using these media. In Study II, based on the findings of the systematic literature review, a mobile digital learning environment was developed and analyzed in an informal learning context to investigate via mixed method approach the effects of different forms of digitally presented WE (no WE vs. non-faded WE vs. faded WE) in the form of videos. In addition to the transfer of learning-relevant knowledge, the motivation and cognitive load of the students were also measured. Based on the results of Study II, the theoretical findings of Study I were expanded to include practical implementation in order to gain a holistic insight into learning with (mobile) digital media in institutional informal learning places using this combined perspective. The combined perspective of the studies of factual and applied knowledge as well as motivational and cognitive aspects contributes to this.

The starting point for the study was, on the one hand, the fact that learning in institutional informal learning places such as museums or zoos has recently become an increasing focus of the educational debate (Schwan et al., 2014). On the other hand, the increasing technological progress is also advancing in the field of education. Combining these two facts appeared to be useful, as digital media have already proven to be a suitable tool for supporting and promoting informal learning processes (Moser, 2017). This is particularly necessary because informal learning is often casual and unstructured (Lewalter & Neubauer, 2019), so support is required for learning success.

The results of Study I showed that the variety of informal learning places in the studies analyzed has increased over the years and that, in addition to traditional learning places such as museums, galleries or outdoor nature are increasingly being used as institutional informal learning places. Study II builds on this, in which outdoor nature is used as an informal learning framework in the context of water body structure mapping.

The analysis of the general characteristics of digital media in institutional informal learning places in Study I revealed that over time the design of digital media tools has become increasingly complex, such as 3D animations. In the last three years digital media tools have mainly been used in portable form, for example, in the form of smartphones or tablets. For Study II portable media tools in the form of tablets were used. Portable media tools can offer greater flexibility, especially in learning places such as outdoor nature where the use of stationary digital media such as tabletops is not possible or not appropriate in the learning setting.The evaluation of the functions of digital media tools in Study I showed that the provision of information and tasks are the main functions available, which corresponds to the results of Kampschulte et al. (2019). This shows that the full range of possible functions that digital media tools can provide is not yet fully used. A specific support function, for example, for adapting the task to the learner's level of knowledge was not found in the studies. Nevertheless, it is precisely this adaptability that is one of the strengths of digital media tools (Bannert & Reimann, 2009). Functions that explicitly support collaboration in groups were also very rarely found in the studies. However, the results of Study I showed that institutional informal learning places were mostly visited in groups. Studies on museum research indicate that museums are usually visited in social groups of families, friends or colleagues, so that the reception of the information is determined to a large extent from social interactions (Gutwill & Allen, 2010 in Schwan & Lewalter, 2019). For this reason, it seems useful to implement functions that support collaboration more strongly in the digital media in institutional informal learning places.

Overall, it can be stated that the number of functions that digital media tools can offer will increase steadily from 2018. With the increase and availability of technological progress, it could therefore be that the possible functions of digital media will continue to expand in the future and, as a result, can be further investigated. This gives rise to a need for further research. Despite the possible increase in functions that digital media can offer, the pedagogical perspective must always be considered. The use of various functions of a digital tool always depends on the (learning) context and the purpose for which the functions are used. This is, for example, the case with the digital learning environment developed for Study II, where the two main functions were providing information and tasks. Functions that promote social interaction were explicitly not intended, as this would bias the data.

One advantage of presenting information via digital media is the ability to easily provide additional and brief specific information, which can be adapted or even individualized as required (Schwan et al., 2018). Also, the information can be presented in different ways. This advantage was utilized when creating the digital learning environment for Study II in order to present the information in the form of videos in addition to the written instructions. In addition to the audio, images and graphics could be added for the visual component.

What Study I showed is that in museums the descriptions of exhibits are often placed next to the artefacts in the form of text displays. This can be suboptimal for the presentation of information, as it overloads the cognitive resources required to process the learning content (Schwan et al., 2018; Sweller et al., 2011). This problem represents the split-attention effect (Sweller et al., 2011), as the learner's visual attention is divided between viewing the picture and reading the text on the screen. One solution to this is the modality effect of the theory of multimedia learning (Mayer & Moreno, 2003). According to this, there is a better transfer of learning when the text is presented audibly as a narrative and not as written text on the screen. By using narrated text with pictures, part of the processing requirements can be transferred from the visual channel to the verbal channel. Schwan et al. (2018) came to the same result: when pictures are accompanied by audio instead of written text, learners develop a more elaborate mental representation of the picture content. This happens by focusing attention on relevant parts of the picture and then transferring them to working memory and by integrating the picture elements with the accompanying text information in working memory. When presenting pictures or objects, for example, this could be realized using audio guides.

Based on the discussion of this result, it was shown how important it is to design the learning materials using the appropriate form of presentation and, in this context, to assess the cognitive load. However, the evaluation of the learning outcomes in Study I showed that this important aspect of cognitive load was not considered or documented in the studies analyzed. This is relevant insofar as the measurement of cognitive load has become a standard procedure in most studies concerned with digital media for learning objectives and is relevant for learning processes, as different design features of digital learning media can have both positive and negative effects on the cognitive processing of information (extraneous and germane load) (Skulmowski & Man Xu, 2021).

In order to ensure that the learning processes in the self-developed learning environment in Study II were not cognitively overloaded by the WE, the cognitive load was measured. Even though the results were just below the significance level, it was shown in consistency with the literature (Renkl, 2014; Paas et al., 2003) that the video-based WE can contribute to reducing the extraneous cognitive load and, in turn, lead to an increase in the germane cognitive load. The results once again highlight the importance of measuring cognitive load in order to be able to evaluate whether the digital tool has been designed adequate to enhance learning.

The further evaluation of the learning outcomes of Study I showed that the use of digital media in informal learning places have a positive effect on informal learning, in particular on knowledge acquisition, motivation, interest and engagement in the context of collaboration and social interaction. The positive results in terms of motivation can possibly be explained by the different types of presentation that digital media offer.

Through the use of AR, media can promote learning motivation and success and improve the flexibility and interactivity of learning activities (Lee et al., 2011). Such different presentation features can support learning on both a cognitive and motivational level (Bannert & Reimann, 2009).

Due to the positive findings from Study I with regard to knowledge, motivation and interest, these variables were also collected in Study II in order to investigate how WE, implemented in a digital learning environment, support the learning processes regarding to these variables. With regard to knowledge, the results showed that WE promote the acquisition of applied knowledge about scientific observation and that both versions of WE (non-faded and faded) are appropriate for this purpose. In contrast to the relevant literature (Renkl, 2014; Renkl et al., 2000), there was no difference between the three groups in the increase in factual knowledge about scientific observation. However, since WE have proven to be helpful in the acquisition of factual knowledge, especially in the version of faded WE, the significance of the study results with regard to factual knowledge about scientific observation should be examined here. As the students already achieved very good results in the pre-test on scientific observation, although half of the students indicated that they were novices in the field of scientific observation, it is possible that the level of difficulty of some test items may have been too low, leading to a biased presentation. On a descriptive level, it was shown that there was a higher level of motivation in the two groups that learned scientific observation with the WE. As the usefulness and overall learning with WE were assessed positively by the students, this could be an indication of the positive learning support provided by WE.

Overall, it has been shown that WE have a positive effect on the application of scientific observation about the scientific observation steps. By investigating applied knowledge using qualitative data analysis, it was possible to differentiate between the two types of knowledge - factual and applied knowledge - within the learning domain. A key implication of these results is that both faded and non-faded WE need to be considered, as no general advantage of faded WE over non-faded WE was found. This information can be used to develop specific interventions that aim to enhance scientific observation competence. In conclusion, both studies show that the use of digital media in an informal learning context, in both institutional and formal settings, is appropriate for achieving positive results in terms of knowledge gain and motivation.

8.2 Limitations and suggestions for future research

The limitations of the two studies mentioned here provide indications for future research. What is the case with most systematic literature reviews is the limitation of the data material to be examined. In the systematic literature review (Study I), the search for appropriate studies was limited to the two databases Scopus and FIS, through which the three databases Eric, EBSCOhost eBooks and BASE were also analyzed.

The databases were chosen, because they offer the most literature references in the field of educational science. Scopus is an abstract and citation database for peer-reviewed literature, including scientific journals, books and conference papers. The database provides a comprehensive overview of global research output in the fields of science, technology, medicine, social sciences, arts and humanities (Scopus, o.D.). The FIS (Fachinformations-System Bildung) literature database offers literature references on all areas of education and currently contains over one million data records, such as monographs, anthologies and articles from specialist journals (Fachportal Pädagogik, o.D.). The search engine BASE (Bielefeld Academic Search Engine) collects references to electronically available research documents from disciplinary and institutional repositories worldwide. EBSCOhost eBooks contains ebooks from small, international publishers with currently around 400,000 predominantly English-language (book) titles based on the BISAC Subject Classification "Education" for all sub-disciplines of educational science, including higher education research. ERIC (Institute of Education Science) is the world's most comprehensive bibliographic database relevant to education and educational science with around 1.7 million journal articles, research and conference papers in English (Fachportal Pädagogik, o.D.)

In addition to the limitation of the search location, the time at which the search was carried out also represents a limitation. The literature search was conducted between December 2020 and February 2021, which means that more recent studies and thus other potentially important findings were not included in the evaluation process. Despite the limited number of articles included in the literature review it must be said that the selection was made according to a systematic procedure in order to avoid bias. As the literature review was conducted three years ago, it would be interesting for future research to conduct another systematic literature review, including other databases. This would provide an overview of what has changed over the past three years with regard to the advancing digitalization of institutional informal learning places. One point to consider when interpreting the results is the consistently positive findings of the study. Only one study (Dieck et al., 2016) mentions disadvantages with regard to the use of digital media in institutional informal learning places. A publication bias cannot be ruled out here, as positive results are easier to publish and these are peer-reviewed articles (Sharma & Verma, 2019).

When designing the search syntax, only some quite well-known institutional informal learning places such as museums, aquariums and zoos were included in the search syntax. However, the general search keywords led to articles involving less well-known institutional informal learning places such as science centers, botanical gardens or nature parks. As the results of the systematic review show that there are many other institutional informal learning places beyond the common learning places, it would be useful for future research to consider this diversity of institutional informal learning places more closely.

The sample size in the Study II represents a further limitation in terms of the generalizability of the results. Nevertheless, a small sample size was necessary in order to be able to conduct the comprehensive qualitative data analysis that was important for this study. With regard to the descriptive tendency, a larger sample might yield significant results in future research and reveal even small effects. In this study, this is the case for cognitive load, where the differences were just above the significance level. The sample also consisted only of students, particularly from the natural sciences. In a future investigation, the study could be repeated with students from other disciplines to increase generalizability. A further limitation of the Study II is the fact that the participants already performed very high in the pre-test on scientific observation, so that participation in the intervention would probably not result in a significant increase in knowledge due to ceiling effects (Staus et al., 2021). Nevertheless, almost half of the students reported that they were novices in the field before the study, which indicates that the difficulty level of some test items may have been too low. Future research could revise the factual knowledge test, for example, the difficulty of the distractors, and test it again in order to obtain more valid results regarding the students' knowledge gain about scientific observation. Another limitation is that only one exemplary topic was examined in Study II. Only the learning domain of the dual content WE were investigated, so that in future research the exemplifying domain could be analyzed or other variables such as learning and performance-related attitudes could be included. Future research could investigate the influence of learners' prior knowledge on learning with WE as studies have shown that WE are particularly beneficial in the initial acquisition of cognitive skills (Kalyuga et al., 2001).

A final suggestion for future research concerns both studies. In both studies analyzed in the literature review and in the empirical study, knowledge and interest were only tested immediately after completion of the treatment and no follow-up test was reported or conducted. It would be interesting to conduct further research into the long-term effects of knowledge and interest gain when learning with digital media.

8.3 Implications for research and practice

The present dissertation extends previous research on informal learning with Study I by providing, for the first time, a systematic overview of learning with digital media in institutional informal learning places and showing how (mobile) digital media are used to support informal learning with a focus on institutional informal learning places. In addition to an initial overview of the characteristics of these learning places, the functions of digital media and their learning outcomes are examined in particular. In this way, Study I provides important findings for media-based educational research.

The results of Study I have several practical implications for the use of digital media in institutional informal learning places. In particular, the design of digital media in terms of their functions as well as motivational and cognitive aspects should be emphasized. The question of what added value digital media can offer for learning in these places of learning needs to be asked. In addition to classic functions such as the provision of information and tasks, however, it is primarily the functions that can support the learning processes that were found very rarely or not at all in the studies. None of the studies analyzed offered the possibility of adapting the learning tasks to the learner's level of knowledge (Gerard et al., 2015), although this type of support function is one of the greatest strengths of digital media tools (Bannert & Reimann, 2009). There is a need for further studies to include this function more in the design of digital media tools. The same applies to the collaboration functions, as the qualitative analysis show that institutional informal learning places were often visited in groups. For example, by playing learning games or quizzes together knowledge could be gained in a playful way through collaborative exchange.

Further action is required with regard to the measurement of cognitive load. The results of Study I revealed that cognitive load was not recorded or reported in the studies analyzed, meaning that no assumptions can be made about the extent to which this could have had a negative impact on the cognitive processing of information relevant to learning. Furthermore, the explicit design of the digital media tools could not be investigated, as the design characteristics were often not mentioned in the analyzed studies. For further research, it could be interesting to analyze the design characteristics of the media tools in greater detail by looking into the design characteristics of the cognitive theory of multimedia (Mayer & Moreno, 2003) (for example, modality effect, chapter 8.1) in order to examine aspects such as the cognitive load, especially the external and internal load (Skulmowski & Man Xu, 2021), or the format of the instructions. This may be especially important in the context of the specific support function through adaptivity and interactivity to provide a tool for active learning (Bannert & Reimann, 2009; Gerard et al., 2015). Interactivity as a support function with a low or medium level of interactivity can enhance learning and motivation while avoiding cognitive overload (Skulmowski & Man Xu, 2021). Interactivity is hardly possible without a minimum level of adaptivity. That means, that statements made by the learning systems should relate to previous statements made by the user and be adapted to the specific characteristics (for example, prior knowledge, interests, learning speed, language) of the individual learner as far as possible (Niegemann & Heidig, 2019). Adaptive guidance is more effective than guidance in traditional learning contexts, especially for learners with little prior knowledge. Adaptivity is most effective when learners generate and integrate ideas, for example, when creating concept diagrams, rather than just selecting from given options. Guidance that encourages self-monitoring is more likely to improve learning outcomes than guidance that focuses only on content knowledge (Gerard et al., 2015).

Study II provides important findings for media-based educational research and for learning in an informal learning context, but in a formal setting. From a theoretical perspective, the results partly replicate the findings of existing studies and represent an extension of previous research. On a descriptive level it has been shown that even in an informal learning context but formal setting, WE lead to higher learning-relevant motivation (Paas et al., 2005; Van Harsel et al., 2019), reduces extrinsic cognitive load and increases germane cognitive load (Paas et al., 2003; Renkl, 2014) and supports learning in the faded version (Hesser and Gregory, 2015; Renkl, 2014). It has been shown that WE significantly enhance the acquisition of applied knowledge. Contrary to what was to be expected from the literature, an increase in learning in acquisition of factual knowledge was not found and faded WE did not prove to be more effective than non-faded WE for the acquisition and transfer of factual knowledge (Renkl, 2014; Renkl et al., 2000). One explanation for this could be the ceiling effects described in chapter 8.2. In addition, the results confirm the existing evidence that WE can be useful for building scientific competences. Further research could focus on investigating the exemplifying domain in more detail to test whether non-faded WE are more effective for learning than faded WE in the case of WE with double-content and complex topics such as scientific observation and water body structure mapping.

8.4 Conclusion

The aim of this dissertation was to investigate how (mobile) digital media are used in informal learning contexts and to what extent the media can support the informal learning in terms of cognitive and motivational aspects. For the first time ever, a systematic literature review of this young field of research was conducted. Study I showed that learning with digital media in institutional informal learning places is appropriate for fostering knowledge acquisition, motivation, interest and engagement. Due to the variety of functions that digital media can offer, they have great potential to structure and support learning, even if they do not yet fully exploit this potential due to the fact that they are often limited to the provision of information and tasks. Functions involving interactivity and adaptivity in particular could be given more attention in the future design of digital media in order to adapt learning even more to the individual needs of learners. There is a need for further research with regard to the measurement of cognitive load, as no information was given in the studies analyzed. As cognitive load can have positive as well as negative impact on the cognitive processing of information, particularly in the case of extraneous and germane load, further research in this field would help to design learning with digital media in institutional informal learning places in such a way that it is not cognitively overloaded.

The results of Study II provide important findings for the application of double-content WE to develop scientific observation competence. Even though only the learning domain was investigated, the analysis of the combined perspective of factual and applied knowledge represents a further added value of the study. In contrast to the existing literature, no general advantage of faded WE over non-faded WE was found, which suggests that WE, not only in their faded version but also in their non-faded version are appropriate to support learners' applied knowledge when learning about scientific observation. These results can be used to develop specific interventions aimed to enhance and promote scientific observation competence. Further research could help to investigate the motivation for learning with double-content WE more precisely as the study results could only confirm the hypotheses on a descriptive level.

The dissertation gives important findings for informal learning and for media-based educational research. The dissertation expands existing research by providing for the first time a comprehensive, and systematic literature overview on the characteristics, functions and learning outcomes of and with digital media in institutional informal learning places. The combined perspective of factual and applied knowledge in the learning domain of double-content WE also provide an initial starting point for this research field to consider and analyze the acquisition of different types of knowledge during learning with double-content WE more closely. Overall, the results can contribute by showing how digital media should be designed in self-directed educational contexts to promote the acquisition of factual and applied knowledge and to be as motivating and cognitively less loaded as possible.

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Appendix

Appendix A - Script Moodle learning environment

Introduction: Dear students, welcome to the water body structure mapping workshop. In the next 2.5 to 3 hours you will independently carry out a water body structure mapping. During this mapping you will support the steps of scientific observation. Please use this Moodle learning environment and the paper-based mapping sheet provided to you. For your individual learning outcome, it is important that you work on your own and do not exchange ideas with your fellow students! Please work on the following questions in order. Important! Please note that it is not possible to scroll back in the learning environment! Have fun and good luck with your mapping!

Next page:

Important! Please click on "Edit task" and enter the test person code you have created and noted on your sheets. Only go to the next page once you have entered and saved your test subject code!

Next page:

Water body structures are often required by municipalities and cities to assess a water body. Such a scenario now also forms the basis for your mapping. Please imagine the following: The Mühlengraben is a water body that flows through the municipality of Freising. The municipality of Freising is responsible for the maintenance of the Mühlengraben. The Mühlengraben is to be renaturalized in the course of flood protection, for which the structure of the water body is to be determined. The morphological characteristics that characterize a flowing water body (water bed and floodplain) or still water body (lake basin and banks with water environment) are described as water body structure. In the case of watercourses, these are in particular the form of the course (elongated, winding, branched), depth variation (pools, fords, banks, etc.), bed substrate and the characteristics of the bank areas. These are essential for the living conditions of animals and plants in and around the water bodies. In the Mühlengraben, in addition to improved flood protection, the main aim is to improve the quality of the habitat for all organisms that use the water body. In addition to the aquatic organisms in the canal, this also applies in particular to terrestrial organisms on the banks, which use the riparian strips that are now required by law. As there is only a very limited budget available for the renaturation measures, the first step is to draw up a water body development concept based on a water body structure mapping. In this water body development concept, all those sections with particularly poor structural quality are to be prioritized for renaturation. This water body structure mapping is to be carried out on behalf of the municipality of Freising by the planning office “Gewässergut” on the basis of the specifications of the Bavarian State Office for Water Management using standardized assessment forms. The stretch of water is divided into 100m long sections, each of which is examined and evaluated separately. These 100m sections will later serve as the basis for prioritization. The 100m sections with the worst watercourse structure are to be identified as the most urgent to restore. Following the water body structure mapping, the planning office should draw up a watercourse development concept of no more than ten pages, which reflects the results of the water body structure mapping, includes a prioritization of the stretches to be restored and explains your self-considered examples of measures in bullet points. You, as an employee of the planning office “Gewässergut”, have now been instructed to carry out this water body structure mapping using the mapping form and the steps of scientific observation and then to draw up a well-founded water body development concept. Please go to the first mapping section and open the next page.

Next page: You are now in the first section of the water body to be mapped. When mapping, you will be guided by the steps of scientific observation, which will help you to determine the structure of the water body in a structured way. For the first two steps of scientific observation, the question and hypothesis, please watch the video first.

Task: After you have watched the video, please formulate a research question and one or more suitable hypotheses. To do this, click on "Edit task" again and write your answer in the field below. When you have finished, please click on "Save and display". Please note: Once you have saved your answer, you can no longer edit it! Important! Please make a note of the research question / hypothesis on your paper-based mapping sheet, as you will need it again later! Once you have completed the task, you can move on to the next page.

Next page: These two steps of scientific observation are about planning and conducting your water body structure mapping in order to answer your research question and your hypotheses. Please watch the video first.

Task: After you have watched the video, please carry out the mapping of the first water body section in the field using your paper-based mapping sheet. When you have finished mapping, please mark the task as "completed" and save your selection. The page will then reload and the "Next activity" button will appear, which will take you to the next page.

Next page: You have now reached the last two steps of the scientific observation, the evaluation of your observation results and the conclusion regarding the assessment of the mapping section (answering the research question and hypotheses). Please watch the video.

Task: After you have watched the video, please evaluate your data on the paper-based mapping sheet (answering the research question and hypotheses). Then click on "Edit task" and write your answer in the field below. When formulating your answer, remember that you are an employee of the planning office "Gewässergut " and should also make recommendations for action. Please remember again: Once you have saved your answer, you can no longer edit it! When you have finished, please click on "Save and display". You can then go to the next page.

Next page: You have now reached the end of the first mapping section. Please collect all your mapping sheets on your clipboard and start mapping the next section with a new sheet.

Next page: You are now in the second mapping section. Please watch the video again for tips on the research question. Task: After you have watched the video, please formulate a new research question and one or more suitable hypotheses. To do this, click on "Edit task" again and write your answer in the field below. When you have finished, please click on "Save and display". Please note: Once you have saved your answer, you can no longer edit it! Important! Please make a note of the research question / hypothesis on your paper-based mapping sheet, as you will need it again later! Once you have completed the task, you can move on to the next page.

These steps are now repeated until the fifth section.

End: You have now completed the water body structure mapping for all five sections and have reached the end. Please complete the questionnaire using the following link. When you have completed the questionnaire, please close the questionnaire window and mark the task as "completed" and save your selection. The page will then reload and the "Next activity" button will appear, which will take you to the next page.

Last page: You have now reached the end of today's workshop. Please hand in the iPad and clipboard to the person responsible and sign the list. Please check again that your subject code is on all five mapping sheets. We would like to thank you very much for your participation in the workshop "Mapping water body structure with the help of scientific observation" and wish you a wonderful day!

Appendix B - Script Video

Script Video Step 1 and 2 of the scientific observation

Theory: Every scientific observation begins with the development of a research question and a suitable hypothesis or several hypotheses. In our case, this involves the topic of water body structure. Because every scientific observation is based on a specific target or question as well as theoretically based expectations that can be formulated as hypotheses. But what makes a good research question? A good research question contains certain criteria that you should always consider when formulating your own research question. In general, your research question should be formulated in one sentence if possible and asked as an open question. This means that it should not be answered with "yes" or "no", but should be based on the W-questions such as "why, how, to what extent or in what way". An example would be "How do raindrops run down a window pane?" This could well be investigated on the basis of scientific observation. In general, when formulating your research question, it is important that your question is self-contradictory, can be answered in theory and is as objective as possible. In addition, the subject of your research should not be too extensive, but rather specific and clearly defined, as well as being observable within the framework of water body structure mapping. Once you have developed your research question, you must then deduce one or more hypotheses. But what are hypotheses? Hypotheses are well-founded assumptions that relate to your research question. Your research question is therefore tested by investigating the hypotheses. The same applies here as for the research question. Hypotheses must also be free of contradictions, answerable in theory and as objective as possible. They should be formulated as statements and include the conditions to be investigated. It is also important to formulate a alternative hypothesis, the null hypothesis, to contradict the hypothesis. If you have to reject your hypothesis, you can temporarily accept the alternative hypothesis.

Example: This all sounds quite theoretical, so I will now give you an example of a research question and corresponding hypotheses. You will see a photo of a section that is to be mapped. We will now think about a research question and the hypotheses, because that is exactly what you are supposed to do. When we look at the picture, we immediately notice the buildings and the closeness to the path, indicators that are mentioned on the mapping sheet under the criterion of riparian strip function. Assuming I want to focus on this in particular during the mapping, then my research question could be something like this: To what extent does development and the closeness of the path to the water body in particular have an influence on the water body structure? I would formulate my hypothesis as follows, for example: It is assumed that the development and the closeness of the path to the body of water have a negative influence on the water body structure and my null hypothesis would then be as follows: It is assumed that the development and the closeness of the path to the body of water do not influence the water body structure. It would therefore assume that it has no influence.

Tip: At the end, I have a tip for you on formulating your research question and hypotheses. Think about the different aspects that can be observed in the context of water body structure mapping. Also think about the mapping sheet that you have already looked at in preparation. Try to focus your research question on this. And now it's your turn, which research question do you want to evaluate? And which hypotheses do you assume? Good luck and see you in the next step.

Script Video Step 3 and 4 of the scientific observation

Theory: You have now thought about a research question and one or more appropriate hypotheses. The next two steps, planning and conducting the scientific observation, are about planning your own observation in detail and collecting observation data in order to test your hypothesis and answer your research question. The basis and tool for scientific observation is an observation instrument that contains precise instructions for defining the observation units and characteristics as well as for coding and recording the observation data. On the one hand, the observation instrument includes a defined category system that is used to record the observation data. In addition to the precise description of the categories, a good category system also includes a precise differentiation of their characteristics, the so-called indicators. It must then be possible to assign each observation unit precisely to a category or its corresponding indicator. Therefore, the developed categories and their indicators must be disjunctive (i.e. have a clear distinction and no common element), exhaustive (assignment to a category must be possible in every case) and described with sufficient precision (assignment is based on precisely defined criteria, including examples). The exact definition of the categories and their indicators, as well as exemplary cases, must be described as precisely as possible in a so-called coding guideline. With the help of the guideline, you now know what is meant by the categories and their indicators and can assess to which category and to which indicator you can assign your observation data. With our water body structure mapping, you do not have to develop the observation tool yourself. You have already received the mapping and assessment instructions, which serve as a coding guide, as well as the assessment sheet for water body mapping with the category system including indicators.

Example: In the assessment sheet, for example, river bank stabilization is an upper category, with the subcategory quantity. The four indicators in this sub-category quantity are "no bank stabilization", "occasional", "moderate" and "predominant". You would now assign the result of your observation to one of the four indicators. Let's take a closer look at one category. On the left-hand image you can see the fourth section of a water body. On the right-hand side, I have shown you the criterion of transverse structures from the water body category. If I now look at the water body in the picture, I would say that no weir, fish ladder or similar can be seen in the picture. I would therefore mark the indicator not present.

Tip: Finally, I have a tip for you on planning and conducting your scientific observation. It is best to go through each evaluation category carefully one after the other, so you are sure not to forget anything! And now it's your turn to start mapping the first section!

Script Video Step 5 and 6 of the scientific observation

Theory: We now come to the last two steps, the data evaluation and the conclusion. You have now mapped the water body section with the help of the assessment sheet. Now it is time to evaluate and interpret the results. The evaluation and interpretation of the data is important, as the data obtained cannot stand for itself. The range of evaluations of observation instruments extends from simple recording of the frequency of appearance to more complex analyses; sometimes statistical evaluations and hypothesis testing are also included. Once the data has been evaluated, the aim is to describe the overall assessment as objectively as possible and without interpretation. Once the results have been described, the final step is to interpret and evaluate the data with regard to the hypotheses and the research question. In this step, it is also assessed whether the hypotheses can be regarded as preliminarily accepted or whether they must be rejected and the alternative hypothesis, the null hypothesis, is accepted. After you have accepted or rejected your hypothesis, you can then answer your research question. Once this has been answered, the resulting consequences and / or recommendations for action can be deduced and given. In our observation protocol, the individual indicators of water body dynamics in the respective categories are first added together and then summarized to form a structural class. The same procedure is then used to calculate the structural class of waterbody dynamics. Finally, the total structural class is determined on the basis of the two structural classes of water bed dynamics and floodplain dynamics. This figure then shows the overall assessment of the water body section to be mapped. You can see this in the image shown. This raises the question of what the number of the overall structural class actually says about the mapped water body section. The number of the structural class should be interpreted with regard to the hypothesis, for example, what does the number of the total structural class say? Is it a good rating (still in the blue or green range) or is the number already in the red range?

Example: Now let's take a look together at a fictional overall assessment. Let's assume that the riverbed structure is rated 6 and the floodplain structure is also rated 6. This results in a rating of 6 for the overall structure class, which shows that the overall rating of the water body structure is in the second worst range of 6 out of 7. We can therefore conclude that there is a need for action in both the river bed structure and the floodplain structure. To do this, we now need to take another look at the individual categories that led to this assessment. For the hypothesis we put forward at the beginning: It is assumed that the development and the closeness of the path to the water body have a negative influence on the water body structure, this means that we can provisionally regard it as accepted. We can now answer our research question: To what extent do the development and the closeness of the path to the water body in particular have an influence on the water body structure? in such a way that the development and the closeness of the path have a negative effect on the floodplain structure and thus a negative effect on the overall structure.

Tip: Finally, I have a tip for you regarding the evaluation and conclusion. Think again about what the individual points were that led to the evaluation. Were there any points on the mapping sheet that were weighted more heavily than others? Also use your knowledge from the introductory video.