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

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ABSTRACT

Digital media can have high potential for supporting learning processes. This assumption also holds true for institutional informal learning places (IILP). However, there is no systematic overview of research on the use of digital media for informal learning in such places yet. In order to fill this gap, this paper reports on the findings of a systematic literature review in the field of informal learning with digital media in IILP. A total of 26 relevant studies, conducted between 2005 and 2020, were identified via database search in Scopus and FIS, as well as through cross-referencing. Subsequently, those 26 studies are analyzed in more detail by a qualitative content analysis, which is used to investigate three research questions: 1) What are the general characteristics of digital media investigated in IILP? 2) What are the functions of digital media investigated in IILP that are relevant for learning? 3) What outcomes were measured, related to informal learning with digital media in IILP? The results show that portable and stationary digital media tools are investigated about equally often and that often, they already offer augmented reality (AR). It also shows that digital media have not yet fully exploited their potential functions, as they mainly offer the retrieval of information, and have only exploited collaboration functions only to a rather small extent. However, they can promote and support motivational and cognitive learning processes, especially with regard to knowledge acquisition and interest, as well as collaboration and social interaction.

1. Introduction

Institutional informal learning places (IILP) e.g., museums, zoos or botanical gardens, are becoming increasingly important in education [46]. Outside of formal institutions such as schools or universities, learners can gain (learning) experience in a variety of ways through the authenticity of the location and objects presented that might not be possible in a more formal setting. For example, in museums, archeological finds can be viewed in real life, which might only be possible through pictures in school. In zoos or aquariums, learners can observe animals in their habitats, which would not be possible in school. However, in contrast to learning in a structured school environment, informal learning in IILP often takes place spontaneously, uncoordinated and the learning process is mostly self-regulated [42]. Accordingly, the individual gain of knowledge is characterized by rather random discoveries [29]. To ensure learning success in unstructured learning environments such as museums, support the informal learning process on different levels is indicated. One way to support learning in this context is the use of digital media. Due to their different functions, digital media have high potential to structure and support informal learning. Digital media offer the chance to present information in a variety of ways, e.g., visually and auditively or by mixing virtual and real environment. Additionally, adaptive and interactive functions can refer to the learner's level of knowledge and provide a means for active learning. So far, the use of digital media in IILP to support informal learning is a field of educational research, with rather older and not systematically examined literature reviews [18,47]. Within new corresponding literature, mainly application-specific analyses can be found, e.g., review articles on AR applications [21,22]. Since there is only a small number of non-systematic and older literature reviews, we conducted an updated, comprehensive, and systematic literature review to report recent research findings in relation to the use of digital media in IILP.

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2. Theoretical background

2.1. Institutional informal learning places and informal learning

IILP such as museums, zoos, aquariums or science centers enable learners to learn independently and in an action-oriented way. They offer a variety of experiences that learners usually do not have in formal educational settings, such as school [31]. The visit takes place both as an individual and in groups, each with their own goals and intentions [15]. The reason for the visit differentiates according to the need for entertainment, education, esthetic appreciation, recreation, social exchange or because of the location itself and relevant in this setting are hands-on activities and narratives [46]. The physical setting is frequently characterized by a large space that has many focal points of attention. The synchronization of attention between visitors is limited. Information is simultaneously presented across the space and approached through locomotion.

In general, there is no clear and conclusive definition of informal learning, but there are various approaches that circumscribe informal learning. Informal learning in informal learning places differ from formal learning in the way that informal learning can be seen as lifelong, self-directed, and mostly occurs away of direct instructions [43]. Further, Gerber et al. (2001) note, that informal learning does not occur in school or at the direction of a teacher. In doing so, it is not structured in terms of learning goals, learning time, and learning support, nor does it lead to certification (European Commission [12,14]). The control of the learning goal, the learning time and the learning content is self-determined and without organized learning support, which mainly occurs on demand. Thus, informal learning is predominantly oriented towards problem-solving and self-direction, whereby the subject matter is mainly viewed holistically [11,28]. The learning outcome is predominantly related to experiential knowledge [42].

These informal learning experiences support learning, interest, and the creation of identities or interests that can lead to continued engagement in natural science activities [39]. Informal learning in IILP is often supported by a variety of materials. Recently, digital forms of supporting material, museum-specific apps, are advancing fast. Why digital media are particularly suitable for supporting the informal learning process will be explained below.

2.2. Digital media to support informal learning

Digital media, often also referred to as multimedia, can be described as electronic devices, where information is stored and transmitted in digital form. Digital media tools, therefore, are carriers and mediators of various types of digitally encoded information, for example texts, images, sounds, videos, animations or a combination of these elements [32]. In particular, mobile web-based media, such as smartphones or tablets, enable access to this information independent of time and location.

Within educational contexts, all these elements have great potential for compiling and providing content adapted to the learners desires and needs, so that they can use it individually, e.g., depending on their own preferences, prior knowledge or learning pace. Moser [37] further notes that mobile digital media, in the sense of "ubiquitous learning," offer promising opportunities for the flexible and self-directed design of learning processes. In addition, rather new digital applications, such as AR options, mix the physical and virtual environments of the learners, by augmenting the learners' real world with additional virtual information on a display [21]. The educational use of digital media seem to be beneficial for increasing learneŕs subject knowledge [5], motivation [30], and media literacy [54]. However, the use of digital information per se does not automatically enhance learning processes, in particular within rather self-directed learning environments, such as informal learning places. Here, support measures to guide the learning process are required [3,30,38]. In this regard, various design features, e.g. interactivity and adaptivity, enable support on both cognitive and motivational levels [3]. As Schwan et al. [45] note, digital media are often used as supporting material in IILP.

Digital media can provide users with an exciting, interactive and educational experience, thus combining free-time entertainment and education [46]. Consequently, information is increasingly prepared for learners with the help of digital media in museums, e.g., as they allow visitors to explore the exhibits in a more self-directed way, instead of passively looking at objects [44].

Two roles of digital media can be described in this context. On the one hand, digital media can serve to complement the experience, by presenting a complex principle via an animation on a screen. On the other hand, the digital medium itself can serve to provide authentic insights, e.g., when learners actively work with the medium and as a result acquire new knowledge on their own. In museums, digital media are mostly found in their complementary role [22].

Additionally, digital media can have different functions that are explained in more detail in the following chapter.

2.3. Functions and use of digital media in institutional informal learning places

Ojstersek and Kerres (2010) describe three didactic-related functions of digital media in teaching-learning processes: media can be used as knowledge tools for 1) Information or for certain contents. Difficult-to-understand facts can be presented more clearly via various representations and thus support understanding and retention in learning. Media also have the function of 2) communication and cooperation via supporting personal dialogs and cooperation in both synchronous and asynchronous communication between individuals and groups. Media are also suitable for 3) controlling or regulating of the learning process.

An extension of these three functions is provided by Petko [41], in which five different functions of media are examined for use in teaching. These functions can also be transferred to the use of media in informal learning places. Media can be used as a 1) tool for information and presentation in order to present learning content in a comprehensible way and to give clear examples, to explain connections and to create links with other content. Digital media can also be used to present information in different codes and modes for example, text, image, audio, video or a combination of these formats. Media can provide various possibilities how 2) Learning tasks can be designed based on a variety of educational media options. Learning tasks can be linked with diverse multimedia materials and thus reality. Media as a 3) tool and means of work can help learners to expand their productive and creative possibilities through word processing and presentation programs or mind map software. Media for 4) learning guidance and communication can support exchanges among learners and between learners and teachers, through chats, forums, audio and video conferencing. 5) Media designed to test assess expand the possibilities for formative and summative evaluation. Standardized examinations, can be carried out more efficiently in digital form, evaluated automatically and reported back.

In 2019, Kampschulte and colleagues conducted a study with 120 informal learning places and asked them about their use of all kinds of media. In addition, the functions of the media used were also evaluated and were divided into the five functions presented in the upper section according to Petko [41]. The results show that in 81 analyzed informal learning places, media are primarily used as "information and presentation tools," followed by media for "designing learning tasks" and media as "tools and work equipment". Media for "learning guidance and communication" are used rather rarely and the function "examination and assessment" plays a very minor role in informal learning places.

Deduced from the literature presented, the research questions to be investigated are presented in the next chapter.

2.4. Research questions

The systematic literature review will examine the following three research questions:

1 What are the general characteristics of the examined digital media in IILP?
2 What are the functions of the examined digital media in IILP that are relevant for learning?
3 What learning outcomes were measured as they relate to informal learning with digital media in IILP in the examined studies?

3. Method

3.1. Manuscript selection process

In order to answer the three research questions above, a systematic literature review was conducted. The period of the literature search was November 2020 - February 2021. To make the literature search as transparent as possible, the review process was undertaken following PRISMA guidelines [19,49]. Along these guidelines, certain inclusion and exclusion criteria were identified to find eligible hits for the review. To be included, a study had to be an original research contribution and had to be peer-reviewed, e.g., peer-reviewed empirical journal articles or book chapters, literature reviews, meta-analyses, book reviews or editorials were excluded. The language of the study had to be English or German, other languages were excluded due to the lack of language skills. Only studies published after 2000 were included in the systematic literature review due to the focus on digital media.

Well-established online research databases related to education were used in order to obtain as many matches as possible. We searched for articles in Scopus databases and the FIS database, which includes Eric, EBSCOhost ebooks, and BASE databases. The keywords or search terms were based on the three main issues of the research questions: media, informal learning, and IILP. A thesaurus search was conducted to identify synonymous words. The finalized search syntax for both databases is:

("digitale Medien" OR "Medien" OR "digital media" OR "media") AND ("informelles Lernen" OR "digitales Lernen" OR "ausserschulisches Lernen" OR "informal learning" OR "digital learning" OR "extracurricular learning") AND ("informelle Lernorte" OR "ausserschulische Lernorte" OR "ausserhalb der Schule" OR "informal learning place" OR "extracurricular learning place" OR "out of school" OR "Zoo" OR "Aquarium" OR "Museum")

To more precisely limit the hits in the Scopus database, only the title, abstract and key words were used to search for the search terms. In the

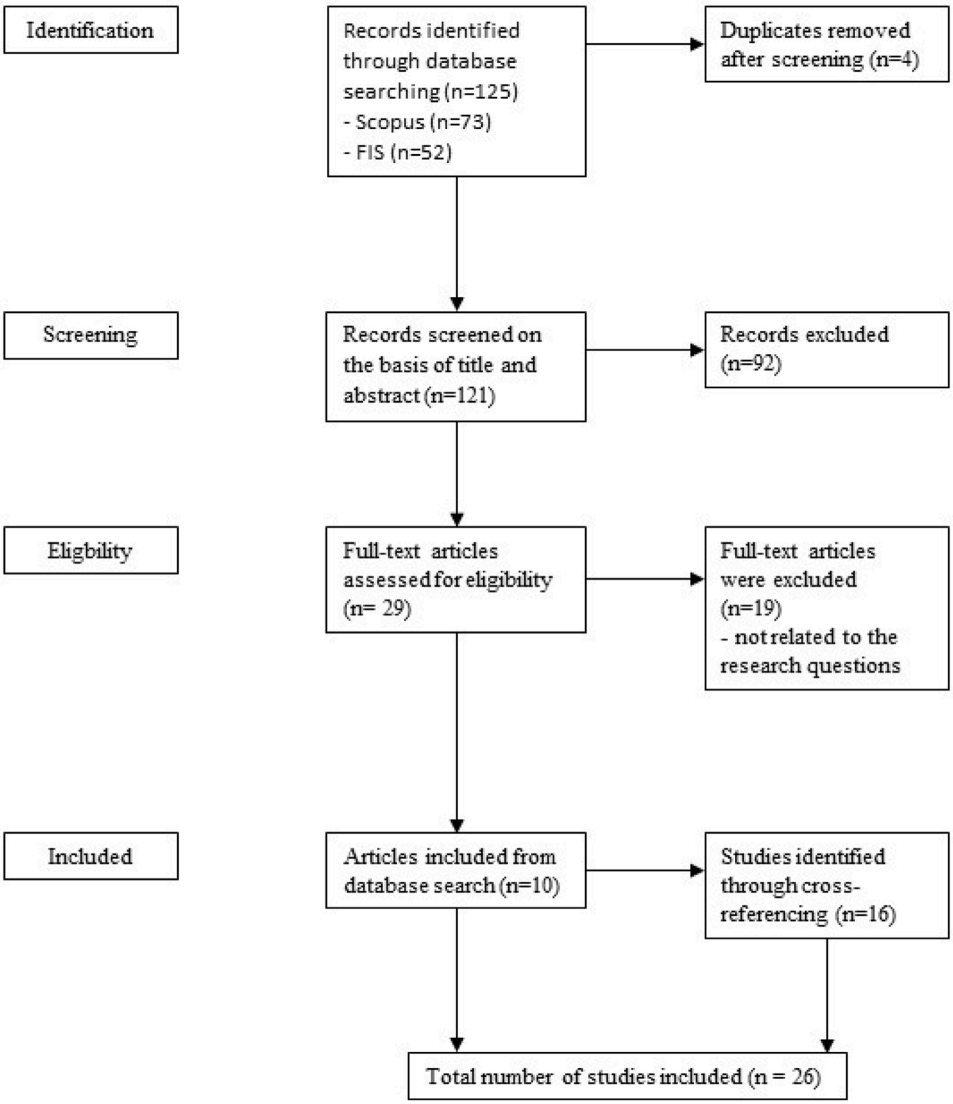

Fig. 1. shows the flowchart of the selection process.

FIS database, this limitation did not lead to a single result. Consequently, we searched within entire texts of articles for the keywords or search terms (free text search). Based on this search, a total of 125 hits emerged, 52 from FIS database and 73 from Scopus. The identified hits were checked for duplicate entries across databases, and four duplicates were removed. In the next step, the title and abstract of the remaining 121 hits were screened for eligibility and another 92 hits were excluded because three reviews and 76 theoretical articles were found among the manuscripts. Eleven articles were excluded due to a lack of focus on digital media and two are not available. The full texts of the remaining 29 hits were reviewed in detail to determine whether they were appropriate for research purpose. Again, 19 articles were excluded because they did not relate to the above-stated research questions. This search contributed 10 articles as part of the systematic review (Fig. 1).

In second step of literature search, the articles included and the literature reviews found in the first step were cross-referenced and cross-checked in order to identify other relevant studies. Cross-referencing included a backsearch, which checked the reference lists in each article for other relevant studies, and a forward search using Google Scholar for identify studies, that cited the included articles. Cross-referencing yielded an additional 16 publications that met all inclusion criteria. In summary, 26 studies were finally included and subsequently analyzed in more detail.

3.2. Analysis regarding the research questions

The studies that met the criteria explained in Chapter 3.1 were analyzed using the qualitative content analysis method [34]. Corresponding categories were formed for each of the three research questions. Categorizing information was useful for grouping the studies according to their common characteristics. The studies were manually coded separately according to their characteristics and classified according to the categories defined. All 26 manuscripts were coded by the first author. For verification purposes, eight randomly selected manuscripts were additionally counter-coded by an external coder. Overall, the level of agreement ranges from Cohen's $\kappa = 0.763$ to Cohen's $\kappa = 0.910$ indicating a strong to very strong level of agreement. This suggests that the category system is clearly formulated and that the individual units of analysis could be correctly assigned. A total of 208 cases were analyzed, and raters disagreed in only 17 cases. In the following, the categories for the three research questions are described. Here, the coders subsequently exchanged views and adapted the coding guide on the basis of a consensus.

In order to identify the general characteristics of digital media, hardware and software was analyzed. "Hardware" was subdivided into "Device," the medium used in the study, for example, tablet. A difference was also made as to whether the medium was "Mobile," such as a smartphone, or "Stationary," such as a tabletop. "Software" was subdivided into "Availability", for example, via an application, the "Name of the software used" and the "Digital format," for example, AR.

To determine the media functions in the studies reviewed (see Table 3), six functions and one sub-function were identified, based on the didactic functions presented by Kerres [23] and Petko [41] (see Chapter 2.3). The "Information" category refers to the pure availability of information via a digital media tool, without any further functions. An example of this is the electronic guidebook discussed in the study by Szymanski et al. (2008), which functions as a digital museum guide. The "Task" category means that via the media tool, users are given a specific task or work instruction to complete. An example of this can be found in the study by Yoon et al. (2012) the instructions on the device provided little direction, simply suggesting "try to complete the circuit." [53,60] The "Task processed" subcategory further differentiates whether the task is to be solved in the virtual world (VW), or in the real world (RW). In the VW e.g., AR applications and in the RW in a geogame in which locations in real life are to be found with the help of the media tool. The "Documentation and processing" category refers to the possibility of documenting information with the digital media tool, using it to take photos, audio recordings or notes. The "Cooperation or collaboration" category refers to the explicit request for cooperation via the media tool, to work on a task in the group. There must be an explicit cooperative or collaborative assignment via the media tool and not only the participation in groups due to the setting, as was the case in most of the studies reviewed. The "Communication" category describes to contact other users via the media tool for example, via a chat forum or how to send one's own content. The "Assessment and feedback" category refers to the function of receiving feedback via the media tool e.g., by checking learning performance or as feedback on a solved task.

To categorize the measured learning outcomes, five categories were identified. The first category is the "Research approach2", followed by the "Data collection" category which is related to questionnaires or observations. The outcomes are then further divided into "Cognitive outcomes," "Motivational outcomes" and "Outcomes related to collaboration and social interaction."

4. Results

This chapter reports the results of the analysis. The results are structured according to the three research questions. First, an overview of the 26 studies reviewed is given.

4.1. Overview of the studies reviewed

The 26 studies reviewed were published between 2005 and 2020. An overview of the studies is provided in Table 1 in the appendix. The majority of the studies (21 articles) were published after 2013. Regarding their domain, we found that the studies dealt mostly with biological content (ten), followed by physics (five), history (three), math (two) and art (two), as well as music (one) and STEM (one). In two studies, the exact domain was not specified. All studies were conducted in IILP, mostly in museums (14), outdoor places such as botanical garden or forest (four), summer camp (two), gallery (two), science/nature center (two), design studio (one) and historical house (one). Over the years, informal institutional learning places have become more and more heterogeneous, for example, besides museums, also galleries and nature parks have been investigated in the studies.

The participants in the studies were middle school students (six), elementary school students (one), students from a suburban charter school (one), university students (one), and high school students (one). In 16 studies, education level was not reported and participants were simply described as visitors, adults, children, or students. The number of participants in the studies ranged from 12 to 1539. A total of 4850 participants took part in the 26 studies reviewed. Most of the studies were carried out with less than 100 participants (16). In six studies, the number of participants varied between 100 and 200, and also in six studies the number of participants was over 200, including one study with more than 1500 participants.

In terms of the duration of visit varies the length between ten minutes and one day. In twelve studies, the visit ranged from ten minutes to one hour. In the other studies, the duration of the visit varied from 60 to 90 min (two), 2.5 h (one), and one day (one). In two studies there was no time limit. In ten studies, there were no information about the duration of visit. Finally, in one study, visit duration was one hour on seven days over a two-week period. The group size in which participants completed the visit varied from one to fourteen persons. In two studies the participants visits the location on their own. In the majority of the studies (13), participants completed the visit in pairs or threes. In six studies in groups of four to fourteen and also in six studies, no information is reported on the group size.

4.2. General characteristics of digital media in informal learning places

Regarding the general characteristics of digital media (first research

Table 1
Overview of the studies reviewed.

Primary author (publication year)	Educational level	Participants	Number of Participants	Domain	Place	Duration of visit	Learning group size
[10]	xxx	Adults & children (6 - 9 years, Ø 7.7)	24	Biology	Botanical garden	Unlimited	2
[53]	xxx	Visitors (18 - 70+ years)	1. Study:14 2. Study: 12 3. Study: 47	History	Historic house	1. Study: 20–25 min. 2. Study: 20–25 min. 3. Study: 15 min.	1. Study:2 2. Study: 2 3. Study: 2–4
[59]	Middle School	Students (grades 6 - 8)	307	Physics	Science museum	xxx	3
[60]	Middle School	Students (grades 6 - 8)	119	Physics	Science museum	25–30 min	6–9
[56]	Middle School	Students (grades 6 - 8)	164	Physics	Science museum	xxx	2–3
[13]	Middle School	Students (10 – 13 years)	15	STEM	Design studio	xxx	3
[62]	Preschool / Middle School	Students (8 - 11 years)	58	Biology	Summer camp	60–90 min	2
[61]	Charter School	Students (grades 5 - 7)	70	Physics	Science museum	xxx	3
[51]	xxx	Visitors (14 - 79 years)	101	Mathematic	Science museum	xxx	xxx
[4]	xxx	Visitors (under 5 years to adults)	629	Biology	Science museum	xxx	1–7
[63]	xxx	Students (9 – 12 years)	42	Biology	Summer camp	7 × 1-hour sessions (over two weeks)	2
[7]	xxx	Visitors	14	history	archeological museum	1 h	xxx
[20]	xxx	Students (8 - 15 years, Ø 11.55)	247	Biology	Natural history museum	10 min	2
[9]	xxx	Visitors (20 - 60 years)	44	Art	Gallery	35–55 min	1
[57]	xxx	Visitors (adults & children)	170	Music	Science center	xxx	Different sizes (1–14)
[58]	Middle School	Students (grades 6 - 8)	58	Mathematic	Science museum	1 h	3
[6]	xxx	Students (9 – 12 years)	25	Biology	Nature center	1 h	2–3
[8]	xxx	Students (10 - 14 years)	67	Biology	Science museum	1 h	3–7
[45]	xxx	Visitors (18 - 63 years)	165	Art	Gallery	60–90 min	xxx
[36]	Primary School	Students (7 - 9 years)	19	xxx	Museum	50 min	6–7
[55]	xxx	Visitors (74% university students, Mean age 27.77)	333	Biology	Science museum	xxx	xxx
[40]	xxx	Adults (64% 26 – 45 years)	1539	xxx	Science museum / History museum	xxx	xxx
[16]	University	Students	47	Biology	Forest	2,5 h	3–4
[26]	High School	Students (grades 7 and 9)	91	Biology	Nature park	One day	xxx
[17]	xxx	Visitors (18 - 65 years)	102	History	Egyptian museum	Unlimited	1
[24]	xxx	Visitors (1 - 60 years)	327	Physics	Science festival	xxx	Ø 2.4

question), the digital media tools are analyzed according to the hardware and software used and then more specifically according to the characteristics device, mobile and stationary for the hardware and according to availability, software used and digital format for the software (Table 2). The most used hardware is tablets (nine), followed by camera (five), computer/laptop (four), tabletops (four) and smartphones (three). The cameras were always combined with a computer or tablet (Table 2). Another distinguishing feature of digital media is whether they are mobile, such as smartphones or tablets, or stationary, such as tabletops or screens. In the 26 studies reviewed, 27 digital media tools were examined. In 15 studies, the digital media tools were mobile and in 12 studies, the digital media tools were stationary. In terms of the year, it shows that the design of digital media tools has become more complex and that digital media tools have been used mainly in portable form over the past three years.

In terms of software, the specific availability was 13 times an application, two times a web-based application and nine times a native application, an application that was newly developed for the specific study. The software used was specified in twelve studies, for example the software Aurasma [51]. In 14 studies, the software used was not mentioned. In terms of digital format nine studies use AR application like interactive visualization such as a magnetic field. In all the remaining 17 studies, text (ten), images (six), video (five), audio (five), or photographs (four) are used most often in combination. The most often combination is text and images with video or audio or photographs (Table 2).

4.3. The functions of media in informal learning places

In summary, 26 different media tools, that were described in the studies reviewed are analyzed. An overview of the different functions (see chapter 3.2) is provided in Table 3.

The "information" function, which provides any relevant content information, was found in all media tools in all 26 studies. The "information" function was the only function of media tools in five studies. For example, the electronic guidebook has only an information delivery mechanism which was provided by different media formats (Szymanski et al., 2008).

Nineteen media tools offered a "task" function, such as tasks that had to be completed by the participants. In 16 studies, the task had to be completed in the virtual world, i.e., within the media tool itself using, for example, mixed reality smart glasses [17]. In three studies, the task had to be completed in the real world i.e., only the task itself was given via the media tool, but not the completion of the task. In the study by Fränkel et al. [16] a geogame was developed in which participants were navigated to specific locations. Once there, they were asked to find information about certain plants or trees in the participant's real world.

The "documentation and processing" function was found in nine media tools. In the study by Civantos et al. [7], the mobile device was used to take pictures of the actual objects or to write down notes about the objects.

Three media tools offered the "collaboration and communication" function. These three tasks, which resulted explicitly in collaboration,

Table 2
General characteristics of digital media.

Primary author (Publication year)	Hardware Device	Software Mobile	Stationary	Availability	Software used	Digital format
[10]	Laptop		x	Not specified	Not specified	Animated video
[53]	Pocket pc	x		Not specified	Not specified	Text, audio
[59]	Camera, digital video projection system, computer		x	Application	Not specified	AR (dynamic visualization)
[60]	Camera, digital video projection system, computer		x	Application	EyesWeb	AR (dynamic visualization)
[56]	Camera, digital video projection system, computer		x	Application	Not specified	AR (instructional labels)
[13]	Tablet	x		Application	Edmodo, notebook +	Text, images, video
[62]	Camera, tablet	x		Web application	Digital postcard maker	Text, photographs
[61]	Camera, computer screen		x	Application	Not specified	AR (dynamic visualization)
[51]	Tablet, headphone	x		Application	Aurasma	AR (video, audio, animation)
[4]	Tabletop		x	Native application	DeepTree, built-a-tree	Dynamic visualization, puzzle game
[63]	Tablet	x		Native application	Tree investigators	AR (text, images, photographs)
[7]	Smartphone	x		Web application	WordPress platform	Text, video, photographs, audio recordings
[20]	Tabletop		x	Native application	DeepTree, FlowTree	Dynamic visualization
[9]	AR glasses	x		Native application	MuseumZoom	AR (images)
[57]	Tabletop		x	Application	Not specified	Tangible music interface
[58]	Screen		x	Application	Not specified	AR (dynamic visualization)
[6]	Tablet	x		Native application	Not specified	Text, images, photographs
[8]	Tablet, whiteboard, tabletop	x (tablet)	x (whiteboard, tabletop)	Native application	MuseWork	Text, images, photographs
[45]	Tablet, iPod	x		Application	Not specified	Text, audio
[36]	Tablet	x		Application	Not specified	AR (2D and 3D avatars, text, images, audio)
[55]	Screen		x	Application	3D Studio Max™	Animated video
[40]	Tablet	x		Native application	Ask Dr. Discovery	Text, images
[16]	Smartphone	x		Application	Actionbound	Text, images, GPS-Tour
[26]	Smartphone	x		Application	Not specified	GPS-Tour
[17]	Mixed reality smart glasses	x		Native application	MuseumEye	3D Avatars, text, audio, video, images
[24]	Screen, VR-Headset		x	Native application	Bigger Than Big	Visualization

were all processed in the virtual world. In the study by Choi et al. [6], the app included a photo capture tool for documentation, which helped learners collaborate within the group. It allowed learners to divide the assigned task, so one learner could take the photo and the other one could find an object to observe. Group members had the opportunity to discuss the task and reach consensus while creating a group artifact. Group members had the opportunity to discuss the task and reach consensus while creating a group artifact. "Communication" options, such as a chat function, were offered by the media tool in two studies. In the study by Evans et al. [13], the app includes an online forum where participants can share their knowledge with other participants and exchange ideas.

The "assessment and feedback" function, which is available via a badge a certain level of tasks are completed, was available in three media tools. In the study by Nelson et al. [40], the app includes a small collection of badges and trophies provided in the game to reward players for answering sets of questions.

In summary, the analysis shows that six tools offer only one function, 11 tools offer two functions, four tools offer three functions, three tools offer four functions, and two tools offer five functions. No tool offers all six functions (Table 3).

4.4. Measured outcomes related to informal learning in informal learning places

Regarding the learning outcomes (third research question), the studies reviewed are analyzed according to the research approaches, the data collection tools and outcomes used in the studies reviewed (Table 4).

Among the 26 analyzed studies, we found qualitative studies (13), mixed-method studies (eight) and quantitative studies (five). In terms of research design, 12 studies did not use any comparison. Only the digital media tool is investigated without varying conditions or a control group. Ten studies use a comparison of different instructional approaches, which means that there are different instructional conditions in the digital media tool related to differentiating labels. For example, different types of scaffolds are used in a learning environment with AR. Four studies compare the digital media tool against no media tool, for example, using AR and no AR.

In the qualitative studies mainly interviews (four), video- and audio analysis (three), video analysis (three), observations (three) and surveys (three) were assessement instruments for collecting data. Data were collected using mixed methods approaches with a combination of two to five methods using interviews (six), surveys (four), video analysis (four), observations (three), or questionnaires (three). Log file data were analyzed in two studies. In the quantitative studies, data were collected mainly through questionnaires (four). Across all research approaches, it

Table 3
Functions of digital media.

Primary author (Publication year)	Information	Task	Task processed RW	Documentation and processing VW	Cooperation or collaboration	Communication	Assessment and feedback	
[10]	x							
[53]	x							
[59]	x	x		x				
[60]	x	x		x				
[56]	x	x		x				
[13]	x	x		x	x		x	x
[62]	x				x		x	
[61]	x	x		x				
[51]	x							
[4]	x	x		x				
[63]	x	x		x	x			
[7]	x	x	x		x			
[20]	Prototype 1: x Prototype 2: x	Prototype 2: x		Prototype 2: x				
[9]	x	x		x				
[57]	x	x		x				
[58]	x	x		x				
[6]	x	x		x	x	x		
[8]	x	x		x	x	x		
[45]	x							
[36]	x	x		x				
[55]	x							
[40]	x	x		x				x
[16]	x	x	x		x	x		x
[26]	x	x	x		x			
[17]	x	x		x	x	x		
[24]	x							

can be seen that video analysis (eleven), interviews (ten), questionnaires (eight), surveys (seven), and observation (six) were the main methods used to gather data.

The outcomes in the studies can be divided into three categories based on their measured content: cognitive outcomes, motivational outcomes, and outcomes related to collaboration and interaction.

The cognitive outcomes were assessed by 16 studies. The analysis shows that mainly content knowledge (eight) and conceptual knowledge (five) are measured. In two studies, both types of knowledge were measured. As an example of content knowledge, Yoon et al. [58] shows in a comparative study with a pre-post-test design using surveys that AR has a positive impact on learning Bernoulli's principles. In terms of conceptual knowledge the comparative study using interviews by Yoon et al. (2014) shows significant gains in students' conceptual knowledge when a device was digitally augmented to demonstrate the flow of electrons [61]. Other cognitive outcomes measured were cognitive understanding (three), and once each were preferred learning style, cognitive theorizing skills, media literacy, procedural knowledge and digital competence. In all 16 studies reviewed, only positive and no negative cognitive effects of the use of ditigal media are found.

Motivational outcomes were assessed in 11 studies. The analysis show that different motivation qualities (five), interest (five) and visitor engagement (four) are measured. In two studies, motivation and interest were both measured and in one study science interest and visitor engagement. Regarding motivation, different aspects are assessed: general motivation (two), intrinsic motivation (one), internal motivation (one) and external motivation (one). In addition, interest is partly stated more specifically: situational interest (two), general interest (two) and science interest (one). As an example of general motivation, Moorhouse et al. [36] shows in a study with a pre-post-test design using a quiz that schoolchildren are motivated to continue learning with AR in museums. Situational interest was measured in the study by Valle et al. [55] using semi-structured interviews. The results show that the informal science learning event had a measurable impact on situational interest. In all 11 studies reviewed, only positive and no negative motivational effects are found.

Regarding visitor engagement, the comparative study by Horn et al. [20] showed by means of interviews, video and log file analysis that the interactive tabletop has a positive influence on visitor engagement. The four studies reviewed reported positive effects on engagement. Only one study [9] additionally cites drawbacks in the use of digital media. The wearable AR application used caused a lack of visitor engagement and social acceptance.

The outcomes related to collaboration and interaction were assessed in seven studies. They show that mostly social interaction (four), followed by collaboration (two) and family conversation (one) are measured. As an example of social interaction, the study by Xambó et al. (2016) was able to show through video and audio analysis that the musical tabletop promoted different approaches to cross-group interaction beyond the usual interaction between groups. The study by Evans et al. [13] showed through observation, video analysis and interviews that most participants enjoyed the collaboration and found it necessary for achieving the given goals. In all 11 studies reviewed, collaboration and interaction were rated positively.

In summary, 19 studies measured outcomes from only one of the three categories (cognitive ten, motivational four, collaboration five), six studies examined two categories (cognitive and motivational five, motivation and collaboration one) and only one study Zimmermann et al., (2014) examined all three categories (Table 4) [62].

5. Discussion

Learning in informal learning places such as museums or zoos, increasingly have recently become the focus of educational debates [46]. It has been shown that learning often takes place casually and with minimal structure [29], so that support is necessary for learning success. Digital media have proven to be a suitable support tool that support and promote informal learning processes [37]. This systematic literature review intends to provide an overview of research on how digital media are used in informal learning places and what learning outcomes are measured. Before the three research questions (see chapter 2.4) are discussed, this article has provided a short general overview of the studies included in the review.

The present review shows that the relevant studies are

Table 4
Measured outcomes.

Primary author (Publication year)	Data collection method	Research design	Cognitive outcomes	Motivational outcomes	Collaboration, social interaction
[10]	Qualitative (video- / audio analysis)	No comparison			Family conversation
[53]	Qualitative (video- / audio analysis)	Instructional			Social interaction
[59]	Mixed method (surveys, worksheets, interview)	Instructional	Conceptual knowledge, Cognitive understanding		
[60]	Mixed method (surveys, student response forms, interview, observation, video analysis)	Instructional	Conceptual knowledge, cognitive theorizing skills		
[56]	Mixed method (questionnaire, reflections, observation)	Instructional	Conceptual knowledge, Cognitive understanding		
[13]	Qualitative (observation, video analysis, interview)	No comparison		Intrinsic motivation, interest	Group collaboration
[62]	Qualitative (observation, survey)	No comparison	Media literacy	Interest	Social interaction
[61]	Qualitative (observation, interview)	Comparison media/ no media	Conceptual knowledge, content knowledge		
[51]	Quantitative (questionnaire)	Comparison media/ no media	Content knowledge		
[4]	Quantitative (video- / audio analysis)	Instructional		Group engagement	
[63]	Mixed method (questionnaire, video analysis, interview)	No comparison	Content knowledge	Situational interest	
[7]	Qualitative (survey, discussion, reflections, thematic analysis)	Instructional	Procedural knowledge	Visitor engagement	
[20]	Mixed method (interview, video analysis, log file)	Instructional	Content knowledge	Visitor engagement	
[9]	Qualitative (interview)	Comparison media/no media	Content knowledge, cognitive understanding		
[57]	Qualitative (video- / audio analysis)	No comparison			Social interaction
[58]	Mixed method (surveys, interview)	Comparison media/ no media	Conceptual knowledge, content knowledge		
[6]	Qualitative (video analysis)	No comparison	Problem-solving skills		
[8]	Mixed method (questionnaire, observation, video analysis, log file)	Instructional			Group collaboration
[45]	Quantitative (log file, questionnaire, knowledge test)	Instructional	Content knowledge		
[36]	Qualitative (quiz)	No comparison	Knowledge, preferred learning style	Motivation	
[55]	Mixed method (surveys, interview)	No comparison		Internal motivation, external motivation, situational interest	
[40]	Quantitative (questionnaire)	Instructional		Science interest, visitor engagement	
[16]	Qualitative (written / oral feedback)	No comparison	Digital competence	Motivation	
[26]	Quantitative, (questionnaire / excursion booklet)	No comparison	Content knowledge		
[17]	Qualitative (questionnaire)	No comparison			Social interaction
[24]	Qualitative, (surveys, video analysis, VR screen captures, interview)	No comparison		Visitor engagement	

predominantly from the natural science context, especially biology and physics. Other domains such as art, history or music are very rarely researched. This is also reflected in the informal learning places that are described. Museums, especially science museums, are the most dominant. Here, the publication year of the studies examined shows that from about 2016 onward, the informal learning places became more heterogeneous. In addition to science and nature centers, outdoor nature is also investigated as an informal learning location in the form of summer camps and nature parks [16,26,62,63]. With regard to the year of publication, it is also apparent that significantly more studies were published starting in 2016. In addition, the length of the visit is on average half an hour to an hour and is predominantly carried out in groups, mostly in pairs or three persons, rather than alone.

5.1. General characteristics of digital media in informal learning places

With regard to the general characteristics of digital media, it can be seen that stationary digital media are used almost as frequently as mobile media in the studies reviewed. However, since 2018, the trend has been toward using mobile digital media, such as tablets or smartphones. Smartphones were generally used rather rarely in the studies examined, with only two studies reporting smartphone use in 2020 and one study in 2016. An explanation might be the advancing technical development and dissemination: On the one hand, smartphones are much better equipped nowadays and can also handle more complex applications [25]. On the other hand, most visitors own smartphones nowadays, so that they can be used more often, also in the sense of the "bring your own device (BYOD)" approach. With regard to the use of applications, it can be seen that the number of existing applications and applications developed specifically for the study (native applications) is about equal with more self-developed applications being investigated since 2018.

With regard to the AR visualization, it can be seen that AR is already found quite often in studies from previous years. However, with regard to the complexity of AR applications, significant differences can be observed. While in the earlier studies AR is mostly found as dynamic visualization or instructional labels [56,59,60], in the studies from 2019 and 2020, 2D and 3D avatars are already being used [17,36]. For example, on one device, a circuit had to be completed and a light bulb made to light up by implementing various configurations. Once the circuit was completed, a projected visualization of the electrons appeared around the complete loop [60]. The Hammady et al. (2020) study uses Microsoft HoloLens to provide visitors with a unique museum experience. A virtual guide that can walk and talk shows visitors important visual information in the form of videos, images and

3D-scanned antiquities [17].

5.2. Functions of digital media in informal learning places that are relevant for learning

With regard to the various functions of digital media, it can be seen that the most common functions within the reported studies are the provision of information and tasks. These results are also consistent with the findings from the study by Kampschulte et al. [22], in which media are also primarily used as "information and presentation tools" and for the "design of learning tasks," analogous to the functions of Petko [41]. Presenting information via digital media offers additional benefits in that the information can be presented in different ways. In museums, exhibit descriptions are often placed next to artifacts by using text displays. However, this might be suboptimal for information presentation because it strains the cognitive resources necessary to process the learning content [45,52]. Digital media can provide additional and brief specific information as required. Also, the information can be presented in a time-specific or even individualized manner. It is necessary to note, that the use of different functions of a digital tool also depends on the pedagogical perspective from which the digital learning tool is used, i.e. if the function to inform the visitors is in the focus, then it is adequate to provide information within the digital tool, while collaborative functions, for example, do not necessarily contribute to the intended objective.

With regard to tasks, it can be seen that these are predominantly to be worked on in the virtual world. Only in the two studies that took place in nature [16,26] and in an archeological museum Civantos et al. [7] were the tasks not processed virtually. Virtual processing spans a wide range of brief work instructions, ranging from "try to complete the circuit" [60] to full work instructions to guide exploration in the museum [8]. Third was the documentation and processing function, which most often consisted of tools for taking photographs or saving notes. Kampschulte et al. [22] also note that media in their study is the third function most often used as "tools and work equipment." Likewise, media for communication is used rather seldom in both the Kampschulte et al. [22] study and in this literature review. The function of "communication", which Petko [41] and Kerres [23] also define, is very rarely found. Only in two studies visitors can communicate via a chat function and an email function [13,62]. Overall, it can be seen that beginning about 2018, the number of digital media tool functions increases. Therefore, with the rise and availability of technological advances, it is very likely that in the future the possible functions of digital media will be further exhausted and in consequence investigated.

Measured outcomes, related to informal learning with digital media in informal learning place

Mainly qualitative or mixed data collection methods are used, while less quantitative research is carried out. Quantitative research analyzes particularly knowledge acquisition. Since the research field is still quite new, it can be important to research as broadly as possible to get comprehensive results[35]. Some aspects, such as engagement or social interaction, are also more precisely measured qualitatively through observation [2]. In terms of research design, it can be seen that most studies do not include control groups to investigate different conditions regarding the media tool. Only a few studies use comparison between media or no media, mostly by evaluating knowledge. This was the same in the beginnings of media research, when the effectiveness of digital media was compared to learning without digital media [1], frequently neglecting finer analysis of those settings. Additionally, it would be interesting to conduct further research on long-term effects of knowledge gain, as most studies tested the knowledge immediately after the completion of the treatment and no follow-up test is reported.

The evaluation of the studies reviewed shows that the use of digital media in informal learning places has an overall positive effect on informal learning, especially on knowledge, motivation, interest and engagement. The positive results in terms of motivation can possibly be explained by the different types of representation that the digital media make possible. By using AR, media can stimulate learning motivation and achievement, and enhance the flexibility and interactivity of the learning activities [27]. Also, different forms of representation and their combination [7,10,17,36]contribute to the presentation of learning material in different ways. Via such different design features, learning can be supported on a cognitive as well as motivational level [3]. Only one study [9] explicitly cites drawbacks to the use of digital media, in this study the wearable AR application, such as lack of visitor engagement and social acceptance. Publication bias cannot be excluded here, since positive findings are easier to publish and these are peer-reviewed articles.

5.3. Limitation

A limitation of this systematic literature review was that the search was limited to the two Scopus and FIS databases. However, the latter includes Eric, EBSCOhost ebooks and BASE databases, which are among the most prominent in education domain. The literature search was completed in February 2021, so more recent articles were not included in the evaluation process. Since the systematic literature review is limited to individual studies, no general conclusions can be drawn, but statements related to available research studies. It cannot be excluded that there are other functions or characteristics in the field of study. In addition, in this search we only included some quite prominent informal learning places such as museums, aquariums, and zoos. Nevertheless, the general search terms led to articles with involving science centers, botanical gardens or nature parks. Future research would benefit from using detailed keywords, including terms associated with the broad variety of informal learning places. Although the number of articles included in the literature review was limited, the selection process was completed using a systematic process in order to avoid bias.

6. Conclusions

This systematic literature review provides an overview of research studies about the use of digital media in informal learning places and its impact on learning outcomes. It turns out that the variety of informal learning places in studies reviewed have increased over the years, for example, galleries or nature parks are increasingly taken into account in addition to museums. Although the study does not claim to be comprehensive, it provides important insights for media-based educational research. The first research question aimed to identify the general characteristics of the examined digital media in informal learning places. In recent years, we can see from the studies that the design of digital media tools has become more and more complex, such as 3D animations. In the last three years, digital media tools were mainly used in portable form. With the ongoing technical development in the smartphone sector, it remains to be seen whether this trend will continue or whether stationary digital media (tabletops) will also be used furthermore. Regarding the functions of digital media tools in the studies reviewed, it has been found that they mainly provide information and tasks. Almost none of the reported digital media tools exploit the full range of functions. A specific support function, e.g., to adapt the task to the learner's level of knowledge, was not found in the studies. However, this adaptivity is exactly one of the strengths of digital media tools [3]. Functions that explicitly support group collaboration were also very rarely found in the studies. Since informal learning places were mostly visited in groups in the studies, this would be a function that could be given more attention. Regarding the outcomes measured in the studies reviewed, cognitive load was not taken into account. This is relevant insofar as in most studies focusing on digital media for learning purposes, the measurement of cognitive load has become a standard procedure and is relevant for learning processes because different design features of digital learning media can have both positive and negative effects on the cognitive processing of information (extraneous - and germane load)

[50]. Therefore, it would be interesting for future research to investigate media tool characteristics in greater detail also by looking into the design characteristics of the cognitive theory of multimedia learning [33] in order to investigate aspects such as cognitive load or the format of the instructions. With regard to the results reported within the studies reviewed, digital media have been shown to promote and support motivational and cognitive informal learning processes. This is particularly apparent with regard to knowledge acquisition and interest, as well as collaboration and social interaction. In terms of knowledge acquisition and interest, follow-up questionnaires could provide interesting insights into whether knowledge acquisition and interest can be enhanced in the long term. This was not reported in the studies reviewed. In summary, the studies reviewed show that digital media in informal learning places offer suitable support options to promote informal learning. In a few years, this type of review could be repeated or a meta-analysis could be done, as it can be assumed that research in this field will increase substantially.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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