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RESEARCH REVIEW

Effects of Out-of-School STEM Learning Environments on Student Interest: a Critical Systematic Literature Review

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Abstract
Inquiry-based out-of-school STEM learning environments, such as offerings from science centers, museums, and out-of-school laboratories, serve as an enrichment to classroom education in many countries. As there is an increasing number of such STEM learning environments in Germany and some other countries and a growing body of research worldwide, it is important to analyze their effects. In this context, student interest is a critical factor in determining the effectiveness of such learning opportunities and the quality of the educational outcomes achieved. Therefore, based on an international comprehensive, systematic literature review of 30 out of 1657 identified studies, various influencing factors that support or hinder interest development are highlighted. Results show that active participation, hands-on activities, and preparation for the visit have strong beneficial effects on interest experience. Out-of-school STEM learning environments are especially suitable for students with little prior knowledge, and they tend to promote interest in areas that are often relatively unpopular among adolescents, depending on their age and gender. The findings also highlight research deficits, particularly with respect to well-defined constructs of interest, and point to useful criteria that informal out-of-school learning environments can apply to promote various forms of interest and thus improve educational programs.

Keywords Promotion of interest · Informal learning environment · Out-of-school learning environment · Field trip · Out-of-school laboratory

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Introduction

Out-of-school learning environments, including science centers, museums, and out-of-school laboratories, serve to enrich school education in many countries. Especially in the field of science, there exist many such learning programs, that aim at fostering students' interest in science, technology, engineering, and mathematics (STEM) and offer opportunities to discover scientific and technical fields of activity (Gumaelius et al., 2016; Jeffers et al., 2004). In Germany alone, the number of officially registered out-of-school learning environments increased from 32 before 2000 to 307 in 2015 to over 430 today (LernortLabor, 2022b). Rising attention is being paid to these settings of learning, as a growing number of publications in this area underlines (Lewalter et al., 2021).

Regarding STEM education environments, the interest of students is considered an important factor worldwide (Freeman et al., 2015). Studies have suggested a positive relationship between interest in a learning subject and success in nondirected learning (e.g., Ryan et al., 1990). Furthermore, higher topic interest appears to mitigate some hindering influences on learning; thus, such interest may lead to greater persistence in working on tasks (e.g., Fulmer & Frijters, 2011). Consequently, student interest can be considered a critical factor in determining the effectiveness of learning opportunities and the quality of the achieved educational success; accordingly, it can be used to evaluate educational learning environments.

To make these educational opportunities particularly effective, it is important to learn from previous research. However, comprehensive overviews of the state of research on the effectiveness of such out-of-school learning environments in terms of interest hardly exist. Therefore, we conducted a systematic review and focused on the following research question: What are the known facilitating and inhibiting factors that influence students' interest in out-of-school STEM learning environments and what are their effects on participating students' interest?

Definitions and Theoretical Background

Out-of-school learning environments are often provided within larger institutions, such as universities, science centers, and museums (Gumaelius et al., 2016). These learning environments are usually accessible to students as part of a field trip or special support program. They often aim to facilitate self-directed, free-choice learning experiences (Falk, 2005). Most out-of-school learning environments focus on hands-on activities and specific topics, such as a particular school subject. In the field of science, there are many learning environments aimed at encouraging young researchers to increase their interest in STEM-related topics.

In this article, out-of-school STEM learning environments are educational offers organized outside of schools, where groups of students experiment with scientific or technical issues in events lasting a maximum of 1 day. Thus, they contain many characteristics of informal learning environments, for example, the focus is on student self-activity. At the same time, they are organized to a certain extent as described, which does not necessarily apply to all informal learning environments (Rogoff et al., 2016), e.g., by universities or museums. Since such educational out-of-school learning environments do not have to meet the requirements of schools in terms of curriculum content, scheduling and budget, they enable new forms of access, methods, and topics.

To understand the effects of out-of-school learning environments on interest promotion and to contextualize the results, we detail the underlying concepts of interest. As research on interest in out-of-school environments uses various theoretical approaches, a short overview of the strands needs to be provided.

The definition of interest varies according to the underlying theory. As stated by Krapp et al. (1992), interest usually "emerges from an individual's interaction with his or her environment" (Krapp et al., 1992, p. 5). Situational interest (SI), which is often short, can be expressed when a person deals with a certain object or certain environmental conditions. In contrast, there is individual or personal interest, which refers to dispositional personality factors that are relatively stable and, at the same time, to their actualized state as the actualized individual interest (Krapp et al., 1992). SI is caused by the attractiveness of the learning object or the learning environment, whereas actualized (individual) interest is momentary interest caused by personal dispositions (i.e., the interest that is already present in a person). The term interest experience is used to describe a current interest independent of cause (Sansone & Thoman, 2005; Tsai et al., 2008). Häußler and Hoffmann (1995) further distinguish between object and subject interest. Object interest is the interest in a concrete object, for example, in physics as a science, and subject interest is the interest in a school subject, such as physics education.

One theoretical approach, the person–object theory of interest (POI), defines interest as a person–object relation. The term "object" refers to both real objects and abstract topics and ideas (Krapp, 2002b). The individual interest pattern not only consists of separate independent interests, but also contains, for example, object areas that are characterized by the combination of contents and activities in a school subject (Krapp, 2002b). From this perspective, situational and individual interests can be divided into a feeling-related, a value-related, and an epistemic component. The feeling-related component describes the emotions that a topic triggers before, during, or after engagement with it, whereas the value-related component describes the more emotionally independent personal meaning that a person associates with the object of interest (Schiefele, 1990, 1991). The desire to increase knowledge represents the epistemic component of interest.

To explain the development of individual interest, Hidi and Renninger (2006) propose a four-phase model (4PM). In the first phase, triggered SI is primarily aroused in the learning environment, for example, through group work, puzzles, or computers ("catch," as referred to by Mitchell, 1993). To maintain SI and thus achieve a "hold" effect, hold factors, such as "meaningfulness" and "involvement," are important (Mitchell, 1993). If a person becomes completely absorbed in engagement with the subject matter, this is also referred to as flow (Csikszentmihalyi, 1975). The "hold" component is of great importance for long-lasting interest (Harackiewicz et al., 2000; Mitchell, 1993) and can be considered the second stage of interest development. In most cases, SI disappears at the end of the learning situation (Krapp, 1998). The third phase of interest development is characterized by emerging individual interest. Under certain conditions, such as the evaluation of the object as (personally) significant and the experience of positive emotions, especially in the area of basic psychological needs, SI can stabilize (Krapp, 1998). Emerging individual interests can lead to well-developed individual interests (Lipstein & Renninger, 2006). In the case of the successful internalization of interest, the fourth phase is referred to as individual interest.

The self-determination theory (SDT) of Deci and Ryan (1985, 1991) is another well-established theory used to explain behavior. SDT identifies significant influences on a person's motivation to act, with motivation being the reason for a particular behavior at a particular time. Deci and Ryan (1985, 1991) distinguish between intrinsic and extrinsic motivation. According to the SDT, the motivation for an action always depends on the extent to which the three basic psychological needs of competence, autonomy, and relatedness are met. Although the SDT refers to the construct of motivation, there is a connection to the construct of interest, as "interest is a powerful motivator" (Deci, 1992, p. 43) and can therefore be a reason for a certain motivation to act. The SDT explicates interest "in terms of the interaction between a person and an activity" (Deci, 1992, p. 49), which is quite like the person–object relation used in the POI.

Another theory related to interest is expectancy–value theory (EVT), according to which expectations and values have an influence on performance (Wigfield & Eccles, 1992). Achievement task values are divided into attainment value, intrinsic value, utility value, and cost. Intrinsic value is the individual's subjective interest and is similar to the construct of intrinsic motivation in the SDT (Wigfield & Eccles, 1992). Since SI can be considered an aspect of intrinsic motivation (Hidi & Harackiewicz, 2000), the SDT and EVT are also significant in defining interest and are further discussed in what follows.

Figure 1 provides an overview of the different theories of interest and how the studies included in this systematic review use them.

Each of the four theories presented above describes aspects of interest, and consequently, they overlap in some ways. However, they each have their own specific emphases. The POI focuses on "structuring and elucidating interest-related concepts, hypotheses, and results" (Krapp, 2002a, p. 408) and therefore also adopts the hypotheses of the SDT, whereas the SDT originally attempts to explain the causes of motivation. In the EVT, intrinsic value is comparable to intrinsic motivation in the SDT (Wigfield & Eccles, 1992). The four-phase model of interest development also shares some of the same views of interest with the POI, even if it does not support the POI's thesis that interest is characterized by the composition of value-related and feeling-related valences (Hidi & Renninger, 2006). Regardless of the theory through which interest is studied, the distinction between interest experience and interest as a disposition seems to be widely accepted. To provide a comprehensive picture of research on interest in out-of-school learning environments, we included all constructs and theories of interest (see Table 2).

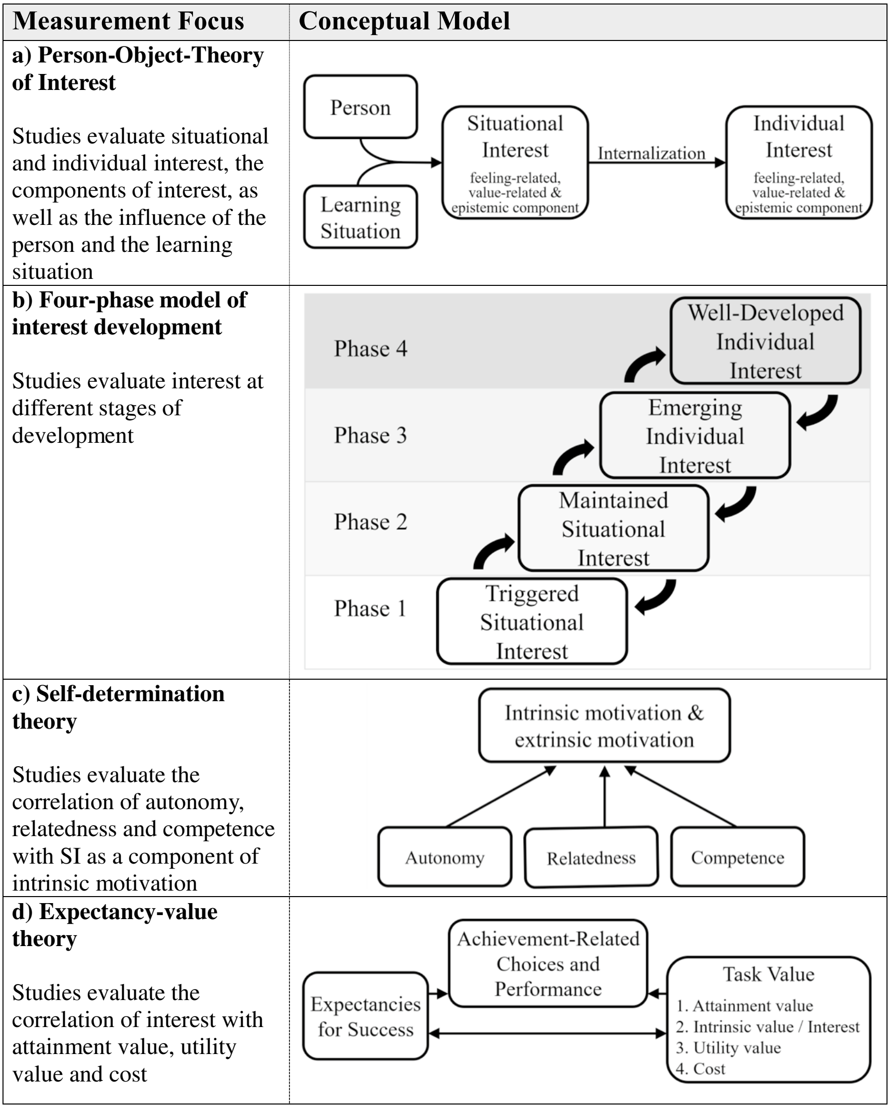

Fig. 1 Interest theories and their relation to the current study. **a**) Interest in POI (based on Krapp, 1998, p. 191 as cited in Krapp, 2002b). **b**) 4PM (based on Hidi & Renninger, 2006). **c**) Model for SDT (based on Deci & Ryan, 1991, 1993). **d**) Subfield of EVT (based on Wigfield & Eccles, 1992 and Wigfield et al., 2020, p. 658)

State of Research, Desiderata, and Aims

To date, there has been no uniform research into the association between out-of-school learning environments and student interest. Several years ago, Guderian and Priemer (2008) published a review of research on out-of-school laboratories conducted in Germany at that time. Later, Schwan et al. (2014) provided a characterization of some science learning settings and the outcomes of visits, but without including the school context. Recently, Suviniitty and Clavert (2020) presented a limited literature review identifying key features that contribute to the effectiveness of STEM outreach activities, but they did not focus on interest. In the same vein, Rehfeldt et al. (2020) published a review on out-of-school laboratories and their effects on teacher education but included only settings in Germany. Most recently, Lewalter et al. (2021) conducted a meta-analysis of interest in out-of-school time programs in which they presented different approaches to interest research but did not elaborate on the various theories of interest used in the relevant studies. They also neglected important factors influencing interest, such as emotions experienced during attendance. Thus, there is still a deficit in the area of clearly presenting the international research on out-of-school learning environments and their impact on student interest. Therefore, the aim of this systematic review is to present an overview of the current state of research on the effects of out-of-school learning environments on the various domains of participating students' interests. Also, we determine interest-facilitating and interest-inhibiting factors that providers of those educational settings can consider to improve the quality of their educational environments.

Methods

This review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al., 2009). The procedure for complying with the individual steps of the PRISMA checklist is described in the following subsections.

Eligibility Criteria

In defining the eligibility criteria, we chose a narrow search term to allow us to draw common conclusions from the studies given the different study settings. The search included the construct "interest" with interest experience, interest as a disposition, and interest development. We only included studies that had a definition of the construct of interest used, or at least examined specific forms of interest, such as situational or individual interest. Since these forms of interest have been researched for a long time, there is a broad consensus on what is meant by them, so that studies without a detailed theoretical framework were also included. Other constructs, such as those of self-concept, were excluded. Studies on motivation were considered only if SI was included as a component. Since there are numerous studies on a wide variety of extracurricular events, we set a very clear focus on the extracurricular learning location and included only the literature on STEM-related programs. All studies on extracurricular learning locations with an experimental component, such as student laboratories, student research centers, hands-on museums, or science centers, were considered, but none on other settings or events, such as normal lessons or online-only events. Studies solely referring to a group composed of K–12 students in class or in small groups were included. We considered only events that could take place within a maximum of 1 day for the experimental group (excluding preparation and post-enhancement), as the timeframe may have an impact on certain components of interest (Dillon et al., 2016). To avoid publication bias, we considered all types of scientific publications. To obtain as comprehensive a picture of the research as possible, we used the relevant publications, regardless of the year of publication. The basis of this work was English language literature.

Search Strategy

The literature was searched using the Education Resources Information Center (ERIC), Scopus, Web of Science and EBSCOhost databases. These databases were chosen because they are well established and include a wide range regarding educational (and psychological) research. In addition, Google Scholar was used as further database, in order to be as comprehensive and complete as possible in this young field of research. Nevertheless, as quality criteria with one exception (Markic et al., 2017), only peer-reviewed studies or accepted doctoral or master's theses were included. The exception is an extended version of an article published in edited conference proceedings, so it can be assumed that the quality is sufficient.

The keywords used to form the search equation were chosen based on a thorough reading of the literature presented in the introduction. The search equation was a combination of different expressions for out-of-school learning environments, different phrases for the school context, and keywords for interest. The components within a category were linked with "OR," and the individual categories were linked with "AND." The components of the search equation are shown in Table 1. Due to the large number of search results, the search equation was deliberately chosen to be narrow and precise to exclude unsuitable entries. To make the search more precise in view of the very high number of hits, we also excluded the terms "FOOD" and "MEDICINE" when searching with Google Scholar. This step seems justified despite the potential of these terms, especially for STEM cross-curricular topics. On

Table 1 Search equation

Categories	Keywords
Expressions for "out-of-school learning environment"	HANDS-ON-LAB; HANDS-ON-LABORATORY; HANDS-ON-MUSEUM; OUT-OF-SCHOOL-INQUIRY; OUT-OF-SCHOOL-LAB; OUT-OF-SCHOOL-LABORATORY; OUT-OF-SCHOOL-PROGRAM; OUT-OF-SCHOOL-PROGRAMME; OUTREACH-LAB; OUTREACH-LABORATORY; OUTREACH-LEARNING; SCIENCE-CENTER; SCIENCE-CENTRE; SCIENCE-OUTREACH; STEM-OUTREACH; STUDENT-LAB; STUDENT-LABORATORY; STUDENT-RESEARCH-CENTER; STUDENT-RESEARCH-CENTRE
Expressions for "school context"	PUPIL; SCHOOL; STUDENT
Expressions for "interest"	INDIVIDUAL-INTEREST; PERSONAL-INTEREST; SITUATIONAL-INTEREST

the one hand, hardly any studies relevant to this article were found with these two terms on the other databases used. On the other hand, an analysis of the hits on Google Scholar with these two terms did not reveal any new relevant results.

The literature search was performed on October 18, 2021. The 1657 articles found with the search equation were filtered according to the PRISMA diagram of the selection strategy (Moher et al., 2009) shown in Fig. 2. After eliminating duplicates, the titles and abstracts of the 1573 identified articles were reviewed for eligibility in two rounds based on the inclusion criteria defined above. The articles were independently reviewed and evaluated by a qualified research assistant and a doctoral student. If an analysis of the title and abstract did not allow for a clear assignment and in cases where the two reviewers did not agree, the entire document was read. As the inter-rater reliability was 95.5%, it can be assumed that the results were independent of the two reviewers. The remaining 135 contributions were read in full and checked for their suitability in terms of content. Articles were excluded if they did not include findings relevant to the aim of research (e.g., Dabamona & Cater, 2019), lacked information on the concept or evaluated form of interest used or did not evaluate interest (e.g., Vennix et al., 2017), did not target K–12 students (e.g., Jeffery et al., 2016), or evaluated programs on non-STEM topics (e.g., Nachtigall et al., 2018) or multi-day events (e.g., Hargraves & Waller, 2015). Because of partial overlap and lack of comparability with the rest of the included literature, one meta-analysis (Lewalter et al., 2021) was excluded. The final sample included 30 studies (see Table 2), whose main characteristics were recorded in a spreadsheet (author,

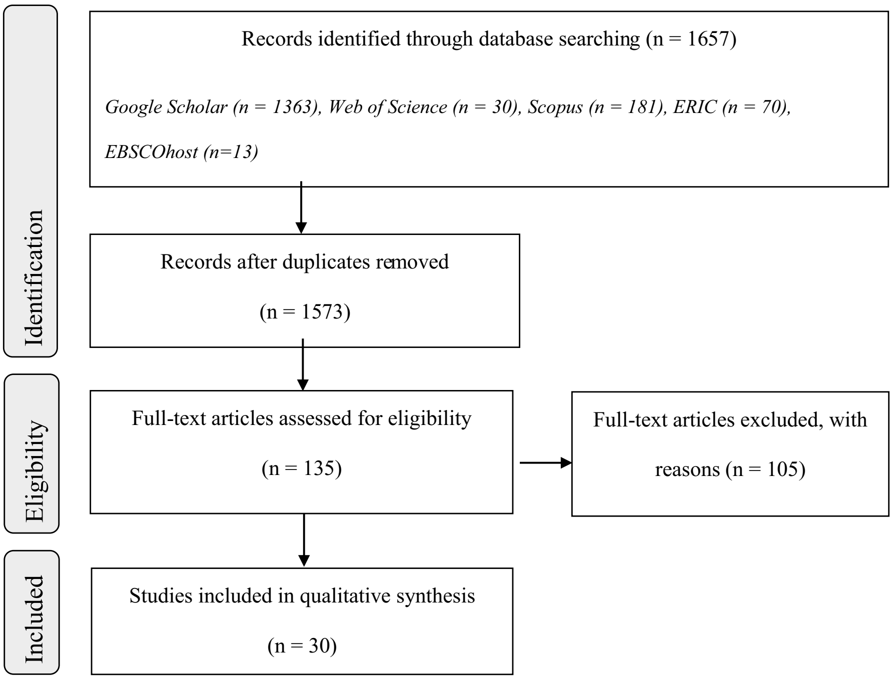

Fig. 2 Flow of information through the different phases of the systematic review (Moher et al., 2009)

Table 2 Characteristics of included studies

Study, country	Concepts of interest		Study design	Setting (location, subject, duration)	Sample size (TG/CG)	Participants ((mean) age in years, school level/type, proportion of females)
	Interest experience (✓) incl. SI (◊)	Interest as disposition (✓) incl. II (◊)				
Affeldt et al. (2018), Germany	◊		⓬ (pairs of students)	Non-formal learning environment "Exploring and Improving the Quality of Water," Chemistry, 3 h	44 (22 interviews/-)	11–13, 6th grade, comprehensive schools, 57%
Affeldt et al. (2015), Germany	◊		i.a., questionnaires	4 student laboratories at 4 German universities, Chemistry, 3 h (additional activities possible)	141 (141/-)	N/A, urban comprehensive school, N/A
Bätz et al. (2010), Germany	✓		① ②	Zoological garden, Biology, 3 workstations with approx. 30 min	223 (197/26)	10.45, 5th grade, 4 school of highest stratification level ("Gymnasium"), 55%
Beranek-Knauer et al. (2020), Austria	◊		① ② ③	Course at the Offenes Labor Graz (OLG), Biology, 1 day	282 (282/-)	17.7 ± 1.3, high school, 69%
Budke et al. (2019), Germany	✓ (current interest)	✓ (general interest)	① ② ③	Student laboratory GreenLab_OS/ mobile lab at school, Chemistry, 1 day	340 (245 mobile lab, 95 university lab/-)	13.09 (SD = 0.825), 7th and 8th grades, secondary school (junior high school), 60.6%
Dohn (2011), Denmark	◊		i.a., ⓬, ❷	Aquarium, Biology, 1 day	16 (16/-)	17–19, 12th grade, high school students, 81%
Dohn (2013), Denmark	◊		i.a., ⓬, ❷	Zoo, Biology, one school day	21 (21/-)	17–19, 12th grade, upper secondary school ("Gymnasium"), 76%

Table 2 (continued)

Study, country	Concepts of interest		Study design	Setting (location, subject, duration)	Sample size (TG/CG)	Participants ((mean) age in years, school level/type, proportion of females)
	Interest experience (✓) incl. SI (◊)	Interest as disposition (✓) incl. II (◊)				
Fröhlich et al. (2013), Germany	◊		① ② retention test	Outreach farm/school, Environmental Education, 2×90 min	176 (176/56)	11.5 (11–13), 5th grade, 3 secondary schools, 53%
Glowinski and Bayrhuber (2011), Germany	◊	◊	②	Student lab on university campus, Biology, 6 h	378 (378/-)	18.3 (SD = 0.76), upper secondary school, about 60%
Gutual (2019), USA	✓		① ②	Open enrollment K-12 engineering lab/school, Biomedical engineering, 60–120 min	55, (29 lab, 26 school/-)	N/A, 6th grade, middle school, 38% (lab)/54% (school)
Hausamann (2012)[a], Germany	✓ (actual interest)	✓	① ② ③	DLR_School_Lab Oberpfaffenhofen, Aeronautics and space, 1 day	734 (734/-)	N/A, secondary-school students, 41%
Itzek-Greulich et al. (2017)[b], Germany	◊	✓	① ② ③	Interactive student research center "EXPERIMENTA"/school, Chemistry, 8 lessons of 45 min	1854 (e.g., in ①: 1252/386)	15.3 (SD = 0.7), 9th grade, 22 secondary schools ("Realschule"), 50.3%
Itzek-Greulich and Vollmer (2017)[b], Germany	◊		① ②	Interactive student research center "EXPERIMENTA"/school, Chemistry, 8 lessons of 45 min	1228 (44 classes/6 classes)	15.3 (SD = 0.6), 9th grade, 22 secondary schools ("Realschule"), 50%

Table 2 (continued)

Study, country	Concepts of interest		Study design	Setting (location, subject, duration)	Sample size (TG/CG)	Participants ((mean) age in years, school level/type, proportion of females)
	Interest experience (✓) incl. SI (◊)	Interest as disposition (✓) incl. II (◊)				
Lelliott (2007), South Africa	◊	◊	i.a., ❶ ❷	Johannesburg Planetarium and Hartebeesthoek Radio Astronomy Observatory, Astronomy, 2–4 h	34 (34/-)	12–15, 7th and 8th grade, 4 primary schools/high schools, 74%
Markic et al. (2017), Germany	✓		②	Non-formal learning environment “Exploring and Improving the Quality of Water”, Chemistry, 3 h	244 (244/-)	11–13, 5th or 6th grade, secondary school, N/A
Marth-Busch and Bogner (2020), Germany		✓	① ② retention test, (③ $n = 183$, 12 weeks & 1 year later)	Zoo, Bionics, 5 school lessons	324 (324/-)	12.2, 6th grade, 58%
Ozogul et al. (2019), USA	✓		① ② ③	Arizona Science Lab (ASL) engineering workshop, Electrical & mechanical engineering, 1 day	3344 (3344/-)	9–14, elementary and middle schools, 51.8%
Röllke et al. (2020), Germany	◊	◊	Intermediate test ②	Laboratory teutolab biotechnologie at Bielefeld University/school, Biotechnology, 4 h	287 (110 university/177 school)	15.6 (SD = 0.8), high school students (“Gymnasium”), 58.9%

Table 2 (continued)

Study, country	Concepts of interest		Study design	Setting (location, subject, duration)	Sample size (TG/CG)	Participants ((mean) age in years, school level/type, proportion of females)
	Interest experience (✓) incl. SI (◊)	Interest as disposition (✓) incl. II (◊)				
Salmi and Thuneberg (2019), Finland	✓	✓	① ②	Mobile science exhibition "Science Circus," Science education (physics, biology, chemistry), 1 day	256 (256/-)	12 years 6 months, 6th grade, 44%
Salmi et al. (2017a), Finland	✓	✓	① ② delayed post-test	Dinosaur exhibition in science center "Heureka," Biology, 1 day	366 (249 with demonstration/-)	12–13, 7 schools, 46%
Salmi et al. (2017b), Finland	✓	✓	① ②	AR Science Exhibition, Physics/math (chemistry), 1 day	146 (146/-)	12.3, 7 schools, 51%
Salmi et al. (2020), Finland	✓	✓	① ②	Mobile exhibition "Mars & Space," Science/mathematics, 115 min	306 (306/-)	12.2 (11–13), 6th grade, 45%
Seakins (2015), UK	✓	✓	❶ ❷ delayed post-session interviews	Natural History Museum, London, 1 day	38 (28 in ❶, 36 in ❷, 32 in delayed post/-)	16–18, A-level students, 50%

Table 2 (continued)

Study, country	Concepts of interest		Study design	Setting (location, subject, duration)	Sample size (TG/CG)	Participants ((mean) age in years, school level/type, proportion of females)
	Interest experience (✓) incl. SI (◊)	Interest as disposition (✓) incl. II (◊)				
Snetinová et al. (2018), Czech Republic	◊		②	Interactive Physics Laboratory (IPL)/physics demonstrations (DEMOS), Physics, IPL: 120 min/DEMOS: 75 min	1122 (303 IPL, 819 DEMOS /-)	15–19, upper secondary school, 48% (IPL)/50% (DEMOS)
Sripaoraya (2020), Thailand		✓	① ②	Traveling science museum "NSM Science Caravan," Science/mathematics, 1 day	1400 (①: 1400, ②: 1084/-)	12–18, Junior and senior high school, ①:67%/②:65%
Stavrova and Urhahne (2010), Germany	◊		① ②	German Museum in Munich, Physics (energy topic), 2 h	96 (54/42)	14.14 (SD = 0.83), 8th and 9th grade, secondary school, 46%
Streller (2015), Germany	◊	◊	① ② ③ (6–8 weeks later)	Out-of-school laboratory at Helmholtz-Zentrum Dresden-Rossendorf research center, Physics, 1 day	855 (570/285)	16.7 (16.7/16.8), 10th–13th grade, lower and upper secondary level, 40%
Vainikainen et al. (2015), Latvia & Sweden	◊	◊	① ②	Mobile interactive mathematics exhibition "Discover the Art of Math," Math, 45-min free exploring & 45-min workshop	793 (793/-)	12.39 (SD = 0.99), 6th or 7th grade, 48%

Table 2 (continued)

Study, country	Concepts of interest		Study design	Setting (location, subject, duration)	Sample size (TG/CG)	Participants ((mean) age in years, school level/type, proportion of females)
	Interest experience (✓) incl. SI (◇)	Interest as disposition (✓) incl. II (◇)				
Wegner and Schmiedebach (2020), Germany		✓ (general interest)	① ②	Student laboratory "Biology Up Close" at Bielefeld University, Biology, 5 h	248 (121 with intervention/-)	12.32, SD = 0.57 (7th grade)/14.6, SD = 0.71 (9th grade)/17.5, SD = 0.95 (12th grade), high school ("Gymnasium" & "Gesamtschule"), 43%/57%/61%
Wünschmann et al. (2017), Germany	✓		i.a. ②	Reptile and amphibian zoo/school, Biology, lesson at school and lesson at school or out-of-school	65 (18 school, 23 Reptilium/24)	8–10, 3rd grade, 1 primary school, 43%

① ≙ pre-test, ② ≙ post-test, ③ ≙ follow-up test, ❶ ≙ pre-interview, ⓬ ≙ interview during visit, ❷ ≙ post-interview, CG ≙ control group, TG ≙ treatment group

[a]Please note that the article by Hausamann (2012) summarizes several studies. Only the description of a study by Pawek (2009) meets the eligibility criteria for this review and is therefore included

[b]The studies by Itzek-Greulich et al. (2017) and Itzek-Greulich and Vollmer (2017) are partly based on the same dataset

year, country, title, journal name, abstract, article type (theoretical or empirical), study design, setting), which enabled further analysis and categorization. By comparing the summaries, we identified two cross-study categories: (1) influencing factors at the level of the learning environment and (2) influencing factors at the student level. Interest experience and interest as a disposition were considered in each of the two categories. The analysis of the articles was performed, and, where necessary, the entire full text was reread to identify the specific contribution of the article to the categories. This resulted in the cross-literature analysis presented in this review paper.

Results

This systematic literature review includes 30 studies from the last 15 years that contain research on interest in out-of-school learning environments. There is a clear trend of increasing publication numbers, from single studies in 2007 to 2014 to up to six published studies in 2020. The studies are from 11 different countries and relate to nine different STEM subjects. A substantial range of adolescent development is covered, with an age span between 8 and 19 years. Table 2 provides an overview of the study parameters. Of the included studies, 27 dealt with aspects of interest experience, and 16 studies focused on areas of interest as a disposition. The interest theories used were not always mentioned by name. Nine studies referred directly to the POI, nine to the SDT, four to the EVT, and seven to the 4PM. A total of 30% of the studies referred to multiple theories, with the POI, SDT, and 4PM being linked particularly often. In contrast, 23% did not specify the interest theory used. The high number of studies from Germany is noteworthy, which can probably be explained by the special tradition in this country, as an association for the coordination and promotion of certain out-of-school learning environments has existed in Germany for many years (LernortLabor, 2022a). Furthermore, four studies from one author (Salmi) are included, but they focus on different learning settings. For these reasons, we saw no need to exclude these studies despite regional or personnel clustering.

In terms of the factors influencing interest that have been investigated to date, a distinction is made between factors influencing interest at the level of the learning environment (i.e., methodical arrangement, learning location, preparation, and post-enhancement, see Table 3) and factors influencing interest at the student level (i.e., gender, age, education, students' perceptions, and their emotions, see Table 4). This list of factors is consistent with the structure of this section.

Setting-Related Factors That Influence Interest

Methodical Arrangement

This section presents the results regarding the relation between student interest and the factor of methodical staging in learning environments, such as active participation and hands-on work, as well as the quality and form of instruction.

Table 3 Main findings of included studies at the level of the learning environment

Study, country	Main findings		
	Methodical arrangement	Location	Pre-/post-enhancement
Affeldt et al. (2018), Germany	- Laboratory instructions using comics promote SI more than traditional instructions (12/22 interviews)		
Affeldt et al. (2015), Germany	- Experimental instructions in creative forms (e.g., comic books, internet forums) generate SI (over 90% at least partially agree)		
Beranek-Knauer et al. (2020), Austria	- Significant difference for SI comparing difference values from ① to ② for 2 framing alternatives (DDF: discourse-directed framing/IDF: instructor-directed framing) (Mann–Whitney-*U* test, $p=0.04$, mean value for difference ①→② in DDF: 0.12 ± 0.06/in IDF: 0.4 ± 0.06)		
Budke et al. (2019), Germany		- ①/②/③: no significant differences in subject interest between mobile (at school) & stationary (at university) lab - ①/②/③: object interest significantly higher ($p<0.05$) for the school group (school: M(①) = 4.27, M(②) = 4.09, M(③) = 4.07; university: M(①) = 3.96, M(②) = 3.66, M(③) = 3.66), analysis of covariance; higher object interest of school group not due to intervention, but to higher general interest at ① - ①/②/③: current interest greater for students in mobile lab ($p<0.01$), main effect for time factor ($p<0.01$), but with no significant interaction - ②: in both experimental groups significant increase in current interest, larger effect in the mobile lab group, significant increase in current interest in mobile lab group partly due to location ($p<0.05$) - ③: no significant differences from baseline in scale scores in both groups	
Dohn (2011), Denmark	- Hand-on activities source of SI (16/16 interviews & informal conversations)		
Dohn (2013), Denmark	- Positive effect of hands-on activities on SI (21/21 interviews)		

Table 3 (continued)

Study, country	Main findings		
	Methodical arrangement	Location	Pre-/post-enhancement
Glowinski and Bayrhuber (2011), Germany	- Students with low II: quality of instruction predicts SI in experiments (path coefficient: 0.25**)/SI in authentic learning environments (path coefficient: 0.28*) - Students with high II: no significant relationship quality of instruction ↔ SI in experiments/authentic learning environments		- Degrees of pre-visit instruction → significant differences for SI in experiments/research & application contexts/authentic learning environments (Mann–Whitney U test, $p<0.001$) due to mediator effects - Significant indirect effect of level of pre-visit instruction on interest in experiments via competence feeling ($z=4.13$***) - Significant effect of pre-visit instruction on SI in authentic learning environments for students with high II (0.22*) but not for students with low II
Gutual (2019), USA		- No significant differences ($p>0.3$) in ①-② shifts between formal/informal settings for factors of interest development (persevere, content, value, questioning, knowledge, self-efficacy)	
Itzek-Greulich et al. (2017), Germany		- Students divided in 3 TGs with different learning locations: school only (SO), student research center & school (RC&S), student research center only (RCO) & CG - TGs: significantly ($p<0.01$) higher SI than CG (M(SO) = 2.70, SD = 0.65; M(RC&S) = 2.70, SD = 0.65; M(RCO) = 2.79, SD = 0.73; M(CG) = 2.38, SD = 0.68), no significant differences among TGs - Dispositional interest: no significant differences within/between groups due to learning location from ① to ② to ③	

Table 3 (continued)

Study, country	Main findings		
	Methodical arrangement	Location	Pre-/post-enhancement
Itzek-Greulich and Vollmer (2017), Germany	- Higher SI during practical part ($p < 0.001$) than during theoretical part of intervention	- Students divided in 3 TGs with different learning locations: school only (SO), student research center & school (RC&S), student research center only (RCO) & CG - Higher SI in theoretical & practical part of intervention in SO ($p < 0.001$), RC&S ($p < 0.01$) & RCO ($p < 0.001$) groups compared to CG, no significant differences among TGs	
Lelliott (2007), South Africa	- Positive effect of hands-on activities on SI		
Röllke et al. (2020), Germany		- Workshop at university/at school: no significant differences in SI & flow experience	
Salmi et al. (2017a), Finland	- Participation in demonstration event during visit has small negative indirect effect on interest in learning biology at science center ($p < 0.01$) via situation motivation		
Seakins (2015), UK	- Interest development may be supported by hands-on engagement		
Snetinová et al. (2018), Czech Republic	- Laboratory & demonstration experiments rated with high average score in "interest/enjoyment" (M(laboratory) = 5.54, SD = 1.52/M(demonstration) = 5.67, SD = 1.17; mean of the used seven-valued Likert scale is 4.0), no significant differences between both scores		
Stavrova and Urhahne (2010), Germany	- Comparison of 2 guided tours (TG: more active participation, group work, larger variety of activities/CG), higher SI in TG (TG: $M = 2.55$, SD = 1.10, CG: $M = 2.15$, SD = 0.75, $t = 2.10$*)		

Table 3 (continued)

Study, country	Main findings		
	Methodical arrangement	Location	Pre-/post-enhancement
Streller (2015), Germany			- ②: students who performed online portal to prepare/post-enhance visit (=TG) scored significantly higher in components of SI than students without the online portal (=CG) (feeling-related component: $r=0.37$***; intrinsic component: $r=0.18$***; value-related component: $r=0.15$**) - ③: no significant differences in SI values/II in science & experimentation due to online portal - ①: significant differences in II in science & experimentation due to online portal with TG scoring higher (interest in science: $r=0.15$***; interest in experimentation: $r=0.11$**) - ①/②/③: TG scored significantly higher for II component "interest in a career in physics" - no significant changes in components of II (interest in science; interest in experimentation; interest in career in physics) over time in TG/CG, no significant differences in development between groups.
Wünschmann et al. (2017), Germany		-②: no significant differences school-based treatment ↔ out-of-school setting regarding "interest/enjoyment"	

① ≙ pre-test, ② ≙ post-test, ③ ≙ follow-up test, CG ≙ control group, TG ≙ treatment group, II ≙ individual interest

*$p<0.05$, **$p\leq 0.01$, ***$p<0.001$

Table 4 Main findings of included studies at the student level

Study, country	Main findings		
	Gender	Age & educational level (knowledge, school grade, cognitive ability, achievement group)	Students' perceptions & emotions
Bätz et al. (2010), Germany	- ♀ higher scores in interest/enjoyment ($d=0.54^{**}$) & flow experience (station 1: $d=0.51^{**}$; station 2: $d=0.44^{**}$) than ♂		
Beranek-Knauer et al. (2020), Austria		- ①→②: mean values for SI significantly increase ($p<0.05$); older students (17–18 years) show more distinct increase compared to younger students (15–16 years) (authors do not indicate whether it is significant)	
Budke et al. (2019), Germany	- No gender difference in general interest, no significant positive change in subject interest for ♀/♂, no gender difference in current interest for the mobile lab group - After attending stationary lab, only ♀ report significantly higher current interest compared to ①		- ①: correlation (*p*-value not specified) current interest with - Self-concept ($r=0.590$) - Enjoyment ($r=0.745$) - Frustration ($r=-0.669$) - Boredom ($r=-0.627$)
Dohn (2011), Denmark		- SI stimulated by knowledge acquisition (8/16 students)	- Social involvement source of SI (15/16 interviews & informal conversations) - Surprise source of SI (12/16 interviews & informal conversations) - Novelty source of SI (15/16 interviews & informal conversations)

Table 4 (continued)

Study, country	Main findings		
	Gender	Age & educational level (knowledge, school grade, cognitive ability, achievement group)	Students' perceptions & emotions
Dohn (2013), Denmark		- SI stimulated by knowledge acquisition (6/21 students)	- Social involvement source of SI (19/21 interviews) - Surprise source of SI (17/21 interviews) - Novelty source of SI (16/21 interviews & informal conversations)
Fröhlich et al. (2013), Germany		- Significant relationship interest ↔ knowledge (Pc: 0.25***)	
Glowinski and Bayrhuber (2011), Germany	- No significant interrelationship gender ↔ SI	- No significant interrelationship grade in biology ↔ SI	- Correlation SI in research & application contexts/authentic learning environment/experiments with - Competence (Sc: 0.21**/0.11/0.39***) - Social relatedness (Sc: 0.39***/0.30**/0.33*** - Autonomy (Sc: 0.20*/0.09/0.20*)
Gutual (2019), USA	- No significant gender difference in shifts in interest after participation - Interest factor "knowledge" lost significance between ① and ② in comparison between ♀/♂ (p(①) = 0.002, p(②) = 0.139), → intervention may increase ♀ beliefs about interest factor "knowledge"		

Table 4 (continued)

Study, country	Main findings		
	Gender	Age & educational level (knowledge, school grade, cognitive ability, achievement group)	Students' perceptions & emotions
Itzek-Greulich et al. (2017), Germany		- No significant correlation SI ↔ science grade	- Correlation SI with - Situational competence (Pc: 0.54***) - Joy (Pc: 0.79***) - Anger (Pc: -0.55***) - Boredom (Pc: -0.66***) -①/②/③: correlation dispositional interest with - Achievement (Pc: 0.17***/0.18***/0.14***) - Attainment value (Pc: 0.72***/0.75***/0.73***) - Competence beliefs (Pc: 0.61***/0.61***/0.56***) - Intrinsic value (Pc: 0.78***/0.78***/0.76***) - Utility value (Pc: 0.63***/0.64***/0.68***) - Cost (Pc: – 0.28***/ – 0.27***/ – 0.25 ***)

Table 4 (continued)

Study, country	Main findings		
	Gender	Age & educational level (knowledge, school grade, cognitive ability, achievement group)	Students' perceptions & emotions
Itzek-Greulich and Vollmer (2017), Germany	- No significant gender differences during theoretical part - SI correlates with gender ($\beta = -0.100^{**}$) during practical part, ♀ more interest	- No significant correlation SI ↔ experimental knowledge during theoretical/practical parts of intervention - SI negatively related to science grade ($\beta = -0.074^{*}$) during theoretical part of intervention (students with better grades report less SI) - No significant correlation SI ↔ science grade during practical part of intervention - Positive correlation SI ↔ cognitive ability during theoretical ($\beta = 0.111^{**}$)/practical ($\beta = 0.079^{*}$) parts of intervention	- Correlation SI theoretical/practical part with - Intrinsic motivation ($\beta = 0.270^{***}/0.314^{***}$) - Situational competence (Pc: $0.466^{***}/0.482^{***}$) - Joy (Pc: $0.760^{***}/0.746^{***}$) - Anger (Pc: $-0.444^{***}/-0.488^{***}$) - boredom (Pc: $-0.600^{***}/-0.616^{***}$)
Lelliott (2007), South Africa		- Interest not necessarily dependent on educational level: student with low prior knowledge entered/won national competition after intervention	
Marth-Busch and Bogner (2020), Germany	- ①, ②, ③ (after 6 weeks, 12 weeks & 1 year): no significant gender differences in interest in technology	- Correlation interest in technology ↔ pre-knowledge (Pc: ① 0.576^{***}, ② 0.674^{***}, ③ 0.697^{***}, after 12 weeks: 0.763^{***})	

Table 4 (continued)

Study, country	Main findings		
	Gender	Age & educational level (knowledge, school grade, cognitive ability, achievement group)	Students' perceptions & emotions
Ozogul et al. (2019), USA	- Main effect for gender (partial $\eta^2=0.05^{***}$), with ♂ reporting stronger interest in engineering (M(♂) = 3.66, SD = 0.89; M(♀) = 3.28, SD = 0.87), stronger interest for ♂ in all age groups, gender differences strongest in older age groups	- ①: main effect for age (2×3 ANOVA, partial $\eta^2=0.02^{***}$); older students (13/14 years, $M=3.24$, SD = 0.90) less interested than middle (11/12 years, $M=3.48$, SD = 0.90) & younger (9/10 years, $M=3.55$, SD = 0.89) students - ① ↔ ②: interaction interest ↔ age (partial $\eta^2=0.002^{*}$) & significant increase in interest in all age groups, strongest change in the oldest age group	- ②: correlation interest according to expectancy–value theory with - Self-efficacy (Pc: 0.72**) - Utility (Pc: 0.30**) - Negative stereotypes (Pc: −0.28**) - ① & ③: very similar values to ②
Röllke et al. (2020), Germany	- No significant gender differences for triggered SI, FC of maintained SI, flow experience - ♀ higher scores for VC of maintained SI (M(♀) = 3.37, SD = 0.91, M(♂) = 3.15, SD = 0.83, $\eta^2=0.02^{*}$) - ♂ higher scores for II (M(♀) = 3.62, SD = 0.91, M(♂) = 3.89, SD = 0.82, $\eta^2=0.02^{**}$)	- The better the biology grade, the greater the II, (M(1st_tertile) = 4.07, SD = 0.79, M(2nd_tertile) = 3.80, SD = 0.87, M(3rd_tertile) = 3.46, SD = 0.87, $\eta^2=0.08^{***}$) - The better the biology grade, the higher the values for VC of maintained SI (M(1st_tertile) = 3.51, SD = 0.73, M(2nd_tertile) = 3.27, SD = 0.76, M(3rd_tertile) = 3.14, SD = 1.03, $\eta^2=0.03^{*}$) - No significant relationship biology grade ↔ triggered SI/FC of maintained SI/flow experience	

Table 4 (continued)

Study, country	Main findings		
	Gender	Age & educational level (knowledge, school grade, cognitive ability, achievement group)	Students' perceptions & emotions
Salmi and Thuneberg (2019), Finland	- No significant direct gender effects in interest in school learning/science center learning context	- No significant correlation interest in learning science in science center ↔ knowledge/cognitive reasoning - Correlation interest in learning science at school ↔ knowledge/cognitive reasoning (pre-knowledge: 0.304**, post-knowledge: 0.239**, cognitive reasoning: 0.162*)	- Positive effect of situation motivation ($\beta = 0.56$***)/autonomy experience ($\beta = 0.15$**) on interest in learning science in science center
Salmi et al. (2017a), Finland	- ♀ higher scores in interest in learning biology at science center (general linear model univariate tests, sig. gender < 0.01, partial $\eta^2 = 0.02$) - ♀/♂ equal scores in interest in learning biology at school	- Significant differences in interest in learning biology at school between lowest-achieving (bottom quartile of pupils in each class) & highest-achieving (top quartile of pupils in each class) groups (GLM univariate tests, partial $\eta^2 = 0.02$*), higher scores in highest-achieving group - No significant differences in interest in learning biology at the science center between achievement groups	- Positive effect of situation motivation ($\beta = 0.63$***)/autonomy experience ($\beta = 0.01$*) on interest in learning biology in science center
Salmi et al. (2017b), Finland	- Interest in learning science in the science center learning context indirectly explained by gender, ♂ indirectly more interest ($\beta = -0.08$**)	- No significant relationship achievement ↔ interest in learning biology at school/science center	- Positive effect of situation motivation ($\beta = 0.84$***)/autonomy experience ($\beta = 0.12$** (indirect)) on interest in learning science in science center

Table 4 (continued)

Study, country	Main findings		
	Gender	Age & educational level (knowledge, school grade, cognitive ability, achievement group)	Students' perceptions & emotions
Salmi et al. (2020), Finland		- Correlation interest in learning science in school context ↔ knowledge (Pc: ① 0.26***, ② 0.23***) - Correlation interest in learning science in science center ↔ knowledge (Pc: ① 0.16**, ③ 0.15*) - Positive effect of cognitive reasoning (β = 0.16**) on interest in learning science in science center	- Positive effect of situational motivation (β = 0.32***) on interest in learning science in science center
Seakins (2015), UK		- Interest development may be supported by knowledge acquisition	- Interest development may be supported by - Social involvement, i.e., meeting scientists - Surprise - Novelty - Authenticity
Snetinová et al. (2018), Czech Republic	- No significant gender differences in "interest/enjoyment"	- Better grades increase students' ratings in "interest/enjoyment" (grades from 1 [best assessment] to 5 [worst], correlation between grade/average scores for visitors: 1/5.65; 2/5.48; 3/5.44; 4/5.12, Pc: – 0.95)	- Correlation (p-value not specified) interest/enjoyment as component of intrinsic motivation in demonstration/laboratory experiments with - Perceived competence (Pc: – 0.53) - Effort/importance (Pc: 0.59/0.67) - Value/usefulness (Pc: 0.70/0.72) - Felt pressure/tension (Pc: – 0.03/ – 0.24)

Table 4 (continued)

Study, country	Main findings		
	Gender	Age & educational level (knowledge, school grade, cognitive ability, achievement group)	Students' perceptions & emotions
Sripaoraya (2020), Thailand	- ① & ②: no significant gender differences in interest in science learning	- Juniors (grade 7–9) lower interest in science than seniors (grade 10–12) (①: $t = 2.97^{**}$, ②: $t = 2.61^{**}$)	
Stavrova and Urhahne (2010), Germany	- Correlation gender ↔ SI (Pc: – 0.24*), ♀ more interested	- No significant correlation age ↔ SI - ① & ②: no significant correlation SI ↔ knowledge	- Correlation SI with - Intrinsic motivation (Pc: 0.74***) - Perceived competence (Pc: 0.32**) - Satisfaction (Pc: 0.73***) - Anger (Pc: – 0.49***) - Boredom (Pc: – 0.59***)

Table 4 (continued)

Study, country	Main findings		
	Gender	Age & educational level (knowledge, school grade, cognitive ability, achievement group)	Students' perceptions & emotions
Streller (2015), Germany	- ②: no gender differences in FC/VC, no interaction development of interest over time ↔ gender in CG/TG for IC/FC/VC - ② & ③: ♂ higher score for IC than ♀ (②: CG: $r=0.22$***, TG: $r=0.18$***; ③: CG: $r=0.21$*, TG: $r=0.22$**) - ③: ♂ in TG higher score for FC/VC than ♀ (FC: $r=0.16$*; VC: $r=0.14$*) - ♂ higher score for components of II than ♀: a) Interest in experimentation: ♂ in TG higher score (①: $r=0.20$***; ②: $r=0.23$***), no differences for CG (①: n.s.; ②: n.s.) b) Interest in science: ♂ in TG/CG higher score (TG: ①: $r=0.32$***, ③: $r=0.33$***; CG: ①: $r=0.23$***, ③: $r=0.17$*) c) Interest in physics career: ♀ lower score (CG: ①: $r=0.33$***, ②: $r=0.33$***, ③: $r=0.26$**; TG: ①: $r=0.37$***, ②: $r=0.32$***, ③: $r=0.31$***)		

Table 4 (continued)

Study, country	Main findings		
	Gender	Age & educational level (knowledge, school grade, cognitive ability, achievement group)	Students' perceptions & emotions
Vainikainen et al. (2015), Latvia & Sweden	- No significant gender differences in a) General interest in learning mathematics in school (indicator of II) b) Experience of learning mathematics during visits (indicator of SI) c) Relation of individual to SI	- No correlation II/SI ↔ pre-knowledge test scores - ②: positive effect of SI on mathematical knowledge (β(♀) = 0.20***, β(♂) = 0.19***) - Positive effect of cognitive ability on II: general cognitive competence test predicts II in school mathematics (β(♀) = 0.14**/β(♂) = 0.13**)	
Wegner and Schmiedebach (2020), Germany	- ①: interaction grade ↔ gender (partial $\eta^2 = 0.003$*) → changes from 7 to 9th to 12th grade independent from gender - ♂ lower interest in biology in 7th & 9th grade than ♀, ♂ higher interest in biology in 12th grade than ♀	- ①: age effect in interest in biology (Tukey post hoc analyses), mean level of interest in biology lower in 9th grade than in 7th grade (0.52, 95%CI [0.14, 0.90] with $p = 0.005$) but higher in 12th grade than in 9th grade (−0.60, 95%CI [−0.93, −0.27] with $p < 0.001$) - ① → ②: no statistically significant interaction between time and group for 7th & 9th grade for interest in biology	
Wünschmann et al. (2017), Germany	- No significant gender effects on "interest/enjoyment" after visit	- ①/②/③: no correlation interest ↔ shallow knowledge retrieval/cognitively activating knowledge	- Correlation interest/enjoyment as component of intrinsic motivation with - Perceived competence (Pc: 0.698***) - Choice (Pc: 0.572***) - Pressure/tension (Pc: 0.123, n.s.)

♀ ≙ female, ♂ ≙ male, ① ≙ pre-test, ② ≙ post-test, ③≙follow-up test, CG ≙ control group, TG ≙ treatment group, IC ≙ intrinsic component of SI, FC ≙ feeling-related component of SI, VC ≙ value-related component of SI, II ≙ individual interest; *Pc*, Pearson correlation; *Sc*, Spearman correlation; *d*, Cohen's *d*

*$p < 0.05$, **$p \leq 0.01$, ***$p < 0.001$, *n.s.*, not significant

Active participation and hands-on activities are key features of many out-of-school learning environments. Active participation promotes SI as well as, or better than, more passive forms of learning (Itzek-Greulich & Vollmer, 2017; Salmi et al., 2017a; Snetinová et al., 2018; Stavrova & Urhahne, 2010). The positive effect of hands-on activities on SI is also supported by several studies (Dohn, 2011, 2013; Lelliott, 2007; Seakins, 2015).

In terms of the form of instruction, Beranek-Knauer et al. (2020) compared two framing types for their course: discourse-directed framing (DDF) and instructor-directed framing (IDF). In comparing the difference values for SI from pre-test to post-test for the two framing types, a significant difference was found, but not between post-test and follow-up.

Regarding the effects of the quality and form of instruction on interest, an interrelationship between the quality of instruction and SI has been reported, at least for some students (Glowinski & Bayrhuber, 2011). Creative forms of instruction, such as comics, may also promote SI (Affeldt et al., 2015, 2018).

All in all, active participation, hands-on work, and creative, high-quality instruction can promote interest in out-of-school learning environments.

Learning Location

Extracurricular learning opportunities exist in different forms, such as stationary laboratories or exhibitions, mobile ones, or similar events in the classroom. Based on the learning location, there were no significant differences for SI (Itzek-Greulich & Vollmer, 2017; Itzek-Greulich et al., 2017; Röllke et al., 2020), interest/enjoyment as a component of intrinsic motivation (Wünschmann et al., 2017), or flow experience (Röllke et al., 2020). Only one study (Budke et al., 2019) found a short-term difference in current interest. In the mobile lab group, current interest increased more in the short term than in the stationary group, in part due to location. However, this effect did not persist. In addition, there were no significant differences in shifts of interest during the intervention (Gutual, 2019) or in dispositional interest (Itzek-Greulich et al., 2017) due to learning location. Furthermore, no difference in subject or object interest was reported between a mobile and stationary student laboratory as a result of the intervention (Budke et al., 2019). However, some studies have indicated the importance of authenticity in the learning environment (Glowinski & Bayrhuber, 2011; Seakins, 2015).

In summary, the learning location itself is not a decisive factor in the promotion of interest experience or interest development.

Preparation and Post-enhancement

The degree of pre-visit instruction influences SI during the visit, especially for students with high individual interest (Glowinski & Bayrhuber, 2011). Preparation with an online portal also led to significantly higher SI, but no lasting effects of preparation or post-enhancement with the online portal on situational or individual interest were measurable (Streller, 2015).

Student-Related Factors Influencing Interest

Gender

The results on the relationship between interest experience and gender are particularly heterogeneous, even within individual studies. The details are presented below according to the individual components of interest.

For the components of SI, some study results suggested that there were no gender differences (Glowinski & Bayrhuber, 2011; Itzek-Greulich & Vollmer, 2017; Röllke et al., 2020; in post-test: Streller, 2015; Vainikainen et al., 2015), while others suggested greater SI through participation in learning environments among girls (Itzek-Greulich & Vollmer, 2017; Röllke et al., 2020; Stavrova & Urhahne, 2010) or among boys (follow-up test: Streller, 2015).

Data on interest in the science center learning context (as an indicator of the interest experience) suggest either no gender differences for a science exhibition with a focus on physics, chemistry, and biology (Salmi & Thuneberg, 2019) or higher scores for girls in a biology context (Salmi et al., 2017a) and for boys at a science exhibition with a focus on physics (Salmi et al., 2017b).

In terms of interest development, there do not appear to be substantial gender differences in out-of-school learning environments (Budke et al., 2019; Gutual, 2019; Streller, 2015).

For individual interests, most studies found no gender differences. Similar to Salmi et al. (2017a) and Salmi and Thuneberg (2019), Vainikainen et al. (2015) found no statistically significant gender differences in general interest in learning (mathematics) in school (as an indicator of individual interest), as did Budke et al. (2019) for general interest. Marth-Busch and Bogner (2020) found no significant gender differences in interest in technology, as did Sripaoraya (2020) for interest in science learning, and Wegner and Schmiedebach (2020) concluded that interest in biology changes with increasing grade level independent of gender. In contrast to this, in other studies, male students scored higher in individual interest (Röllke et al., 2020) and in the individual interest components of "interest in experimentation," "interest in science," and "interest in a career in physics" (Streller, 2015).

Overall, for the SI, studies of different learning environments come to different conclusions regarding the influence of gender. For interest development and individual interest, there are predominantly no gender-specific differences.

Age

The effect of age on interest in extracurricular learning sites was analyzed in only a few studies. Stavrova and Urhahne (2010) could not find a significant correlation between age and SI. Ozogul et al. (2019) found a main effect for age before a workshop, with older students reporting less interest than middle and younger students. Comparing the results of a pre- to post-survey, there was a significant interaction between interest and age and a significant increase in interest in all age groups, with the strongest change in the oldest age group, which was originally less interested. Beranek-Knauer et al. (2020) also found a significant change in SI between a pre-test and post-test, with older students showing a more distinct increase than younger students, although the authors did not specify whether this age effect was significant. Wegner and Schmiedebach (2020) found a decrease in interest in biology from grades 7–9 before their intervention and an increase in grade 12. Comparing pre- and post-tests, there was no statistically significant interaction between time and group for seventh and ninth grade students for interest in biology. Similar to Wegner and Schmiedebach (2020), Sripaoraya (2020) found that interest in science was lower in younger students in grades 7–9 than among students in grades 10 through 12.

All in all, the students' interest before the intervention differs according to their age, while age-related differences in interest through the intervention can only be detected in some studies.

Education

This section reports the findings on the relationship between students' interest and their educational level, as represented by their (prior) knowledge, grade in the learning site-related subject, or cognitive ability.

A correlation between interest in technology and prior knowledge is indicated in the findings of Marth-Busch and Bogner (2020). Also, a significant correlation between pre- and post-knowledge and interest in learning science in school was highlighted (Salmi & Thuneberg, 2019; Salmi et al., 2020). At the same time, Vainikainen et al. (2015) found that individual interest was uncorrelated with pre- and post-knowledge test scores. A single case, as part of a study by Lelliott (2007), showed that even students with little prior knowledge could be encouraged in their interest by a visit to an out-of-school learning environment. For interest experience, there seems to be no prediction by experimental knowledge (Itzek-Greulich & Vollmer, 2017) and no correlation with prior knowledge (Salmi & Thuneberg, 2019; Stavrova & Urhahne, 2010; Vainikainen et al., 2015; Wünschmann et al., 2017). Only Salmi et al. (2020) found a significant correlation between interest in learning science in a science center and knowledge. However, knowledge acquisition seems to stimulate SI (Dohn, 2011, 2013; Seakins, 2015). Even though some studies could not find a significant correlation between SI and knowledge in the posttest (Salmi & Thuneberg, 2019; Stavrova & Urhahne, 2010; Wünschmann et al., 2017), Fröhlich et al. (2013) illustrated a significant correlation, and Vainikainen et al. (2015) even found SI to predict mathematical knowledge in the post-test.

A relationship between SI and school grade has not been found in many studies (Glowinski & Bayrhuber, 2011; Itzek-Greulich et al., 2017; for the practical part of the intervention, see Itzek-Greulich & Vollmer, 2017; for triggered SI, the feeling-related component of maintained SI, and flow experience, see Röllke et al., 2020). Other studies found a positive relationship between interest experience and school grade (Snetinová et al., 2018, but authors do not indicate whether the results are significant; for the individual interest and value component of maintained SI, see Röllke et al., 2020), and others reported a negative relationship (for the theoretical part of the intervention, see Itzek-Greulich & Vollmer, 2017).

Regarding the relationship between interest and cognitive ability, some studies stated that cognitive ability predicts SI (Itzek-Greulich & Vollmer, 2017) and individual interest (Vainikainen et al., 2015). In line with this, Salmi and Thuneberg (2019) also described a significant correlation between interest in learning science at school and cognitive reasoning, but in contrast to Salmi et al. (2020), no significant correlation between interest in learning science at the science center and cognitive reasoning was found.

Overall, the data predominantly show no effect of knowledge or grade on interest experience, whereas knowledge acquisition promotes SI. Studies show a positive effect of cognitive ability on SI and individual interest.

Students' Perceptions and Emotions

Numerous studies have examined the relationship between interest and the feelings that occur when visiting an extracurricular learning environment. SI was shown to be positively correlated with intrinsic motivation (Itzek-Greulich & Vollmer, 2017; Stavrova & Urhahne, 2010); moreover, interest in learning science at a science center was promoted by situation motivation (Salmi & Thuneberg, 2019; Salmi et al., 2020, 2017a, 2017b). Furthermore, SI was positively correlated with competence perceived during a visit (Glowinski & Bayrhuber, 2011; Itzek-Greulich & Vollmer, 2017; Itzek-Greulich et al., 2017; Snetinová et al., 2018; Stavrova & Urhahne, 2010; Wünschmann et al., 2017), social relatedness and involvement (Dohn, 2011, 2013; Glowinski & Bayrhuber, 2011; Seakins, 2015), and satisfaction (Stavrova & Urhahne, 2010). Autonomy was also correlated with SI (Glowinski & Bayrhuber, 2011) and predicted interest in learning biology/science in a science center (Salmi & Thuneberg, 2019; Salmi et al., 2017a, 2017b). Moreover, interest in the learning situation was found to be positively correlated with joy or enjoyment (Budke et al., 2019; Itzek-Greulich & Vollmer, 2017; Itzek-Greulich et al., 2017), effort or importance (Snetinová et al., 2018), self-concept (Budke et al., 2019), and value or usefulness (Ozogul et al., 2019; Snetinová et al., 2018). Interest also correlated significantly with choice (Wünschmann et al., 2017) and self-efficacy (Ozogul et al., 2019). Surprise, novelty, and authenticity can also be sources of SI (Dohn, 2011, 2013; Seakins, 2015).

SI was reported to be negatively correlated with anger (Itzek-Greulich & Vollmer, 2017; Itzek-Greulich et al., 2017; Stavrova & Urhahne, 2010), boredom (Budke et al., 2019; Itzek-Greulich & Vollmer, 2017; Itzek-Greulich et al., 2017; Stavrova & Urhahne, 2010), negative stereotypes (Ozogul et al., 2019), and frustration (Budke et al., 2019). Regarding dispositional interest, Itzek-Greulich et al. (2017) demonstrated a significant correlation with achievement, attainment value, competence beliefs, cost, intrinsic value, and utility value.

In sum, the data show a positive correlation of interest experience with positive emotions such as competence, satisfaction, and autonomy and a negative correlation with negative emotions such as anger, boredom, or frustration.

Discussion

In this section, we derive recommendations for out-of-school learning environments from the study results and discuss the weaknesses in the previous research. We conclude by presenting the limitations of our literature review and highlighting where future research should focus.

Implications and Recommendations for Out-of-School Learning Environments

Based on the analysis of the study results, this section summarizes the main recommendations for operators of out-of-school learning environments according to the categories obtained from the results.

Setting-Related Factors That Influence Interest

Based on the studies on methodical arrangements and interest, it can be concluded that active participation is an important interest-promoting factor that should be considered when planning extracurricular learning opportunities. The results emphasize that hands-on activities and high-quality instruction that appeal to students make a difference and seem to be key factors in promoting interest, especially among less interested students. These findings are consistent with broader learning research that recommends learner activation in school settings (Hattie, 2009). However, the role of different instructional framing alternatives for visits in out-of-school learning environments has scarcely been explored and would benefit from further investigation.

The location of the intervention (e.g., if it takes place at a university campus, in a mobile lab/exhibition, or at school) does not have a larger impact on interest, and mobile events turned out to be just as beneficial as stationary ones (Budke et al., 2019; Gutual, 2019; Itzek-Greulich & Vollmer, 2017; Itzek-Greulich et al., 2017; Röllke et al., 2020; Wünschmann et al., 2017). However, an important influence of the learning environment has emerged in the perception of authenticity (Glowinski & Bayrhuber, 2011; Seakins, 2015). The importance of authentic science research in promoting interest has already been highlighted for multi-day events (Habig & Gupta, 2021). This leads to the recommendation to ensure that interventions in out-of-school learning environments are perceived as authentic.

Regarding the preparation and post-enhancement of the settings, there was a positive effect of visit preparation on SI, but the first results indicated that it may not last (Streller, 2015). As school interests generally are promoted through the interaction of classroom and extracurricular activities in science (Kazarenkov, 1994), preparation and post-enhancement could still have a positive effect on specific subconstructs of interest in addition to the short-term increase in SI. Therefore, further investigation of this issue seems reasonable. To ensure the maintenance of learning effects, providers of out-of-school learning environments should consider creating learning material for use in pre- or post-classroom lessons.

Overall, when analyzing setting-related factors, it is noticeable that the use of different theories of interest led to very similar results. In particular, the impact of the location was examined according to all theories, with consistent results. Nevertheless, certain factors have only been studied with a single theoretical focus, such as the role of preparation primarily with the POI (Glowinski & Bayrhuber, 2011; Streller, 2015) and the role of active participation primarily with the SDT (Salmi et al., 2017a; Snetinová et al., 2018).

Student-Related Factors Influencing Interest

The results on the relationship between interest experience and gender are particularly heterogeneous, even within individual studies. However, if one considers the disciplines of the studies and the age of the participants, great similarities with the existing literature on the age- and gender-typical distribution of interests become apparent, which states that with increasing age, male students tend to show more interest in physics than female students, while female students show more interest in biology and chemistry (Baram-Tsabari & Yarden, 2011). This general distribution of interests was also observed for out-of-school learning environments (Itzek-Greulich & Vollmer, 2017; Ozogul et al., 2019; Röllke et al., 2020; Salmi et al., 2017a, 2017b; Streller, 2015).

In contrast, several studies reported findings from out-of-school learning environments that did not fit this distribution of interest, as, for example, female students showed more interest in physics (Stavrova & Urhahne, 2010) or there were no gender differences, even though they are usually present in this age group (Glowinski & Bayrhuber, 2011; Gutual, 2019; Snetinová et al., 2018; Streller, 2015; Vainikainen et al., 2015). This may indicate that out-of-school learning locations can at least temporarily equalize gender differences in the distribution of interests. The reason for this could be that the special forms of access offered by many out-of-school learning environments appeal equally to both genders. Further research is needed here to determine the causes for the potential elimination of gender differences and the possible relationships with setting-related factors like instructional framing. Until this is clarified, it is advisable to focus on gender-sensitive programs when planning learning environments.

The relationship between students' interest and their ages and educational levels (as represented by their [prior] knowledge, grade in the learning site-related subject, or cognitive ability) presumably consists of interdependencies, because older students normally have greater cognitive abilities and (prior) knowledge of a topic, which are also related to the school grade.

Older students showed less interest at the beginning of the interventions (Ozogul et al., 2019; Wegner & Schmiedebach, 2020), which fits with the finding that individual interest becomes increasingly concentrated in certain areas during adolescence, which consequently leads to a decline in individual interest in other topics (Krapp, 2002b). An increase in interest observed in grade 12 was explained by a change in the composition of the test subjects since only students who are already interested might choose a specific subject (Wegner & Schmiedebach, 2020).

For interest experience, some studies reported no age differences (Stavrova & Urhahne, 2010), while others found a stronger increase in interest from the pre- to post-survey for older students (Ozogul et al., 2019). The participants' ages ranged between 13 and 16 years in the study by Stavrova and Urhahne (2010) and between 9 and 14 years in the study by Ozogul et al. (2019). Thus, it is conceivable that the smaller age range in Stavrova and Urhahne (2010) is not sufficient to measure an effect like that examined by Ozogul et al. (2019). However, it could also be that out-of-school learning settings are able to appeal to students of all age and thus have the potential to counteract the general age-related decline in interest in science that numerous studies have reported (Osborne et al., 2003; Potvin & Hasni, 2014). Nevertheless, the small amount of data is insufficient to determine the impact of age on interest.

A correlation between interest and prior knowledge has generally been reported for individual interest (Tobias, 1994). For out-of-school learning environments, this was confirmed for interest as a disposition (Marth-Busch & Bogner, 2020; Salmi & Thuneberg, 2019; Salmi et al., 2020), but not for interest experience (Salmi & Thuneberg, 2019; Stavrova & Urhahne, 2010; Vainikainen et al., 2015; Wünschmann et al., 2017), although exceptions are possible (Lelliott, 2007; Vainikainen et al., 2015). Out-of-school learning environments appear to have the potential to stimulate the interest of all visitors, relatively independent of their prior knowledge, with the acquisition of knowledge contributing to greater SI (Dohn, 2011, 2013; Seakins, 2015). High SI can potentially lead to more knowledge (Fröhlich et al., 2013; Vainikainen et al., 2015). Thus, out-of-school learning environments may be particularly beneficial for students with previously limited STEM knowledge.

The heterogeneous results on the correlation between interest and school grade could be due to the correlation only for certain components of interest (e.g., individual interest in Röllke et al., 2020) while most components of SI were uncorrelated with school grade (Glowinski & Bayrhuber, 2011; Itzek-Greulich et al., 2017; for the practical part of the intervention, see Itzek-Greulich & Vollmer, 2017; for triggered SI, the feeling-related component of maintained SI, and flow experience, see Röllke et al., 2020). Similarly, the interest experience does not appear to correlate with belonging to a special achievement group (Salmi et al., 2017a, 2017b).

Furthermore, there does seem to be a correlation between interest and cognitive ability or cognitive reasoning (Itzek-Greulich & Vollmer, 2017; Salmi & Thuneberg, 2019; Vainikainen et al., 2015), so it seems reasonable for out-of-school learning environments to offer learning activities with different levels of difficulty and access modes.

The findings on the relation between interest and students' perceptions and emotions show strong evidence that promoting positive emotions and avoiding the occurrence of negative ones really matter when promoting interest in out-of-school learning environments. Positive emotions in this context are elements of the SDT and EVT, such as autonomy, perceived competence, or social relatedness/involvement, whereas negative emotions are boredom, anger, frustration, and negative stereotypes.

Altogether, the analysis of the use of interest theories to evaluate student-related factors reveals a predominantly consistent picture across underlying theories. Regarding the role of students' perceptions and emotions, as well as the influence of age and gender, the studies come to very similar results regardless of the theories used. With respect to the role of educational level, the number of studies is too small to identify theory-based differences. For example, studies on the impact of prior knowledge often have an SDT focus, while comparable studies with different theories are still rare.

Criticism of Previous Research

We identified several obstacles to study design and comparability in our analysis of the studies. A major obstacle to comparing studies on interest is the different and often missing definitions of the term interest, which was also noted by Fortus (2014) in his overview of the research on the importance of emotional perspectives for teaching and learning science. Many studies focus on SI but do not include the different components, such as triggered/maintained SI or flow. A finer distinction should be made in future studies.

One specific factor that could insert bias into the described studies is gender coding. Gender often seems to be binarily coded (male/female: Röllke et al., 2020; Streller, 2015; boy/girl: Itzek-Greulich & Vollmer, 2017; Salmi et al., 2017a; Wünschmann et al., 2017). The category "other" was rarely used (Gutual, 2019). In the questionnaire studies, gender was self-reported by the participants. However, physical sex is not necessarily as important as mental representation and one's own expectations. Thus, social expectations as associated norms and stereotypes could also have an influence on the study results. Therefore, the elimination of erroneous stereotypes is recommended to counteract the age-related decline in interest among girls (Happe et al., 2021).

Another obstacle we encountered was the inconsistent use of the constructs under study with influence on interest. This is particularly evident in the student-related factors of age and education in the results section of the present study. Several studies have examined the relationship between interest components, age factors, and educational factors, such as (prior) knowledge, cognitive abilities, and school grade/achievement group. This, in turn, resulted in few studies on the individual constructs (e.g., only three studies on cognitive ability/reasoning). The limited data make it difficult to draw firm conclusions in this respect. At the same time, it is probably not possible to clearly separate the evaluated constructs. Cognitive abilities and (prior) knowledge probably increase with age and presumably influence school grade (Mousavi et al., 2018; Salthouse, 1998). Therefore, we see a need to examine more closely the influence of these individual constructs on each other in out-of-school learning settings.

Limitations

Despite an extensive and careful search of five major databases, one cannot be sure of having found all the relevant literature. Nevertheless, this article has compared the results of this search as carefully as possible. It was found that the results vary due to differences in the content and methodology of the studies, such as different settings and subjects, the use of various study designs with qualitative or quantitative survey instruments, and the rare inclusion of control groups. The high number of 135 contributions that were read but still excluded shows how complex this type of study is. Within the quantitative studies, it is not always apparent whether validated and reliable instruments were used (e.g., Affeldt et al., 2015) and the number of items used to evaluate "interest" varied widely (e.g., four items in Itzek-Greulich & Vollmer, 2017, and Fröhlich et al., 2013; 27 items in Streller, 2015). This, together with the varying quality of the selected journals, makes direct comparisons of the studies difficult, and due to the lack of standardization of the studies, a meta-analysis is not indicated. Due to the already rather small number of results, we decided to include all the thematically relevant studies, even those with methodological weaknesses, in order to obtain a broad data basis. Nevertheless, the narrowly formulated search term was used to ensure that the studies were as focused as possible. In addition, four theories of interest were used, each with a different focus. They enrich the holistic coverage of the term "interest" through the affordance of different perspectives. Some of the included studies refer to multiple theories of interest, some are based on one theory, and others report no theory at all. Therefore, the results in the discussion were not ordered by theories, but by the different constructs of interest. Studies with students voluntarily participating in the program could lead to biased results of interest, as students who choose to participate in out-of-school learning environments may already have a greater interest in STEM. Although this was not a focus of our search, the events evaluated are typically required (e.g., school-related field trip) and students did not have a personal choice to participate. Therefore, it can be assumed that the interest of participants is consistent with the normal distribution in the student population.

Thus, this article provides a structured overview of the facilitating and hindering influences on student interest in visiting out-of-school learning environments and can serve as a guide for operators of such facilities in the further development of their programs. The learning settings researched deal predominantly with STEM subjects, but the results may be transferred to other subjects as well.

Future Directions

This work offers numerous avenues for future research. First, a detailed comparison of the theories used in the context of out-of-school learning environments, combined with a further specification of the concept of interest and the comparability of theories of interest, seems necessary for future research. Based on this, future research on out-of-school learning environments should then include as specific and detailed an examination as possible of each clearly defined component of interest. In this way, it will be easier to determine which components are promoted in general and by which influencing factors. Especially in the view of the very different quality standards of previous studies, it would be advantageous to use uniform, precise survey instruments for different learning environments to enable better comparability.

Furthermore, it seems worthwhile to explore the role of age and gender in the potential for promoting interest. Here, it is necessary to further investigate the influence of age on the interest experience in the learning environments with different subject focus, as initial studies show the potential to benefit less-interested, older students in particular. As out-of-school learning environments might be able to eliminate gender differences in interest, it seems necessary to determine the causes and the possible relationships with setting-related factors like instructional framing. Special consideration should be given to gender coding as shown in the section on criticisms of previous research in the discussion section.

One criticism of this article is the insufficient analysis of the relationship of previously studied factors influencing interest in out-of-school learning environments. Age, cognitive abilities, (prior) knowledge, and school grade are presumably related to each other. In order to be able to investigate the influence of these factors on student interest, the relationship of these factors to each other in the context of out-of-school learning environments should first be analyzed in more detail.

Likewise, opportunities for heterogeneous groups of students with different levels of knowledge, the influence of different types of tasks, and the effect of pre- and post-enhancement on the forms of interest should be further explored. Research into other parameters, such as the influence of digitization, also seems promising. Here, special attention should be paid to the multiple components of interest. As studies on SI in station-based learning locations generally do not differentiate between the influences of the framing of learning environments and those of individual learning stations, further research is also needed in this area.

Conclusion

Out-of-school learning environments hold great potential in encouraging STEM interest. Learning activities in these settings are presumably suitable for all school levels, especially for students with little prior knowledge, and they also tend to promote interest in areas that are often relatively low in adolescent engagement depending on their age and gender. In particular, active participation and hands-on activities, as well as good preparation for the visit, seem to have strong beneficial effects on the interest experience, whereas the learning location itself does not seem to play an important role.

Our comparison of the studies shows that, at least for the constructs examined, similar results can be obtained with different theories of interest. Nevertheless, studies on well-defined constructs of interest that are comparable to previous studies and that examine the abovementioned open questions are urgently needed.

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Declarations

Competing Interests The authors declare no competing interests.

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