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Dinosaurs as skeletons or lifelike replicas - effects on interest in extinct animals

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Introduction: Since their discovery Dinosaurs have attracted the interest of scientists and the general public alike, and are therefore an attractive way of introducing students to various aspects of the Earth's history and stimulating their interest. There are different types of dinosaur exhibitions, ranging from original excavation sites to theme parks, all with varying levels of scientific accuracy and authenticity.

Methods: In this study we developed and conducted a guided tour of a dinosaur exhibition in a natural history museum, showing dinosaur fossils or their replicas and a special dinosaur exhibition with lifelike animatronic models in a zoo. We investigated the effect on interest in extinct, prehistoric animals in these dinosaur exhibitions.

Results: The results show that the skeletons in a natural history museum showed a significant increase in interest, while the lifelike animatronics had no effect. An examination of the gender results shows that boys were the main contributors to the increase in interest in extinct animals.

Discussion: The main reason for this difference may be that natural history museums, with their original dinosaur fossils (or detailed replicas, which are legitimate substitutes for original objects), provide a more authentic atmosphere that arouses interest, curiosity and surprise, something that the lifelike dinosaur models could not do. However, these effects were not long-lasting, as demonstrated by follow-up tests.

KEYWORDS

interest, extracurricular learning, museum education, dinosaurs, dinosaur exhibition

1 Introduction

Since their first description in 1824, dinosaurs have captured the interest of scientists and the general public. Especially since the 1960s, with the beginning of the so-called dinosaur revolution, interest in dinosaurs has steadily increased (Currie, 2023; Brusatte, 2018). The peak of the dinosaur boom was reached in the mid-1990s, when the movie Jurassic Park

triggered a long-lasting "dino-mania" that continues to this day (Benton et al., 2011; Salmi et al., 2017). In this context, dinosaur exhibits are of great interest to the public and have become a symbol of natural history museums. Dinosaurs are of interest to the public not only for entertainment, but also from a scientific point of view. Since the first dinosaur exhibitions in the 19th century, they have been an influential tool for the public understanding of science (Salmi et al., 2017). For example, a large-scale survey by Special Eurobarometer 419 (2014) confirms that interest in and knowledge of evolution and dinosaurs is continuously increasing among the European adult population. As an attractive and fascinating topic, dinosaurs offer a fruitful learning opportunity for students. In biology classes, dinosaurs are one possible way to introduce evolutionary biology content to primary and lower secondary school students (Mayr, 2004). Research on conversations between parents and their children shows that children often have a greater depth of knowledge and specific details on various topics than their parents. Children who know a lot about dinosaurs will be keen to share this knowledge with their parents, while parents are more likely to listen and ask questions rather than explain themselves (Palmquist and Crowley, 2007; Tunnicliffe, 2000).

2 Dinosaur exhibitions

Natural history museums and zoological gardens are important extracurricular learning sites, covering a wide range of scientific topics and contributing to students' interest in science (Falk et al., 2007; Schwan et al., 2014; Gibson and Chase, 2002; McMeeking et al., 2016; Mujtaba et al., 2018). To achieve this goal, most natural history museums and zoos offer a variety of educational programs such as guided tours, informational materials, and special educational programs for school groups (DeWitt and Storksdieck, 2008; Tinio et al., 2010). Promoting science education in students can be effectively achieved through school field trips. These trips offer authentic experiences, enabling direct interaction with the objects, fostering positive social interactions, and igniting curiosity and fascination in the subject matter (Falk et al., 1986; Schwan et al., 2014). According to multiple studies (Tinio et al., 2010; Sachatello-Sawyer et al., 2002; Johnson et al., 2009; Bamberger and Tal, 2008; Best, 2012), guided tours are the most prevalent method of education in museums. Visitors highly value the opportunity to interact with a knowledgeable guide, as it allows them to ask questions and respond to their individual needs, which cannot be achieved through written texts, audio guides, or the objects themselves (Tinio et al., 2010). Additionally, student groups place importance on the social aspect of guided tours, in addition to their desire for learning (Bitgood, 2002).

Dinosaur exhibitions can be categorized into three distinct types: theme parks, museums, and excavation sites (Cohen, 2010). At original excavation sites, guests have the chance to witness how dinosaur fossils were embedded in rock formations and observe the on-site fieldwork. However, numerous excavation sites are located in remote areas and are not well-equipped for tourism (Laws and Scott, 2003; Antczak, 2020). Natural history museums serve as the primary venue for the scientific display of dinosaurs, yet they often lack the "authenticity" found at original excavation sites, as many dinosaur skeletons on display are replicas rather than actual fossils. Nevertheless, research indicates that replicas can effectively replace original objects if they are created with high fidelity (Hampp and Schwan, 2014). Since the 1980s, dinosaurs have frequently been showcased in contemporary exhibitions, not only as skeletons but also as "replica models" or animatronic figures that move and roar (Tunnicliffe, 2000). Despite this, many of these modern exhibitions typically prioritize entertainment over paleontological accuracy compared to museums. Today, several specialized commercial companies collaborate with scientific advisory boards to produce these exhibits with a focus on accuracy. They are the least authentic dinosaur exhibitions, according to Cohen (2010).

Dinosaurs are therefore an attractive way to introduce students to various aspects of Earth history (fossilization, extinction, geological eras, evolutionary processes) and to increase their interest in dinosaurs and related topics. Interest is considered particularly important as it has a direct impact on learning success. Out-of-school learning sites such as museums are particularly suitable to increasing interest because they create a special form of practical relevance in school education.

3 Theory of interest

The person-object theory of interest defines this concept as a dynamic relationship between a person and an object of engagement. The object of interest can be a topic, an idea, or an activity (Krapp, 1993; 1998; 2000; 2002). Interest is associated with increased attention and learning ability, and it has been demonstrated to have a positive impact on learning success (Ainley et al., 2002; Hidi, 2006; Hidi and Renninger, 2006; Renninger and Hidi, 2011).

Interest is differentiated between individual interest (II) and situational interest (SI) (Krapp, 1992; Hidi, 2006; Hidi et al., 2004; Silvia, 2006). While SI is a short-term psychological state, generated by the stimulation of a specific learning situation (Krapp, 1992; Hidi, 2006), II is a stable personal tendency to engage with an object of interest, without external triggers. Over time, SI can develop into a durable and stable II through repeated engagement with the object of interest (Ainley, 2017; Hidi and Renninger, 2006; Hidi, 2006; Silvia, 2006). In a real learning situation, however, both the situational characteristics of the learning environment (SI) and the individual characteristics of the person (II) contribute to interest in a learning object. It is not possible to distinguish between situational and individual interest at the subjective level. One experiences the same psychological state (Ainley, 2017; Harackiewicz and Knogler, 2017; Knogler, 2017; Silvia, 2006).

Interest can be divided into three components: An emotional, a value-related, and a cognitive component (Krapp, 2002; Ainley, 2017; Hidi, 2006). The emotional component refers to the positive feelings generated when engaging with the object of interest. The value-related component emphasizes the personal relevance of the object of interest and the cognitive component of interest involves the desire to expand, deepen, and learn more about the object of interest (Krapp, 2002; Krapp and Prenzel, 2011).

4 Research question

In this study, we developed and conducted guided tours in two different exhibitions dealing with dinosaurs: the permanent exhibition at the Senckenberg Natural History Museum, which displays original fossils and replicas of various dinosaurs, and the special exhibition "Superheroes of Prehistory" at the Leipzig Zoo, which features lifelike animatronic models of various dinosaurs. This raises the question of whether different ways of presenting dinosaurs have an effect on interest in extinct prehistoric animals. So far, there are no studies that have measured interest in extinct animals by comparing dinosaur skeletons to life-like replicas.

5 Methods

5.1 Participants and learning sites

The study was conducted in the period from April 2022 to April 2023 for the Senckenberg Natural History Museum (location: Senckenberganlage 25, 60325 Frankfurt am Main, Hesse, Germany) and in September 2021 for the Dinosaur exhibition at the Zoo Leipzig (location: Pfaffendorfer Straße 29, 04105 Leipzig, Saxony, Germany).

The Senckenberg Museum in Frankfurt, Germany is one of the largest natural history museums in Germany with an exhibition area of 6,000 square meters and over 10,000 exhibits in the permanent exhibition (Mosbrugger et al., 2015). The museum is famous for its dinosaurs, most of which are exhibited in the first atrium. These are either original fossils (e.g. *Diplodocus*, *Psittacosaurus*, and *Triceratops* skull) or replicas (casts) of original fossils (e.g. *Tyrannosaurus*, *Iguanodon*, and *Stegosaurus*).

With an area of 26 hectares and 630 animal species, the Zoo Leipzig is one of the largest and most species-rich zoos in Germany and is characterized by its modern and large facilities, such as Pongoland and Gondwanaland (Kulturstiftung Leipzig, 2018). From spring 2020 to fall 2022, 20 life-size and realistic animatronic dinosaur exhibits were on display in a special exhibition curated by Don Lessem, who worked as a consultant for Jurassic Park, and prepared by biology educators. The dinosaur exhibits were spread throughout the zoo area.

Several public schools of the greater Rhine-Main area (Hesse, Germany) and Leipzig (Saxony, Germany) were approached in order to generate a sufficiently large sample. The schools were recruited through email and personal contacts. The period of the study was longer for the Senckenberg Natural History Museum because the schools took longer to respond to our queries and the short time of the exhibition at the Zoo Leipzig was due to the limited duration of the exhibition. Taking part in the surveys was completely optional and ensured anonymity. Prior to the study, parents of the students were notified about the survey's subject matter and were required to give their written consent. Students faced no negative consequences for choosing not to participate in the survey.

Participants in the guided tours at the Senckenberg Natural History Museum were students from nine different classes from four schools in the greater Rhine-Main area (Hesse, Germany). A total of 164 students took part in the guided tours and the surveys in the museum. The average age was 11.26 years (age range 10-15 years). Of the participating students, 81 (49.4%) were male, 81 (49.4%) were female, and 2 (1.2%) did not indicate gender.

Participants in the guided tours at the Zoo Leipzig were students from six different classes from two schools at Leipzig Zoo (Saxony, Germany). A total of 114 students took part in the guided tours and the surveys at the zoo. The average age was 11.33 years (age range 10-13 years). Of the participating students 58 (50.9%) were male, 53 (46.5%) were female, and 3 (2.6%) did not indicate gender.

5.2 Procedure

After the school had given positive feedback on their participation in the tour, the guide led them through the relevant out-of-school learning sites. To maintain a high standard of consistency and quality for both learning sites, the tours were all developed and conducted by the same guide, who happens to be the first author of this study. The guide has extensive knowledge and skills acquired through years of experience in guiding at the Senckenberg Natural History Museum and other extracurricular learning sites. Even though there were some differences in the selection of the dinosaur taxa on display - due to the available exhibits - the same common thread and thematic content and questions were developed at both learning sites. Both sites focused on the size, anatomy, diet and lifestyle of dinosaurs, as well as their chronological classification in the Mesozoic Era, their extinction and the topic of fossilization in general. In the Senckenberg Natural History Museum, following species were shown: *Diplodocus* (original), *Iguanodon* (replica), *Tyrannosaurus* (replica), *Triceratops* (original and replicas), *Oviraptor* (replica), *Maiasaura* (painting) and Eggs of Dinosaurs (original). The tours at the Zoo Leipzig had *Triceratops*, *Giganotosaurus*, *Ornithomimus*, *Maiasaura* (including eggs), *Troodon*, *Spinosaurus*, *Tyrannosaurus* and *Argentinosaurus* on its list. Both tours focused on the dinosaurs that both had in common (*Tyrannosaurus*, *Triceratops*, *Maiasaura*) or were quite similar in the thematic focus like the sauropods *Diplodocus* and *Argentinosaurus* or the small Theropods *Oviraptor* and *Troodon*. The other dinosaurs (*Iguanodon*, *Giganotosaurus*, *Ornithomimus*, *Spinosaurus*) were treated in passing, because they were near the main exhibits (*Giganotosaurus*, *Ornithomimus*) or, for example, to explain the difference between an original fossil or replica (comparing the *Iguanodon* skeleton to the *Diplodocus* skeleton) or the size differences between the biggest theropods (*Giganotosaurus* and *Spinosaurus* with *Tyrannosaurus*). Every class received the same guided tour, which lasted about one hour.

5.3 Measurement

To examine the effects of this educational format on interest in extinct animals, students were surveyed in writing in a pre/post/

follow-up design. The pretest (T1) took place approximately one week before the tour, the posttest (T2) immediately after the tour, and the follow-up test (T3) approximately three weeks after the tour. The same questions were asked on all three questionnaires. Paper and pencil questionnaires were used. The questionnaire took a maximum of 15 minutes to complete.

To assess the level of interest in extinct animals, a questionnaire was utilized. This questionnaire was adapted from the Nature Interest Scale (NIS) developed by Kleespies et al. (2021). The NIS questionnaire has been proven to possess adequate model fit, validity, and reliability. It is grounded in the theoretical concepts of the interest construct, as described by Krapp (2002) and Prenzel et al. (1986), and encompasses three key components of interest: emotional (EMO), cognitive (COG), and value-related (VAL). To ensure that the questionnaire remained suitable in length for the surveyed age group, two items were allocated to each component of interest (as shown in Table 1). The only modification made to the original NIS scale was the substitution of the term 'nature' with 'extinct animals'. This adapted questionnaire has also been used in other contexts (Kubi et al., 2024). Students were given the opportunity to rate the extent to which each item reflected their own traits, using a five-point Likert scale ranging from 'not at all true' (1) to 'very true' (5).

5.4 Analysis

The statistical analyses were conducted using IBM SPSS 28 (1 Orchard Road, Armonk, NY, United States). To verify the normal distribution of the data for the three test time points (T1, T2, T3), the Kolmogorov-Smirnov test was applied (Field, 2018). However, the results of the Kolmogorov-Smirnov test indicated a deviation from normal distribution. Consequently, the Friedman test was utilized to determine if there were any changes in interest across the three test time points (Field, 2018). In the event of significant results, the Dunn-Bonferroni test was employed as a *post-hoc* analysis (Field, 2018). To calculate the effect size, the formula $r = \frac{z}{\sqrt{N}}$, as described by Fritz et al. (2012), was used.

TABLE 1 Items on interest in extinct animals.

	Items extinct animals
EMO1	I find it exciting to deal with extinct animals.
EMO2	Learning about extinct animals is fun for me.
COG1	I would like to know much more about extinct animals.
COG2	I would like to learn more about extinct animals.
VAL1	I find it meaningful to be involved with extinct animals.
VAL2	The subject of extinct animals is important to me.

The three components of the interest construct (emotional [EMO], cognitive [COG], and value-related [VAL] components) were each represented by two items according to Kleespies et al. (2021).

6 Results

6.1 Overall interest in extinct animals

6.1.1 Exhibition with dinosaur skeletons (originals or replicas)

For the guided tour at the Senckenberg Natural History Museum, a significant increase ($p< 0.001$) with a medium effect size ($r= 0.42$) was measured from T1 (MV= 3.61; SD = 0.94) to T2 (MV= 3.95; SD= 0.88). However, the decrease from T2 to T3 (MV= 3.72; SD= 0.87) was significant ($p< 0.001$) with small effect size ($r= 0.33$). The differences between T1 and T3 are significant ($p= 0.003$) with small effect size ($r = 0.18$; Figure 1).

6.1.2 Exhibition with lifelike dinosaur models

Mean values for interest in extinct animals at the Zoo Leipzig are lower than for the Senckenberg Natural History Museum. The mean value for interest in extant animals during the guided tours at the Zoo Leipzig showed no significant increase ($p= 0.130$) from T1 (MV= 3.41; SD= 0.85) to T2 (MV= 3.60; SD= 0.82). At T3, the mean value (MV= 3.33; SD= 0.96) decreased significantly ($p= 0.01$) with small effect size ($r= 0.20$). Even though the value of T3 is smaller than for T1, the differences are not significant ($p= 1.000$; Figure 1).

6.2 Components of interest in extinct animals

6.2.1 Exhibition with dinosaur skeletons (originals or replicas)

The mean values of the individual components of interest in extinct animals during the guided tours at the Senckenberg Natural History Museum essentially correspond to the course of the overall interest (Figure 2a). For the emotional component, there is a significant increase ($p< 0.001$) from T1 (MV= 3.63; SD= 1.04) to T2 (MV= 4.01; SD= 0.91) with a small effect size ($r= 0.27$). This drops again at time T3 (MV= 3.76; SD= 0.93) significantly ($p= 0.001$) with small effect size ($r= 0.20$), but remains above the value of T1. However, there are no significant differences between T1 and T3 ($p= 0.555$).

A comparable trend stands out for the cognitive and value-related components. It is noticeable that the cognitive component is greater than the emotional component for extinct animals at T1. The cognitive component for extinct animals at T1 is at a mean of 3.75 (SD= 1.01). It increases significantly ($p= 0.002$) with a small effect size ($r= 0.19$) at time T2 (MV= 3.97; SD= 0.98). At T3 (MV= 3.79; SD= 0.93), it decreases, but not significantly ($p= 0.057$) to a slightly higher value than at T1. However, the differences between T1 and T3 are not significant ($p= 0.921$).

The value-related component has the lowest mean values of all components across all three time points. From T1 (MV= 3.45; SD= 1.04), it initially increases significantly ($p< 0.001$) with a small effect size ($r= 0.3$) to T2 (MV= 3.87; SD= 0.90). This drops again at time T3 (MV= 3.59; SD= 0.93) significantly ($p< 0.001$) with small effect size ($r= 0.21$). The differences between T1 and T3 are not significant ($p= 0.310$).

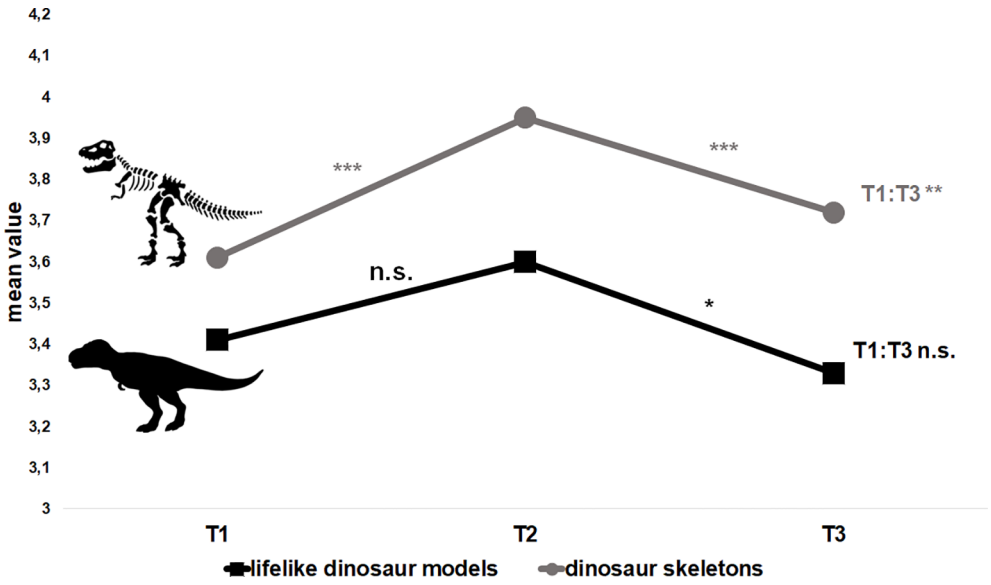

FIGURE 1
Mean values of interest in extinct animals during guided tours at the Zoo Leipzig (lifelike dinosaur models) and Senckenberg Natural History Museum (dinosaur skeletons). T1 = pre-test, T2 = post-test, T3 = follow-up test. n. s., not significant, *p < 0.05, **p < 0.01, ***p < 0.001.

6.2.2 Exhibition with lifelike dinosaur models

The general trend of the individual components of interest in extinct animals during the guided tours at the Zoo Leipzig essentially corresponds to the trend of the overall interest (Figure 2b). The emotional component has the highest mean values at time T1 (MV= 3.55; SD=0.87), but increases barely and not significantly (p=0.177) at T2 (MV=3.73; SD= 0.83). At T3 (MV= 3.43; SD= 0.98) there is a significant drop (p= 0.003) with small effect size (r= 0.22). Even though the value of T3 for the emotional component is smaller than for T1, the differences are not significant (p= 0.493).

A similar picture emerges for the cognitive component. In contrast to the Senckenberg Natural History Museum the values for T1 (MV= 3.50; SD= 0.97) are comparable to the emotional component and stay the same at T2 (MV= 3.57; SD= 0.91) and fall slightly at T3 (MV= 3.43; SD= 1.09). Multiple comparisons were not carried out because the overall test resulted in the null hypothesis that there are no differences (p= 0.593).

For the value-related component, there is a slight but scant non-significant increase (p= 0.018) from T1 (MV= 3.18; SD= 0.98) to T2 (MV= 3.49; SD= 0.87), and there is a significant decrease (p= 0.01) at T3 (MV= 3.14; SD= 1.03) with small effect size (r= 0.19), although the values between T1 and T3 are also non-significant (p= 1.000).

6.3 Gender comparison

6.3.1 Exhibition with dinosaur skeletons (originals or replicas)

For the tours at Senckenberg Natural History Museum, boys (n= 81) have a higher mean value at T1 (MV= 3.73; SD= 0.95) than girls (n= 81; MV= 3.49; SD= 0.92; Figure 3). Differences between boys and girls at T1, using the Mann-Whitney-test are significant (p= 0.04). In both genders there is significant increase at T2 with medium effect size (boys: MV= 4.07; SD= 0.88; p< 0.001; r= 0.4, girls: MV= 3.84; SD= 0.88; p< 0.001; r= 0.44) and a significant decrease at T3 with small effect size (boys: MV= 3.81; SD= 0.89; p= 0.003; r= 0.26, girls: MV= 3.63; SD= 0.85; p= 0.023; r= 0.21). While the differences between T1 and T3 are not significant in boys (p= 0.195) there is a significant difference in girls with small effect size (p= 0.01; r= 0.23).

6.3.2 Exhibition with lifelike dinosaur models

A comparison of interest in extinct animals across genders during the tours at the Zoo Leipzig (male: n= 58; female n= 53) reveals that boys have a slightly higher mean value at T1 (MV= 3.45; SD= 0.92) than girls (MV= 3.35; SD= 0.60; Figure 4). Differences between boys and girls at T1, using the Mann-Whitney-test are not significant (p=0.442). In girls no significant increase was measured at T2 (MV= 3.61; SD= 0.60; p= 0.139) but a significant drop with small effect size at T3 (MV= 3.21; SD= 0.76; p= 0.006; r= 0.3). The differences between T1 and T3 are not significant in girls (p= 0.792). While we see in boys a slight increase at T2 (MV= 3.60; SD= 0.86) and decrease at T3 (MV= 0.43; SD= 1.02), multiple comparisons were not carried out because the overall test resulted in the null hypothesis that there are no differences (p= 0.222).

7 Discussion

7.1 Exhibition with dinosaur skeletons (originals or replicas)

Overall, we see very high values at T1, T2 and T3 (Figure 1). The Senckenberg Natural History Museum is one of its kind in Germany, with an over 200 year old history, a high international

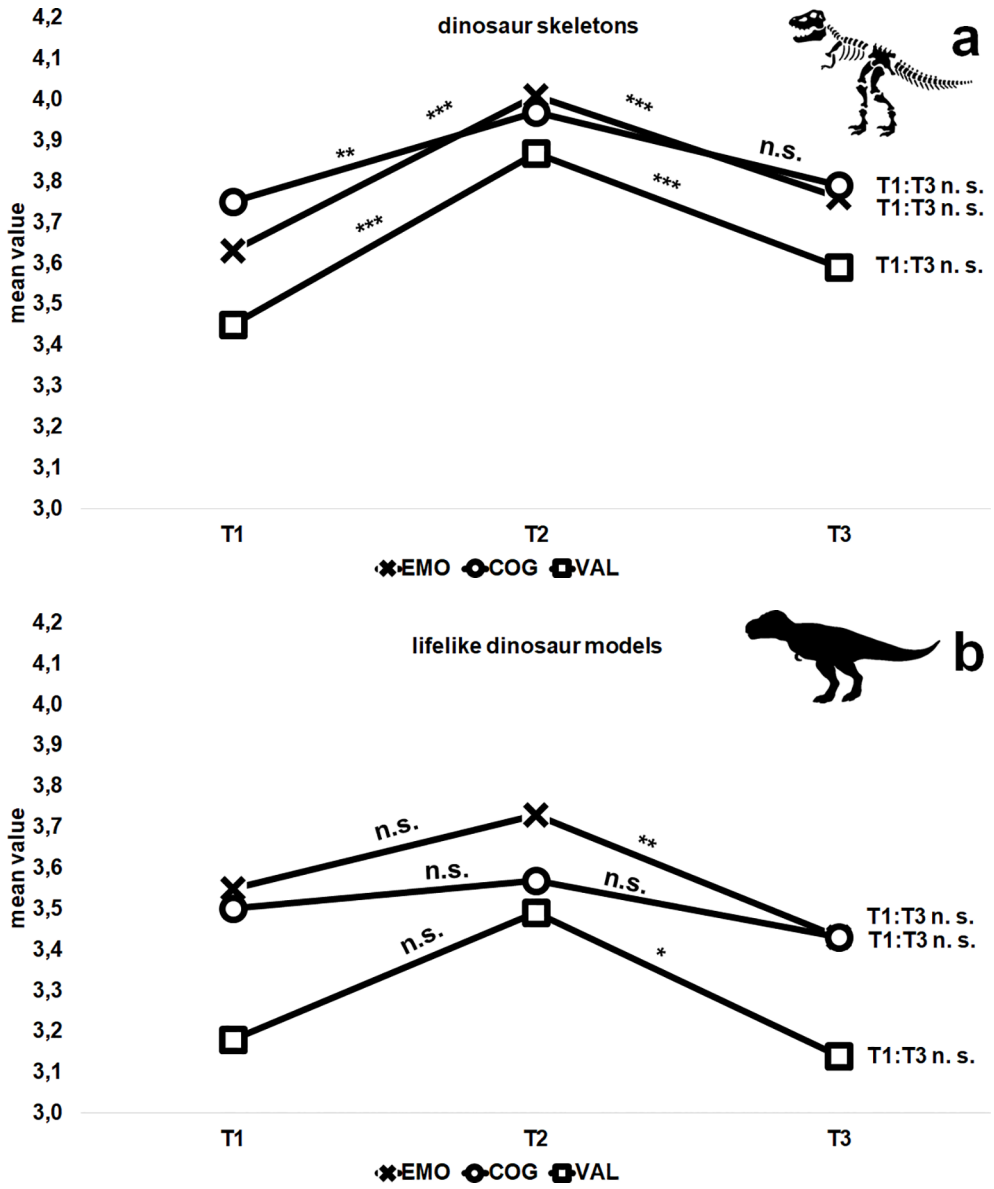

FIGURE 2
(a) Mean values of the emotional (EMO), cognitive (COG), and value (VAL) components of interest in extinct animals during guided tours at the Senckenberg Natural History Museum (dinosaur skeletons). **(b)** The same components measured during guided tours at the Zoo Leipzig (lifelike dinosaur models). T1 = pre-test, T2 = post-test, T3 = follow-up test. n. s., not significant, *p < 0.05, **p < 0.01, ***p < 0.001.

reputation and one of the largest dinosaur collection (Mosbrugger et al., 2015). Students find various evolutionary biological phenomena captivating when they are personally significant. If students have an interest in a particular biological species, they are more likely to be drawn to evolutionary biological phenomena (Jördens and Hammann, 2019). Non-avian dinosaurs, among extinct creatures and topics in evolutionary biology, are widely regarded as both popular and fascinating (Currie, 2023). The high values can be explained by the popularity of dinosaurs and the general interest in them. These high values also reflect the high motivation of the classes. Falk and Dierking (2000) suggest that the most significant learning outcomes in museums occur when visitors come with a pre-existing motivation.

Despite the high T1 values, there is a significant increase in interest in extinct animals at T2 (Figure 1). If we look at the individual components of interest (Figure 2a), the course of the components at the three test points was consistent with the overall interest. Interestingly, the differences between T1 and T3 are not significant in all three components, in contrast to the overall interest. It seems that the combination of all three components leads to significant differences between these two time points. The emotional component contributes mostly to the increase in overall interest at T2 and achieves the highest levels. This aligns with research regarding interest in nature or student laboratories that attain elevated scores in the emotional aspect of interest (Kals and Ittner, 2003; Kals et al., 1998; 1999; Rennie, 1994; Kubi et al., 2024).

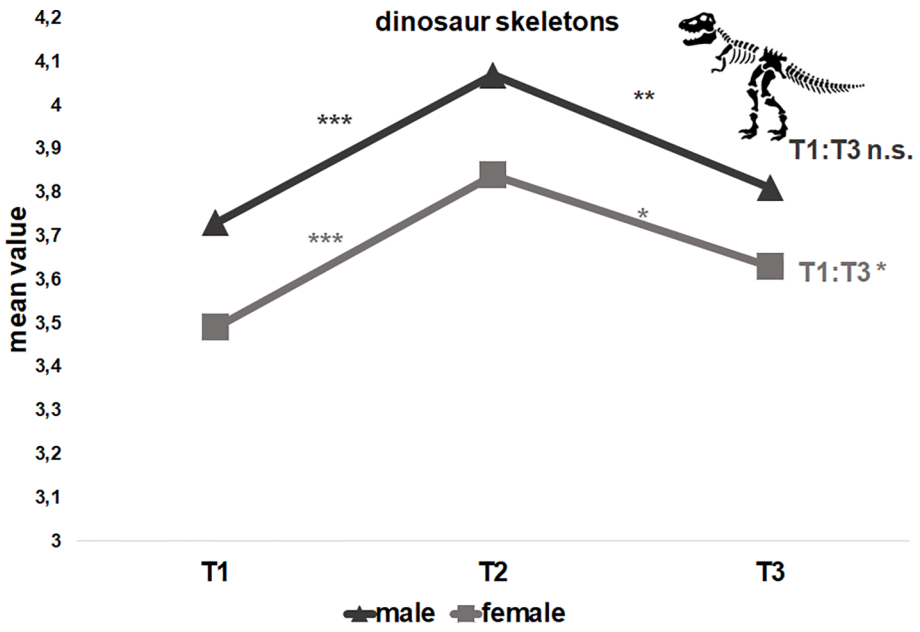

FIGURE 3
Mean values of interest in extinct animals in boys (male) and girls (female) during guided tours at the Senckenberg Natural History Museum (dinosaur skeletons) at the three test time points. T1 = pretest, T2 = posttest, T3 = follow-up test. n. s., not significant, *p < 0.05, **p < 0.01, ***p < 0.001.

The trend of the value-related component mirrors that of the emotional component, yet it remains lower in comparison; in fact, among all three components, it records the lowest values across all three test items.

According to Falk and Dierking (2013), most vivid memories of museum experiences are often associated with emotional elements, which is consistent with the emotional components of interest found in our data. Looking at the original fossil skeleton of *Diplodocus* or the *Triceratops* skull with all its details can evoke positive reactions. But even the replicas, like the *Tyrannosaurus* skeleton, elicited positive reactions. The *Tyrannosaurus* skeleton at Senckenberg Natural History Museum is a detailed replica of the

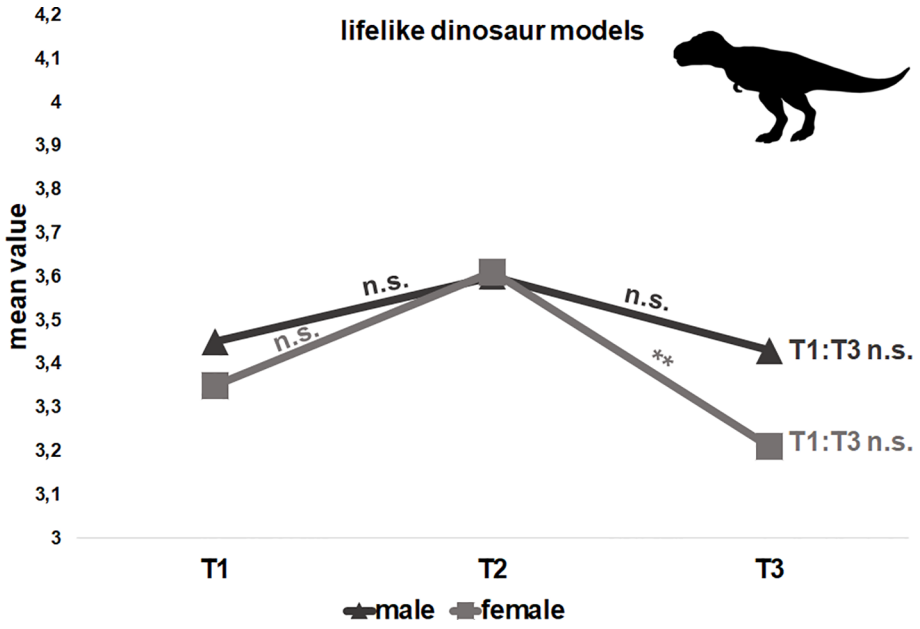

FIGURE 4
Mean values of interest in extinct animals in boys (male) and girls (female) during guided tours at the Zoo Leipzig (lifelike dinosaur models) at the three test time points. T1 = pretest, T2 = posttest, T3 = follow-up test. n. s., not significant, **p < 0.01.

specimen AMNH 5027 in the American Museum of National History in New York that was found in 1908 and was the very first mounted (45% of the skeleton is preserved) *Tyrannosaurus* skeleton (Norell et al., 1995). Its skull and arms were also the template for the logo of the movie Jurassic Park. A study by Hampp and Schwan (2014), done with adults, showed that a difference between original objects and replicas would not matter, if these replicas are legitimate substitutes for original objects. According to Schwan and Dutz (2020) replicas are also justified, if the original objects do not exist anymore, or can be easily damaged or the presentation of the copy is necessary for completing the exhibition. These characteristics hold also true for the *Tyrannosaurus* replica at the Senckenberg Natural History Museum. Because many fossil dinosaur skeletons are not complete, even they are supplemented by castings (which is also true for the original *Tyrannosaurs* skeleton AMNH 5027 in New York). Such details are conducive to interest, as they attract learners' attention, e.g. via discrepancy experiences, recognition of familiar objects, surprise effects (Scheersoi, 2016; Scheersoi and Weiser, 2017) or special features of objects, e.g. their size or details (Scheersoi, 2015). Details like these, or the history of these objects, foster engagement by capturing the attention of learners through various means, such as experiences of discrepancy, the recognition of familiar items, surprising effects (Scheersoi, 2016; Scheersoi and Weiser, 2017), or unique characteristics of objects, including their size or intricate details (Scheersoi, 2015). Typically, visits to museums are social occasions where individuals exchange experiences, engage in conversation, or collaboratively address a presented challenge (Falk and Dierking, 2000; Dierking, 2002; Heath and vom Lehn, 2008). Indeed, Bitgood (2002) suggests that social interactions can often serve as the primary motivation for attending a museum. Museum educators and professionals appreciate the positive emotional and social experiences that field trips can facilitate (Anderson et al., 2006). If we look at the cognitive component of interest in the museum, it is higher than the emotional component at T1, but is slightly lower at T2. It falls non-significant at T3 to a slightly higher value that at T1 (and higher than the emotional component at T3). The strong enthusiasm exhibited by students in this age group for engaging with dinosaurs likely contributes to this trend (Salmi et al., 2017). Research by Swarat (2008) demonstrated that subjects deemed dynamic and popular among peers are often viewed as especially intriguing. Factors such as personal relevance, familiarity with the topic, and its challenging aspects also hold significant importance.

In the follow-up test (T3), the mean values fell again, but were still higher than at T1. The differences between T1 and T3 are significant (Figure 1). While the mean values at T3 were slightly higher than at T1, they fell after the guided tour (T2) significantly. The noticeable fluctuations in interest here indicate that we can only expect a temporary impact from the museum visit, as evidenced by Heuken et al. (2021). Randler and Bogner (2007) suggest that the decrease in interest observed in their intervention study regarding the lake ecosystem may stem from the students' curiosity being fulfilled, and they also propose this as a general explanation for diminishing interest in other research.

7.2 Exhibition with lifelike dinosaur models

If we compare the mean values of the guided tours at the Zoo Leipzig with those of the Senckenberg Natural History Museum, it is noticeable that the mean values are much lower at T1 (Figure 1). Why are T1 and subsequent values lower than in the Senckenberg Museum? The Zoo Leipzig is famous for its modern animal enclosures and its wealth of exotic animal species, which is why the zoo logically focuses on the animal enclosures and the infrastructure for zoo visitors. Because the temporary special exhibition was spread across the entire zoo grounds and lacked a common thread (e.g. a chronological classification of the individual dinosaurs in their respective eras), it cannot be ruled out that the dinosaurs, despite their size, were lost in the "mass of zoo animals". In addition, the school classes that were guided were distracted by animal enclosures with characteristic species, playgrounds, restaurants and long visitor routes. When visiting a zoo, visitors have different expectations than when visiting a museum. They don't expect to see dinosaurs, but (exotic) animals, which means that their interest lies more in these zoo animals than in the dinosaurs that are scattered around the zoo. Research has shown that the context in which an exhibit is presented significantly affects visitor behavior. The animatronics must be well developed and placed in a meaningful context (Tunnicliffe, 2000). For example, didactic arrangement of the exhibits is important (Araújo et al., 2024), taking into account the chronological order of the individual dinosaur genera (Triassic, Jurassic, Cretaceous) or taxonomic, anatomical, ecological or evolutionary biological issues (e.g. the origin of birds from non-avian theropods, ecological niches, biogeography, or other Mesozoic fossil taxa, e.g., mammals). The species signage described comparisons with modern animals found at Zoo Leipzig (e.g. a comparison of the gigantism of sauropods with large mammals living today, such as elephants). However, this interesting comparison suffered from the fact that the animals compared were rarely found near the dinosaur exhibits. These factors, in addition to the expectation of seeing exotic animals instead of animatronics of prehistoric animals in a zoo, can have an influence on visitors. In addition, the size and attractiveness of the surrounding exhibits can greatly influence the amount of attention that visitors pay to a particular authentic object (Eghbal-Azar et al., 2016; Turgay and Imamoğlu, 2020).

We also see no significant increase in the mean values at T2 at the Zoo Leipzig. Even at T2, the mean value of overall interest is below the T1 value of the Senckenberg Natural History Museum (Figure 1). A similar pattern can also be seen in the individual components of interest (Figure 2B). The emotional component has the highest value at T1 and the value-related component the lowest. The cognitive component is almost on a par with the emotional component at T1. While there is a slight but non-significant increase in the emotional and value-related components at T2, only to drop again significantly at T3, the mean value for the cognitive component remains stable across all test times. What could be the reasons for the advantages of the guided tours in the museum compared to the dinosaur exhibition at the Zoo Leipzig?

One important factor is the authenticity of the learning location. While the dinosaur exhibition at the Zoo Leipzig featured life-like and animatronic dinosaur models, the Senckenberg Natural History Museum has dinosaur skeletons (originals and replicas) in its exhibition. The Zoo Leipzig exhibition was curated by scientific advisory boards, and Salmi et al. (2017) showed positive learning outcomes in another exhibition with dinosaur-robots, but they are the least authentic type of dinosaur exhibition (Cohen, 2010). The positive learning outcomes of a dinosaur theme park, as measured by Salmi et al. (2017), are also related to the exhibition design. Salmi et al. (2017) investigated a dinosaur exhibition in a science center in Finland, which was the fifth dinosaur exhibition in the 25-year history of this science center. The exhibition was located on an external site, in a park of the science center. The exhibit heavily focused on observing, experiencing, and interacting closely with the robotic dinosaurs. The exhibition at the Zoo Leipzig was spread across the entire zoo. Authentic objects in a museum have some characteristics, which is a relational concept between the object and the perceiver (Kirchberg and Tröndle, 2012). Such characteristics include whether it is original, of historical significance, unique, allows stories to be told, is of high monetary value or provides important insights of research (Schwan and Dutz, 2020). Such authentic objects rise their interest, arouse curiosity, surprise visitors and stimulate their imagination. As mentioned in the discussion section about the Senckenberg Natural History Museum, the dinosaur skeletons, like the original fossil skeleton of *Diplodocus*, the *Triceratops* skulls or the dinosaur eggs fulfill these characteristics of authenticity, which the dinosaur life-like models at the Zoo Leipzig could not. Studies on children, aged 8-12 years, have shown, that they value authentic dinosaur bones (original fossils) more than bone replica (van Gerven et al., 2018), but also value a complete object over fragments, independent of its status as an original object or replica (Hampp and Schwan, 2014).

8 Gender comparison

Numerous studies indicate variations in interest in science between boys and girls (Babarović, 2021; Jia et al., 2020). The gender differences at the exhibition with dinosaur skeletons (originals or replicas) at the Senckenberg Natural History Museum show that boys have a higher interest in extinct animals than girls, whereby a significant increase was observed in both genders at T2, which decreased again significantly at T3. The fact that boys have a higher interest in extinct animals than girls is also partly evident at the Zoo Leipzig. Here, however, the difference between the two genders is smaller and at T2 they are on a par. However, no significant increase was found for either gender at T2. For girls, however, there was a significant drop at T3 to a value below T1. It should be emphasized, however, that all effects were small. Certain research highlights gender-specific preferences leaning towards boys (Kang et al., 2018; Sainz et al., 2021), others favor girls (Kang et al., 2021) or find no significant differences between the genders (Cheung, 2017; May et al., 2022). Findings demonstrate that girls seem to show a greater interest in biology when compared to chemistry and physics (Jia et al., 2020; Kang et al., 2018). A greater preference and/or knowledge for dinosaurs in boys is found in some studies (Salmi et al., 2017; Chin, 1997). Nevertheless, such findings cannot be applied universally. One study, for example, examined the successful results of a project to integrate girls into the geosciences in Brazil (Witovisk et al., 2021). During early adolescence, the influence of role modeling and the increasing pressure to adhere to adult gender stereotypes often occurs, which may also affect wider societal perceptions of human-animal relationships (Muldoon et al., 2015, 2019). The degree to which these gender stereotypes impact interest in extinct animals falls outside the parameters of this study.

9 Conclusion

The aim of this study was to investigate the effect on interest in extinct, prehistoric animals in different dinosaur exhibitions (skeletons in a natural history museum and lifelike animatronic models in a special exhibition in a zoo). Although the lifelike models of the dinosaurs that roamed the earth during the Mesozoic Era look more realistic than fossils can show, these skeletons seem to hold a strong fascination. The main reason for this difference might be, that natural history museums provide a more authentic atmosphere with its original dinosaur fossils (or detailed replicas which are legitimate substitutes for original objects), which raise interest, curiosity and surprise - something the dinosaur lifelike models at the Zoo Leipzig could not. As discussed, the distribution of the animatronics and the zoo, as well as the focus on living animals at this institution, can also influence the outcome. An examination of the gender results shows that boys were the primary contributors to the increase in interest in animals. However, these effects were not long-lasting, as demonstrated by follow-up tests. Visiting an extracurricular learning-site like zoos and museums, covering a wide range of scientific topics, are always worthwhile, because they contribute to students' interest in science. But to generate a lasting enhancement of interest, a single visit is not enough. This is because genuine learning typically does not arise from a single experience. To achieve a sustained boost in interest, it is essential to employ various interventions and/or integrate the content from the tour into the educational curriculum. A possible follow-up study could be related to the degree of specific knowledge and knowledge retention gained from visits to skeletal mounts compared to animatronic ones. It might be expected that increased emotional, cognitive and value engagement would lead to increased learning.

Dinosaurs have fascinated children and adults for many decades. This is despite the fact that they have been extinct for several million years and no human has ever come into contact with a living specimen. The examination of the impressive world of dinosaurs not only offers a unique opportunity to impart knowledge, but also opens up the chance to explore extracurricular places of learning as a lively addition to school lessons. Unlike in the classroom through illustrations or texts, students can discover the dinosaurs in their true size in the museum. Misconceptions about these extinct creatures can never be fully corrected in the classroom using texts or traced pictures. With the help of the exhibits, students get an impression of the actual size of these fascinating animals. In addition, viewing real skeletons of dinosaurs can awaken children's interest in the

subject of dinosaurs in a completely different way. An important aspect for every dinosaur exhibition, or a museum exhibition in general, is the presence of trained museum educators who can enrich the experience of a museum visit by sharing knowledge in a way that is appropriate for the target audience (Araújo et al., 2024). A potential follow-up study might be related to the degree of specific knowledge and knowledge retention acquired in visits to skeletal mounts compared to animatronic ones.

10 Limitations

While this study was approached with considerable care, it is important to acknowledge certain limitations. One limitation that could influence the findings is the unique living situations that students encountered during the pandemic. Besides gender, other factors should also be considered, such as the social and economic reality of the students who visited these exhibitions. Individual circumstances and family dynamics lead to varied coping mechanisms among students, potentially impacting the results. Additionally, although both tours at the Senckenberg Natural History Museum and Zoo Leipzig were designed to deliver as similar content as possible and were led by the same guide, each class and student is distinct. The differences in the dinosaur species presented mean that achieving a perfectly uniform tour experience is not feasible in real-world settings.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Ethics Committee of the Science Didactic Institutes and Departments (FB 13, 14, 15) of the Goethe University Frankfurt am Main. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the minor(s)' legal guardian/next of kin for the publication of any potentially identifiable images or data included in this article.

Author contributions

MK: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. MWK: Formal analysis, Investigation, Methodology, Validation, Writing – review & editing. VW: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Validation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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