Research in Science Education
https://doi.org/10.1007/s11165-023-10140-7

On the Interest-Promoting Effect of Outreach Science Labs: A Comparison of Students' Interest during Experimentation at an Outreach Science Lab and at School

Tim Kirchhoff[1] · **Matthias Wilde**[1] · **Nadine Großmann**[2]

Accepted: 31 October 2023

Abstract
Outreach science labs aim to promote students' interest. Previous research has often suggested that performing experiments in such labs has a positive effect on their interest. However, these studies often lack a comparison to the effects of performing them at school. This research gap was addressed in the present study. The sample consisted of 402 upper-secondary level students (age: M = 16.53 years, SD = 0.80 years) who performed three experiments on the topic of enzymology either in an outreach science lab (n = 203) or at school (n = 199). Contrary to the assumption, experimentation at the outreach science lab did not outperform experimentation at school in terms of students' psychological state of interest in the comparison to the school setting. Surprisingly, differences in the value-related component of the psychological state of interest were even found in favor of the school treatment.

Keywords Outreach science lab · Interest · Experimentation · Biology classes

Introduction

Science education aims to promote students' interest in science as it is an important factor of successful student learning and of unique importance for students' choice of future profession (Krapp & Prenzel, 2011; Organization for Economic Co-operation and Development [OECD], 2016; Renninger & Hidi, 2016; Zhang & Bae, 2020). However, science education in Germany seems to be failing in achieving this goal (Potvin & Hasni, 2014). Among 15-year-old students in Germany, interest in science is below the international average and has been declining since 2006 (OECD, 2016; Potvin & Hasni, 2014; Schiepe-Tiska et al., 2016). When it comes to the subject of biology, students in higher grades show lower interest when comparing the students from Grades 5 to 9 (Großmann et al., 2021).

✉ Matthias Wilde
matthias.wilde@uni-bielefeld.de

[1] Bielefeld University, Faculty of Biology, Didactics of Biology, Bielefeld, Germany

[2] University of Cologne, Faculty of Mathematics and Natural Sciences, Institute for Biology Education, Cologne, Germany

Published online: 22 November 2023

This negative trend is accompanied by declining enrollment and graduation rates in science, technology, engineering, and mathematics (STEM) courses (OECD, 2016) as well as a significant shortage of skilled STEM employees (Anger et al., 2022).

In Germany, visiting an outreach science laboratory (hereafter 'lab') is a popular approach to counteract these negative trends in STEM education (Euler & Schüttler, 2020). An outreach science lab is a non-formal, out-of-school learning environment (Affeldt et al., 2015; Euler & Schüttler, 2020; Garner et al., 2014; Hofstein & Lunetta, 2004) that aims to promote students' interest in STEM and in science-related hands-on activities (Guderian & Priemer, 2008; Itzek-Greulich & Vollmer, 2017; Scharfenberg et al., 2019). In order to achieve this goal, the students engage in hands-on activities to investigate scientific questions in an authentic, science-related, and well-equipped learning environment (Dähnhardt et al., 2007; Euler & Schüttler, 2020; Garner et al., 2014; Scharfenberg et al., 2019). Generally, their performance is ungraded (Glowinski & Bayrhuber, 2011; Pawek, 2009), and they are supervised by (scientific) laboratory staff (Affeldt et al., 2015; Kirchhoff et al., 2022; Garner et al., 2014).

Research on the interest-promoting effect of outreach science labs is mostly based on the person-object-theory of interest (e.g., Krapp, 2005, 2007) in which interest is conceptualized as a relationship between a person and an object (Krapp & Prenzel, 2011; Renninger & Hidi, 2011, 2016). Objects can be physical objects or subject areas (Krapp, 2005, 2007) as well as activities (Holstermann et al., 2010; Jördens & Hammann, 2021; Krapp et al., 2014). Interest is characterized by three components: an attribution of a high personal value to the object (*value-related component*), an experience of positive emotions during an active engagement with the object (*emotional component*), and a high degree of readiness to expand one's knowledge about the object (*epistemic component*; Krapp, 2007; Krapp et al., 2014; Renninger & Hidi, 2011). In addition, there is a distinction between interest as disposition and interest as a current psychological state (Krapp, 2007; Renninger & Hidi, 2011). *Individual interest* is cross-situational and refers to a motivational disposition and individual characteristics (e.g., an individual's general interest in biology), while *situational interest* is focused on the momentary state and depends on environmental conditions (e.g., interest in experimenting in a classroom situation; Krapp et al., 2014; Renninger & Hidi, 2016; Vogt, 2007). Interest during an individual's interaction with an object arises from the interaction between both existing individual interest and the situational characteristics of the environment (Krapp, 2007; Renninger & Hidi, 2011) and is referred to as *psychological state of interest* (Renninger & Hidi, 2016).

The effects of outreach science labs on students' interest have been described especially for the psychological state of interest during an outreach science lab visit (e.g., Itzek-Greulich & Vollmer, 2017; for an overview see Guderian & Priemer, 2008; Nickolaus et al., 2018; Scharfenberg et al., 2019). As learners usually attend the workshops of outreach science labs in the context of a one-time, half-day field trip (Itzek-Greulich, 2020), the effects on the psychological state of interest are expected at first in the short term (Lewalter, 2020; see also Palmer et al., 2017). In general, previous research has shown that outreach science lab visits seem to promote students' psychological state of interest (for an overview see Guderian & Priemer, 2008; Nickolaus et al., 2018). Closer inspection shows that the current state of research is more complex, ambiguous, and requires further research. Starting with a more differentiated consideration of the psychological state of interest, the results on the impact of an outreach science lab visit on situational interest are not uniform across the three components of interest (Guderian & Priemer, 2008; Nickolaus et al., 2018; Scharfenberg et al., 2019). There are usually no medium-term changes in the value-related component (e.g., Pawek, 2009). However, Engeln (2004) did find an increase therein. The values of the emotional component are often the highest and ceiling effects can be found (e.g., Damerau, 2012; Scharfenberg, 2005). The emotional and epistemic components tend to decrease in the medium term after visiting an outreach science lab (e.g., Brandt, 2005; Damerau, 2012; Engeln, 2004; Pawek, 2009; Scharfenberg, 2005), whereas the level of the epistemic component appears to be maintained by connecting the visit with regular classes (e.g., Guderian, 2007).

Despite the generally favorable portrayal of outreach science labs, a comparison to the school learning environment where experiments are also performed is often lacking (Kirchhoff et al., 2022, 2023; Itzek-Greulich & Vollmer, 2017; Nickolaus et al., 2018). As the positive effects of hands-on activities on students' interest have also been found in the school context (e.g., Holstermann et al., 2010; Palmer et al., 2017; Potvin & Hasni, 2014; Swarat et al., 2012), the question arises as to whether experimentation at an outreach science lab outperforms experimentation at school in terms of the psychological state of interest. To our knowledge, there are only a few studies that have addressed this issue, such as the studies by Itzek-Greulich and Vollmer (2017), Schüttler et al. (2021), and Röllke et al. (2021).

Itzek-Greulich and Vollmer (2017) conducted a quasi-experimental study in chemistry education in which they compared three treatments (outreach science lab only, school only, and a combination of outreach science lab and school) with a control group (a group that was not taught in the study in either the outreach science lab or at school). The students in the three treatments developed a more intense psychological state of interest compared to the control group, but no differences among these treatments were found. However, in all learning environments, the same laboratory equipment was used, although many laboratory materials are usually not available at schools due to their high cost. In addition, the treatment conditions were conducted by different pedagogical staff that might have led to "a 'bias' towards the teachers" (Itzek-Greulich & Vollmer, 2017, p. 20) who conducted the parts at school.

In a study in the field of physics education, Schüttler et al. (2021) used a two-factor design to examine the influence of the learning environment (outreach science lab vs. school) and the quality of the materials (high-end vs. low-cost) on students' psychological state of interest. They found that the epistemic component was higher when the students worked with high-quality laboratory equipment in the outreach science lab than at school. By contrast, no differences were found in the emotional and value-related components. However, the sample size was not very large ($N = 148$) and the participants only attended a *Gymnasium* (i.e., a university track high school in Germany).

The studies by Itzek-Greulich and Vollmer (2017) and Schüttler et al. (2021) were conducted in the fields of chemistry and physics. Other effects might occur in the field of biology (Euler & Schüttler, 2020) as students' interest in physics or chemistry is usually lower than in biology (Krapp & Prenzel, 2011). Moreover, girls often exhibit lower interest in chemistry and physics than boys but higher interest in biology (Krapp & Prenzel, 2011). Therefore, the findings cited can only be transferred to other STEM fields to a limited extent, and studies in the field of biology are required. For instance, Röllke et al. (2021) compared students' psychological state of interest during inquiry-based learning at an outreach science lab and at school in the field of biology education. They found differences in a certain type of interest (triggered situational interest and the feeling component of maintained situational interest; see Linnenbrink-Garcia et al., 2010) in favor of the students at the outreach science lab; however, no differences were found in the value component (of maintained situational interest). At school, the teaching unit was structured differently because the regular teachers supervised the theoretical parts of the unit while the practical parts were supervised by the tutors of the laboratory treatment. Moreover, the tutors provided laboratory equipment that is generally not available at school such as thermocycler and electrophoresis chambers.

In summary, outreach science labs aim to promote students' interest in STEM fields by providing opportunities to perform hands-on experiments in a scientific laboratory. According to previous research in this field, there are preliminary findings to support this claim. However, these results are non-uniform regarding the three components of interest and there are several limitations to overcome such as a lack of a comparison group at school that performs the same experiments as in the laboratory with materials usually available at school, different pedagogical staff conducting the lessons, and small sample sizes. In our study, we addressed these limitations by implementing the same teaching unit dealing with experiments on enzymology at an outreach science lab and at school with materials that are usually available at an outreach science lab (e.g., microliter pipettes) or at school (e.g., disposable pipettes), the same teaching staff, and a quite adequate sample (n = 402). Based on the aforementioned rationale, we investigated the following research question:

How does the psychological state of interest of students who perform experiments at an outreach science lab differ from the psychological state of interest of students who perform the same experiments at school?

Methods

Sample

Four hundred two students (64% female) in the first year of the upper secondary school (age: M = 16.53 years, SD = 0.80 years) from two university track high schools (*Gymnasium* 50%) and three comprehensive schools (*Gesamtschule*) in the German state of North Rhine-Westphalia took part in this study. They performed experiments either at an outreach science lab (n = 203, 62% female, 55% *Gymnasium*) or at school (n = 199, 67% female, 46% *Gymnasium*).

Study design

This study is based on a quasi-experimental design with the treatments *outreach science lab* and *school*. In both treatments, we assessed the students' individual interest in biology immediately before the intervention. Then the students performed three experiments on enzymology in either the outreach science lab or at their school. The experiments were the same in both treatments. In the outreach science lab treatment, a workshop was implemented in one session (180 minutes). In the school treatment, the workshop was conducted in the regular biology classes and therefore divided into three lessons (two 45-minutes and one 90-minute lessons or three 60-minute lessons). Immediately after the experiments, the students' psychological state of interest was measured.

Test instruments

Before the intervention, the students' individual interest in biology was assessed using an adapted scale used in previous PISA studies (e.g., OECD, 2007; see Frey et al., 2009). We used this scale in the pretest to check whether the treatment groups differed regarding their individual interest in biology prior to the intervention as differences in their prior interest could influence their psychological state of interest during the intervention (see Krapp, 2007; Renninger & Hidi, 2011). This scale consisted of 5 items (e.g., "In general, I enjoy dealing with biology."; Cronbach's alpha α = .94).

Immediately after the intervention, the students' psychological state of interest was assessed with an adapted scale consisting of 16 items (piloted in Desch et al., 2016; Großmann & Wilde, 2020), which was similar to the scales developed by Engeln (2004), Pawek (2009), and Schüttler et al. (2021). This scale was not used before the intervention, since it relates to a momentary state of being interested that depends on situational characteristics of the environment (Krapp, 2007; Renninger & Hidi, 2011) that differ between the classes before the intervention. The scale comprised three subscales that addressed the three components of interest: the value-related component (5 items, "It was important to me that we performed the experiments", α = .78), the emotional component (5 items, "I enjoyed performing the experiments", α = .89), and the epistemic component (6 items, "I would like to learn more about experimenting", α = .81). The items of both test instruments were rated on a five-point rating scale from (0) "not true at all" to (4) "completely true." Internal consistency was satisfactory (see Taber, 2018).

Teaching and treatments

This study was conducted as part of an outreach science lab workshop on enzymology. We designed the workshop in such a way that it can be conducted at an outreach science lab and at school (Kirchhoff et al., 2022). The workshop dealt with *biocatalysts*, *temperature dependence*, *pH dependence*, *substrate specificity*, and *competitive inhibition*. In both treatments, the students worked in self-selected groups of three or four persons to perform the experiments at workstations. To structure the teaching unit, they received the same scripts that included all information about the experiments in the form of stapled worksheets. Thus, the experiments in both treatments were framed with the same information. Experimentation at outreach science labs usually corresponds to *structured inquiry* (Euler & Schüttler, 2020; Scharfenberg et al., 2019). Thus, in reference to Hodson (2014), we designed the experiments in our study as follows: In each experiment, the students developed hypotheses based on an informational text and predetermined research questions. Afterwards, they tested their hypothesis by conducting a pre-structured experiment involving a controlled manipulation of the variables (e.g., enzyme; pH; temperature; substrate) and the use of a blank sample (e.g., no enzyme). To conduct the experiments, the learners followed the detailed instructions provided in the scripts and performed the hands-on elements of the experiments (e.g., operating the pipette). The collected data (i.e., observations) were interpreted to address the hypothesis.

In the first experiment about enzymes as biocatalysts, the students investigated whether amylase degrades starch. For this, they conducted an experiment involving three starch solutions (1%), one with water (blank), one with α-amylase (extracted from *Aspergillus oryzae*), and one with salvia that contains α-amylase. All solutions were stained with

Lugol's iodine that contains iodide polymers. These molecules form blue-violet complexes with starch, but not with dextrins, maltose, and glucose. As α-amylase cleaves the glycoside bond of starch, a starch solution stained with Lugol's iodine loses its color when adding α-amylase. Thus, during the experiment, the students observed a decolorization in the two solutions with α-amylase and saliva that indicates the degradation of starch catalyzed by amylase. To quantify the degradation rate of starch, the students additionally analyzed data from a photometry of a starch solution treated with amylase involving 24 measuring points of absorbance ($\lambda = 576$ nm).

In the second experiment, the students investigated whether the enzyme's activity is dependent on temperature (part 1) and on pH (part 2). For this, catalase (extracted from *Saccharomyces cerevisiae*) was treated with different temperatures (0, 20, 37, and 80°C) for 10 min and pH for 5 min (pH = 1 [hydrochloric acid, 1%], 7 [water], 14 [caustic soda, 1%]). After the incubation, the students added 10% hydrogen peroxide and observed foam formation depending on the temperature and pH. The foam is formed by the oxygen produced during the decomposition of the hydrogen peroxide. As enzymes are proteins, the conformation of enzymes depends on environmental conditions such as temperature and pH. Hence, enzymes can become denatured and lose their function by a change in these factors.

In the third experiment about substrate specificity, the students investigated whether an enzyme could catalyze different reactions (part 1) and whether the presence of a similar substrate may inhibit the reaction (part 2). In the first part, the students conducted an experiment involving two urea solutions (2%), one methyl urea solution (2%), phenolphthalein (0.1%), and urease (extracted from *Canavalia gladiata*). They added phenolphthalein and treated the solutions with urease except of one urea solution. This untreated urea solution was used as a blank sample. By adding the enzyme, the reaction of urea and water to form ammonia and carbon dioxide is catalyzed. The increasing concentration of ammonia leads to an increasing pH value, which can be detected by the indicator phenolphthalein. Since methyl urea fits more poorly than urea into the active site of the enzyme, the reaction proceeds more slowly. During the experiment, the students carefully observed and interpreted the varying colorization in the samples considering the lock and key principle. In the second part, the experiment involved a suspension with urea (2%) and one with both urea (2%) and methyl urea (5%) as well as the blank sample from the first part. The students added phenolphthalein (0.1%) and urease. Methyl urea blocks the active site and slows down the reaction of urea to ammonia (competitive inhibition). The slower colorization rate in the mixed sample (urea and methyl urea) was observed and interpreted by the students.

Based on literature (e.g., Sommer et al., 2018, 2020; for a detailed description, see Kirchhoff et al., 2022), we designed the treatment conditions under the consideration of the environmental characteristics *location*, *time*, *supervision*, *materials*, and *grading*, as shown in Table 1.

Data analysis

First, in order to compare the students' individual interest that was assessed prior to the intervention between the investigated groups, a univariate analysis of covariance (ANCOVA) was performed. Gender was considered as covariate (see Krapp & Prenzel, 2011). Afterwards, we tested whether the students' psychological state of interest differed between the treatments. We analyzed differences in students' value-related, emotional, and epistemic components of interest using multivariate analysis of covariance (MANCOVA). Their individual interest and gender were considered as covariates (see Priemer et al., 2018).

Table 1 Varied characteristics of the learning environments outreach science lab and school

	Outreach science lab	School
Location	Laboratory at the university	Regular biology classrooms at school
Time	Field trip (180 min)	Regular biology lesson times (two 45-minute and one 90-minute lessons or three 60-minute lessons)
Supervision	One supervisor for six to eight students	One supervisor for all students (20-25 students)
Materials	Lab coats, safety glasses, and gloves for all students	Lab coats, safety glasses, and gloves for the students working directly with hazardous materials
	Microliter pipettes	Disposable pipettes
	Water baths with a built-in thermostat and tube rack	Water bucket with thermometer and test tube stand; external water boiler for heating the water
	Mixing of enzyme suspensions using a vortexer	Mixing the enzyme suspensions by hand
Grading	Performance during experimentation was not graded by the supervisors or their regular teachers	Performance during experimentation was graded by their regular teachers

Results

We did not find differences in students' individual interest before the intervention (ANCOVA: $F(1, 399) = 1.11$, $p = .292$; outreach science lab: $M = 2.39$, $SD = 1.09$; school: $M = 2.29$, $SD = 0.98$). Gender had no impact on individual interest ($F(1, 399) = 2.88$, $p = .090$). That is, there were no differences between female and male students in our sample.

When it came to the analysis of our research question about differences in the psychological state of interest between the outreach science lab and school treatments, we considered the value-related, emotional, and epistemic components of interest. A MANCOVA yielded a significant treatment effect (Wilks $\Lambda = 0.97$, $F(3, 396) = 3.96$, $p < .010$, $\eta^2 = .03$). The covariates individual interest (Wilks $\Lambda = 0.69$, $F(3, 396) = 60.10$, $p < .001$, $\eta^2 = .31$) and gender (Wilks $\Lambda = 0.98$, $F(3, 396) = 2.66$, $p < .05$, $\eta^2 = .02$) had a significant effect on the students' psychological state of interest.

In the differentiated analysis of the components of interest (Fig. 1), a significant difference ($F(1, 398) = 8.20$, $p < .010$, $\eta^2 = .02$) in favor of the school treatment was found for the value-based component (outreach science lab: $M = 2.36$; $SD = 0.84$; school: $M = 2.53$; $SD = 0.82$). Regarding the emotional and epistemic components, there were no significant differences (emotional: $F(1, 398) = 2.54$, $p = .112$; epistemic: $F(1, 398) = 0.06$, $p = .801$). In both treatment groups, the mean scores for the emotional component (outreach science lab: $M = 2.80$; $SD = 0.92$; school: $M = 2.90$; $SD = 0.85$) and the epistemic component (outreach science lab: $M = 2.38$; $SD = 0.77$; school: $M = 2.36$; $SD = 0.80$) were in the agreeing range (mean scores higher than 2 = "neither agree nor disagree").

Discussion

In this study, we aimed to investigate students' psychological state of interest when performing experiments at an outreach science lab and at school. In contrast to the assumption that performing experiments at an outreach science lab may be more beneficial for one's psychological state of interest (Guderian & Priemer 2008; Scharfenberg et al.

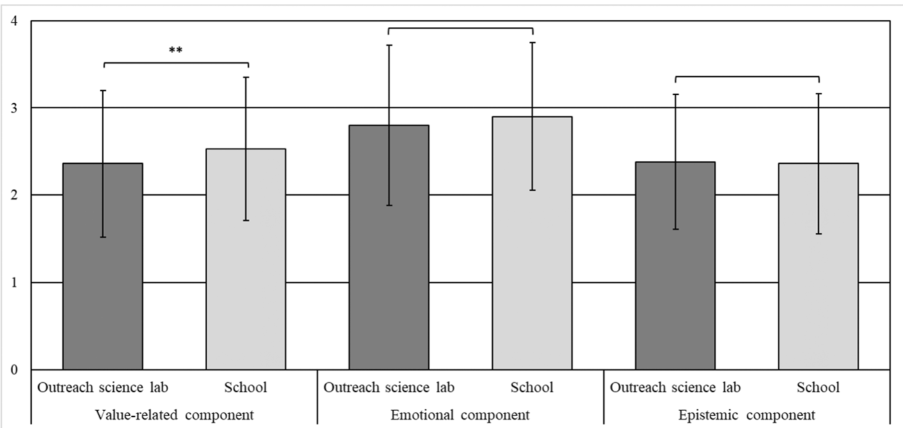

Fig. 1 Means and standard deviation of the students' psychological state of interest during experimentation at the outreach science lab and at school (** $p < .010$)

2019), our findings reveal that the students who performed experiments at the outreach science lab did not exhibit a more intense psychological state of interest than those who performed them at school. Regarding the value-related component of situational interest, even small differences in favor of the students in the school treatment could be found.

The findings on the value-based component might be related to the integration of the treatment into regular biology lessons in the school treatment (Guderian & Priemer, 2008; Klees & Tillmann, 2015; Reimann et al., 2020). In this case, the workshop was implemented during the learners' regular biology lessons and their regular teachers graded their performance. Therefore, the connection to the regular biology class and, as a result, a higher degree of personal value of the content might have been clearer to the students in the school treatment than during the singular visit to the outreach science lab. In the outreach science lab, the students' performance was not graded by their regular teachers. However, the tutors provided support and instruction during experimentation to ensure that they could use the laboratory equipment themselves and perform the experiments successfully. In this way, the students received implicit feedback about their performance on the experiments. Nevertheless, the tutors' informal feedback had no relation to the formal school assessment. When experimenting at school, the students might have attributed a higher degree of personal value to their experimental activities than the students in the outreach science lab treatment.

In both learning environments, we found all components of the psychological state of interest on a moderate to high level, with the highest values in the emotional component. Accordingly, the students had quite similar emotional experiences during their experiments in the outreach science lab and at school. In general, students evaluate hands-on activities such as hands-on experiments positively and report that these activities favored their psychological state of interest (Hofstein & Lunetta, 2004; Holstermann et al., 2010; Palmer et al., 2017; Potvin & Hasni, 2014; Swarat et al., 2012); for instance, Itzek-Greulich and Vollmer (2017) suggest that the added value of outreach science labs for the development of a psychological state of interest lies less in the learning environment itself and more in performing hands-on experiments (see also Formella-Zimmermann et al., 2022), which are rarely or never performed at school (e.g., Dierkes, 2010; Gerhard & Wrede, 2016). The fact that students performed the same experiments in both learning environments accordingly might have led to similarly high scores in their emotional component (Itzek-Greulich & Vollmer, 2017; Scheersoi et al., 2019).

In addition, we found no differences in the epistemic component between the learning environments. However, previous studies have shown different findings; for instance, in the study by Schüttler et al. (2021), the epistemic component was higher for students in the outreach science lab who worked with high-end equipment such as high-resolution thermal infrared cameras and a very precise scientific field spectrometer than for students who did not have access to such devices at school. However, no differences were found between the learning environments when low-cost equipment was used in the outreach science lab (Schüttler et al., 2021). In this regard, the materials used in our study might have differed less between the learning environments compared to the materials used in the study by Schüttler et al. (2021). This circumstance may explain why no differences were found in the epistemic component.

In previous studies (e.g., Priemer et al., 2018), the epistemic component received particular attention as this component may play a key role in re-engaging with an object of interest and, thus, in developing individual interest (Lewalter & Geyer, 2009; Mitchell, 1993; Renninger & Su, 2012). However, since students usually attend the courses of outreach science labs during a single one-day field trip, long-term effects after such a visit can hardly be expected (see Palmer et al., 2017) and are usually not evident (Guderian & Priemer, 2008; Lewalter, 2020; Nickolaus et al., 2018; Scharfenberg et al., 2019). Therefore, it is important to incorporate the students' experiences and impressions in the subsequent lessons after visiting an outreach science lab and to provide additional opportunities for the students to engage with the subject of interest (Itzek-Greulich & Vollmer, 2017; Reimann et al., 2020; Schwarzer & Itzek-Greulich, 2015; Wüst-Ackermann et al., 2018).

In this regard, it has already been shown that content-related and organizational preparations contribute to the effectiveness of visits to out-of-school learning environments (Glowinski & Bayrhuber, 2011; Orion, 1993; Wilde & Bätz, 2006) and that preparation can have positive effects on both knowledge acquisition (Reimann et al., 2020) and the psychological state of interest (Guderian & Priemer, 2008; Streller, 2015). However, the workshop conducted in this study was offered and used by teachers as an introduction to a teaching unit on enzymology; hence, they did not provide content-related but only organizational preparation (e.g., travelling to and from the workshop, meals, etc.) for the outreach science lab visit. This was agreed upon with the regular biology teachers of the participating students and we did not further control for instructional preparation. To control for this, the students' prior knowledge could be considered. In general, however, a visit to an outreach science lab or other out-of-school learning environments should not be considered as a separate event or a substitute for regular science lessons (Euler & Schüttler, 2020; Glowinski & Bayrhuber, 2011), but instead should be understood as a complementary educational learning opportunity to regular school lessons. Therefore, it is a desirable approach to intertwine school lessons and visits to an outreach science lab (Eshach, 2007; Itzek-Greulich, 2020; Orion, 1993).

In our study, we compared students' psychological state of interest between the learning environments outreach science lab and school where students performed the same experiments with the materials usually available in these environments based on a quite adequate sample. We found that experimentation in the outreach science lab did not yield a benefit in terms of students' psychological state of interest compared to experimentation at school. It may be possible that the key factor in the expression of the students' psychological state of interest was the activity of experimentation rather than differences between the learning environments (see also Itzek-Greulich & Vollmer, 2017).

However, we have to note that the effects found cannot be attributed to single characteristics of the two treatments investigated such as the different distribution of time (see Table 1). This aspect was not within the scope of our focus and represents another open field of research (see Nickolaus et al., 2018). For instance, it may be possible that the different distribution of time between the treatments (see Table 1) had an impact on the students' psychological state of interest. Although the students performed the experiments in both treatments for the same amount of time (in total 180 mins), the school treatment was conducted within students' regular biology class and was implemented across a sequence of lessons similar to how a regular teaching unit would be conducted (e.g., Sommer et al., 2018, 2020). On the one hand, the students in the outreach science lab were able to dive deeper into the lesson (i.e., to deal with the content more intensively) as all experiments were performed during the field trip, whereas in the school treatment the break between two subsequent lessons could have been more than one day. On the other hand, it is possible that the students in the school treatment could cognitively better comprehend the contents of the previous lesson in the time between the lessons and thus have some advantage in this respect. Future studies may investigate the effects of single characteristics on students' psychological state of interest. For instance, the effect of the distribution of time could be investigated by conducting the workshop in school on one school day as well. Nonetheless, our design yields ecological validity (Lewkowicz, 2010) since we compared students' psychological state of interest between two authentic environments (e.g., Euler & Schüttler, 2020; Sommer et al., 2018, 2020).

Furthermore, we have to note that our study involves only one data source taken from one certain type of workshop at one single outreach science lab. Under these circumstances, the ability to draw general conclusions is limited. However, we considered different school types (university track high schools [*Gymnasium*] and comprehensive schools [*Gesamtschule*]) and previous descriptions of outreach science labs (e.g., Sommer et al., 2018, 2020; for a detailed description, see Kirchhoff et al., 2022) in the design and implementation of our treatments (see Table 1). Therefore, the design is representative and it is not excluded that the effects found can be replicated using other data sources. Nevertheless, future studies could take other perspectives (i.e., data sources or methods) to achieve a more comprehensive understanding of the interest-promoting effect of outreach science labs.

Regarding classroom teaching practice, these findings suggest that experimentation at school can have similar positive motivational effects as conducting it in outreach science labs. However, these results do not generally indicate that an educational field trip to an outreach science lab does not provide an added value for science classes. Outreach science lab programs can complement regular school science classes by providing positive experiences and insights into practical laboratory work and working areas in a "real" scientific laboratory that school-based instruction alone may not provide. School-based instruction is limited in this regard (Euler & Schüttler, 2020; Hofstein & Lunetta, 2004; Röllke et al., 2021; Sommer et al., 2018, 2020). Science classrooms at schools lack (high-end) laboratory equipment and are designed very differently from the laboratory rooms at outreach science labs at universities (see Goldschmidt & Bogner, 2016; Röllke et al., 2021). As we aimed to compare the students' psychological state of interest during experimentation in an outreach science lab and at school, we had to choose experiments that could be carried out in both learning environments with the materials normally available in these environments; otherwise, the students' psychological state of interest would be hard to compare or it would even be incomparable. When it comes to performing more complex hands-on experiments that require special laboratory materials that are not available in schools (e.g., genetic engineering, Goldschmidt & Bogner, 2016), there may be currently no alternative to outreach science labs.

Acknowledgments The authors want to thank the participating schools, teachers, and students for their support and participation in the study.

Author contributions TK developed the concept of and design for the study, recruited the sample, performed the statistical analysis, and wrote the first draft of all article sections. MW contributed to the study design and reviewed the article. NG contributed to the study design and the statistical analyses and reviewed the article. All authors agree to be accountable for the content of the work, as well as read and approved the submitted manuscript.

Funding Open Access funding enabled and organized by Projekt DEAL. This project is part of the "Qualitätsoffensive Lehrerbildung", a joint initiative of the Federal Government and the*Länderwhich aims to improve the quality of teacher training. The programme is funded by the Federal Ministry of Education and Research (funding number 01JA1908). The authors are responsible for the content of this publication.*

Data Availability The raw data supporting the conclusions of this article will be made available by the authors on reasonable request.

Declarations The study involving human participants was reviewed and approved by the ethics committee at Bielefeld University (Ethik-Kommission der Universität Bielefeld) and written informed consent was obtained from each participant.

Competing interests The authors have no competing interests to declare that are relevant to the content of this article.

References

Affeldt, F., Weitz, K., Siol, A., Markic, S., & Eilks, I. (2015). A non-formal student laboratory as a place for innovation in education for sustainability for all students. *Education in Science, 5*(3), 238–254. https://doi.org/10.3390/educsci5030238

Anger, C., Kohlisch, E., Koppel, O., & Plünnecke, A. (2022). *MINT-Frühjahrsreport 2022* [STEM Spring Report 2022]. Gutachten für BDA, MINT Zukunft schaffen und Gesamtmetall, Köln. Retrieved, August 26 2022, from https://www.iwkoeln.de/studien/christina-anger-enno-kohlisch-oliver-koppel-axel-pluennecke-demografie-dekarbonisierung-und-digitalisierung-erhoehen-mint-bedarf.html

Brandt, A. (2005). *Förderung von Motivation und Interesse durch außerschulische Experimentierlabors [Promoting motivation and interest through extracurricular experimental laboratories]*. Cuvillier Verlag.

Dähnhardt, D., Sommer, K., & Euler, M. (2007). Lust auf Naturwissenschaft und Technik. Lernen im Schülerlabor [Desire for science and technology. Learning at an outreach science lab]. *Naturwissenschaften im Unterricht Chemie, 18*, 4–10.

Damerau, K. (2012). *Molekulare und Zell-Biologie im Schülerlabor - Fachliche Optimierung und Evaluation der Wirksamkeit im BeLL Bio (Bergisches Lehr-Lern-Labor Biologie) [Molecular and cell biology in the outreach science laboratory - Subject-specific optimisation and evaluation of effectiveness in BeLL Bio (Bergisches Lehr-Lern-Labor Biologie)] (Dissertation).* Bergische Universität Wuppertal.

Desch, I., Stiller, C., & Wilde, M. (2016). Förderung des situationsspezifischen Interesses durch eine Schülerwahl des Unterrichtsthemas. *Psychologie in Erziehung und Unterricht, 63*(1), 60–74. https://doi.org/10.2378/peu2016.art06d

Dierkes, P. (2010). Forschen, Lernen und Lehren im Schülerlabor. Das Goethe-BioLab verbindet attraktive Lernangebote mit didaktischer Forschung [Doing research, learning and teaching in the outreach science lab. The Goethe-BioLab combines attractive learning opportunities with didactic research]. *Forschung Frankfurt, 2*, 44–47.

Engeln, K. (2004). *Schülerlabors: Authentische und aktivierende Lernumgebungen als Möglichkeit, Interesse an Naturwissenschaften und Technik zu wecken* [Outreach science labs: Authentic and activating learning environments as a way to foster interest in science and technology] (Dissertation). Logos.

Eshach, H. (2007). Bridging in-school and out-of-school learning: Formal, non-formal, and informal education. *Journal of Science Education and Technology, 16*(2), 171–190. https://doi.org/10.1007/s10956-006-9027-1

Euler, M., & Schüttler, T. (2020). Schülerlabore [Outreach science labs]. In E. Kircher, R. Girwidz, & H. E. Fischer (Eds.), *Physikdidaktik: Methoden und Inhalte* (pp. 127–166). Springer.

Formella-Zimmermann, S., Kleespies, M. W., & Dierkes, P. W. (2022). Motivation and technology acceptance in a neuroscience student lab – an empirical comparison between virtual experiments with and without hands-on elements. *Frontiers in Education, 7*, Article 817598. https://doi.org/10.3389/feduc.2022.817598

Frey, A., Taskinen, P., Schütte, K., Prenzel, M., Artelt, C., Baumert, J., …, Pekrun, R. (2009). *PISA 2006 Skalenhandbuch. Dokumentation der Erhebungsinstrumente* [PISA 2006 Scale Manual. Documentation of the survey instruments]. Waxmann.

Garner, N., Hayes, S., & Eilks, I. (2014). Linking formal and non-formal learning in science education – a reflection from two cases in Ireland and Germany. *Journal of Education, 2*(2), 10–31. https://doi.org/10.25749/sis.4064

Gerhard, M., & Wrede, J. (2016). Mehr Zeit zum Experimentieren –Erfahrungen mit vorbereitenden Videoclips (ICM) während einer Unterrichtseinheit „Enzymatik" in der Oberstufe [More Time to Experiment –Experience with preparatory video clips (ICM) during an enzymology lesson in high school].

Zeitschrift für Didaktik der Biologie (ZDB) - Biologie Lehren und Lernen, 20(1), 82–91. https://doi.org/10.4119/zdb-1637

Glowinski, I., & Bayrhuber, H. (2011). Student labs on a university campus as a type of out-of-school learning environment: Assessing the potential to promote students' interest in science. *International Journal of Environmental & Science Education, 6*(4), 371–392.

Goldschmidt, M., & Bogner, F. X. (2016). Learning about genetic engineering in an outreach laboratory: Influence of motivation and gender on students' cognitive achievement. *International Journal of Science Education, 6*(2), 166–187. https://doi.org/10.1080/21548455.2015.1031293

Großmann, N., & Wilde, M. (2020). Promoting interest by supporting learner autonomy: The effects of teaching behaviour in biology lessons. *Research in Science Education, 50*, 1763–1788. https://doi.org/10.1007/s11165-018-9752-5

Großmann, N., Kaiser, L.-M., Salim, B., Ahmed, A.-K., & Wilde, M. (2021). Jahrgangsstufenspezifischer Vergleich der motivationalen Regulation im Biologieunterricht und des individuellen Interesses an biologischen Themen von Schülerinnen und Schülern der Sekundarstufe I. *Zeitschrift für Didaktik der Biologie (ZDB) Biologie Lehren und Lernen, 25*, 134–153. https://doi.org/10.11576/zdb-4095

Guderian, P. (2007). *Wirksamkeitsanalyse außerschulischer Lernorte - Der Einfluss mehrmaliger Besuche eines Schülerlabors auf die Entwicklung des Interesses an Physik [Analysis of the effectiveness of out-of-school learning environments - The influence of repeated visits to an outreach science laboratory on the development of interest in physics] (Dissertation)*. Humboldt-Universität zu Berlin.

Guderian, P., & Priemer, B. (2008). Interesseförderung durch Schülerlaborbesuche – Eine Zusammenfassung der Forschung in Deutschland [Promoting interest through visiting outreach science labs - A summary of research in Germany]. *Physik und Didaktik in Schule und Hochschule, 7*, 27–36.

Hodson, D. (2014). Learning science, learning about science, doing science: Different goals demand different learning methods. *International Journal of Science Education, 36*(15), 2534–2553. https://doi.org/10.1080/09500693.2014.899722

Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: foundations for the twenty-first century. *Science Education, 88*, 28–54. https://doi.org/10.1002/sce.10106

Holstermann, N., Grube, D., & Bögeholz, S. (2010). Hands-on activities and their influence on students' interest. *Research in Science Education, 40*, 743–757. https://doi.org/10.1007/s11165-009-9142-0

Itzek-Greulich, H. (2020). Die Anbindung von Schülerlaborprojekten an die Schule [Connecting outreach science labs to the school]. In K. Sommer, J. Wirth, & M. Vanderbeke (Eds.), *Handbuch Forschen im Schülerlabor* (pp. 139–149). Waxmann.

Itzek-Greulich, H., & Vollmer, C. (2017). Emotional and motivational outcomes of lab work in the secondary intermediate track. The contribution of a science center outreach lab. *Journal of Research in Science Teaching, 54*, 3–28. https://doi.org/10.1002/tea.21334

Jördens, J., & Hammann, M. (2021). Driven by topics: High school students' interest in evolutionary biology. *Research in Science Education, 51*(3), 599–616. https://doi.org/10.1007/s11165-018-9809-5

Kirchhoff, T., Randler, C., & Großmann, N. (2023). Experimenting at an outreach science lab vs. at school – differences in students' basic need satisfaction, intrinsic motivation, and flow experience. *Journal of Research in Science Teaching*. Advance online publication. https://doi.org/10.1002/tea.21859

Kirchhoff, T., Wilde, M., & Großmann, N. (2022). "I've always thought that I was not good at experiments…" – The benefit of non-formal learning in terms of students' perceived competence. *Frontiers in Psychology, 13*, Article 882185. https://doi.org/10.3389/fpsyg.2022.882185

Klees, G., & Tillmann, A. (2015). Design-Based Research als Forschungsansatz in der Fachdidaktik Biologie [Design-Based Research as a research approach in biology didactics]. *Journal für Didaktik der Biowissenschaften, 6*(1), 91–110.

Krapp, A. (2005). Basic needs and the development of interest and intrinsic motivational orientations. *Learning and Instruction, 15*(5), 381–395. https://doi.org/10.1016/j.learninstruc.2005.07.007

Krapp, A. (2007). An educational-psychological conceptualisation of interest. *International Journal of Educational and Vocational Guidance, 7*, 5–21. https://doi.org/10.1007/s10775-007-9113-9

Krapp, A., & Prenzel, M. (2011). Research on interest in science: theories, methods, and findings. *International Journal of Science Education, 33*, 27–50. https://doi.org/10.1080/09500693.2010.518645

Krapp, A., Geyer, C., & Lewalter, D. (2014). Motivation und Emotion [Motivation and emotion]. In T. Seidel & A. Krapp (Eds.), *Pädagogische Psychologie* (6th ed., pp. 193–222). Beltz PVU.

Lewalter, D. (2020). Schülerlaborbesuche aus motivationaler Sicht unter besonderer Berücksichtigung des Interesses [Outreach science lab visits from a motivational point of view with special attention to interest.]. In K. Sommer, J. Wirth, & M. Vanderbeke (Eds.), *Handbuch Forschen im Schülerlabor* (pp. 63–70). Waxmann.

Lewalter, D., & Geyer, C. (2009). Motivationale Aspekte von schulischen Besuchen in naturwissenschaftlich-technischen Museen [Motivational aspects of school visits to science and technology museums]. *Zeitschrift für Erziehungswissenschaft, 12*, 28–44.

Lewkowicz, D. J. (2010). The concept of ecological validity: What are its limitations and is it bad to be invalid? *Infancy, 2*, 437–450. https://doi.org/10.1207/S15327078IN0204_03

Linnenbrink-Garcia, L., Durik, A. M., Conley, A. M., Barron, K. E., Tauer, J. M., Karabenick, S. A., & Harackiewicz, M. (2010). Measuring situational interest in academic domains. *Educational and Psychological Measurement, 70*(4), 647–671. https://doi.org/10.1177/0013164409355699

Mitchell, M. (1993). Situational interest: Its multifaceted structure in the secondary school mathematics classroom. *Journal of Educational Psychology, 85*(3), 424–436.

Nickolaus, R., Steffensky, M., & Parchmann, I. (2018). *Expertise zu Effekten zentraler außerschulischer MINT-Angebote. Nationales MINT Forum* [Report on the effects of central extracurricular STEM offerings. National STEM Forum]. Retrieved January 28, 2020, from https://www.nationalesmintforum.de/fileadmin/medienablage/content/veranstaltungen/6_NMG_2018/pdf/NMF-Expertise_zu_Effekten_zentraler_au_erschulischer_MINT-Angebote_2018.pdf

Organisation for Economic Co-operation and Development (OECD). (2007). *PISA 2006. Science competencies for tomorrow's world* (volume 1: analysis). PISA, OECD Publishing. https://doi.org/10.1787/9789264040014-en

Organisation for Economic Co-operation and Development (OECD). (2016). *PISA 2015 Results (Volume I): Excellence and Equity in Education*. PISA, OECD Publishing. https://doi.org/10.1787/9789264266490-en

Orion, N. (1993). A model for the development and implementation of field trips as an integral part of the science curriculum. *School Science and Mathematics, 93*(6), 325–331. https://doi.org/10.1111/j.1949-8594.1993.tb12254.x

Palmer, D., Dixon, J., & Archer, J. (2017). Using situational interest to enhance individual interest and science-related behaviours. *Research in Science Education, 47*(4), 731–753. https://doi.org/10.1007/s11165-016-9526-x

Pawek, C. (2009). *Schülerlabore als interessefördernde außerschulische Lernumgebungen für Schülerinnen und Schüler aus der Mittel- und Oberstufe [Outreach science labs as interest-promoting out-of-school learning environments for middle and high school students] (Dissertation)*. Christian-Albrechts Universität.

Potvin, P., & Hasni, A. (2014). Interest, motivation and attitude towards science and technology at K-12 levels: A systematic review of 12 years of educational research. *Studies in Science Education, 50*(1), 85–129. https://doi.org/10.1080/03057267.2014.881626

Priemer, B., Menzl, C., Hagos, F., Musold, W., & Schulz, J. (2018). Das situationale epistemische Interesse an physikalischen Themen von Mädchen und Jungen nach dem Besuch eines Schülerlabors [Girls' and boys' situational epistemic interest in physics topics after a visit to an out-of-school science lab]. *Zeitschrift für Didaktik der Naturwissenschaften, 24*, 279–285. https://doi.org/10.1007/s40573-018-0073-z

Reimann, M., Herzog, S., Parchmann, I., & Schwarzer, S. (2020). Wirksamkeit der schulischen Vor- und Nachbereitung eines Schülerlaborbesuches [Effectiveness of preparation and follow-up lessons in school of a student lab visit]. *Zeitschrift für Didaktik der Naturwissenschaften, 26*, 227–240. https://doi.org/10.1007/s40573-020-00121-y

Renninger, K. A., & Hidi, S. (2011). Revisiting the Conceptualization, Measurement, and Generation of Interest. *Educational Psychologist, 46*(3), 168–184. https://doi.org/10.1080/00461520.2011.587723

Renninger, K. A., & Hidi, S. E. (2016). *The power of interest for motivation and engagement*. Routledge.

Renninger, K. A., & Su, S. (2012). Interest and its development. In R. M. Ryan (Ed.), *The Oxford handbook of human motivation* (pp. 167–187). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780195399820.013.0011

Röllke, K., Sellmann-Risse, D., Wenzel, A., & Grotjohann, N. (2021). Impact of inquiry-based learning in a molecular biology class on the dimensions of students' situational interest. *International Journal of Science Education, 43*(17), 2843–2865. https://doi.org/10.1080/09500693.2021.1993377

Scharfenberg, F.-J. (2005). *Experimenteller Biologieunterricht zu Aspekten der Gentechnik im Lernort Labor. Empirische Untersuchung zu Akzeptanz, Wissenserwerb und Interesse [Experimental biology lessons on aspects of genetic engineering in the laboratory learning environment. Empirical study on acceptance, knowledge acquisition and interest] (Dissertation)*. Universität Bayreuth.

Scharfenberg, F.-J., Möller, A., Kaufmann, K., & Bogner, F. X. (2019). Schülerlabore und Lehr-Lern-Labore [Outreach science labs and teaching-learning labs]. In J. Groß, M. Hammann, P. Schmiemann, & J. Zabel (Eds.), *Biologiedidaktische Forschung: Erträge für die Praxis* (pp. 229–250). Springer. https://doi.org/10.1007/978-3-662-58443-9_13

Scheersoi, A., Bögeholz, S., & Hammann, M. (2019). Biologiedidaktische Interessenforschung: Empirische Befunde und Ansatzpunkte für die Praxis [Biology didactic research on interest: Empirical findings and starting points for practice.]. In J. Groß, M. Hammann, P. Schmiemann, & J. Zabel (Eds.), *Biologiedidaktische Forschung: Erträge für die Praxis* (pp. 37–55). Springer. https://doi.org/10.1007/978-3-662-58443-9_3

Schiepe-Tiska, A., Simm, I., & Schmidtner, S. (2016). Motivationale Orientierungen, Selbstbilder und Berufserfahrungen in den Naturwissenschaften in PISA 2015 [Motivational orientations, self-perceptions, and career experiences in science in PISA 2015]. In K. Reiss, C. Sälzer, A. Schiepe-Tiska, E. Klieme, & O. Köller (Eds.), *PISA 2015 Eine Studie zwischen Kontinuität und Innovation* (pp. 99–132). Waxmann.

Schüttler, T., Watzka, B., Girwidz, R., & Ertl, B. (2021). Die Wirkung der Authentizität von Lernort und Laborgeräten auf das situationale Interesse und die Relevanzwahrnehmung beim Besuch eines naturwissenschaftlichen Schülerlabors [Effects of an authentic location and laboratory equipment for the situational interest and the perception of content relevance when visiting an out-of-school science lab]. *Zeitschrift für Didaktik der Naturwissenschaften, 27*, 109–125. https://doi.org/10.1007/s40573-021-00128-z

Schwarzer, S., & Itzek-Greulich, H. (2015). Möglichkeiten und Wirkungen von Schülerlaboren. Vor- und Nachbereitung zur Vernetzung mit dem Schulunterricht [Possibilities and effects of outreach science labs. Pre- and post-processing for networking with school lessons]. *Naturwissenschaften im Unterricht: Chemie, 26*(147), 8–13.

Sommer, K., Firstein, A., & Rothstein, B. (2020). Authentizität (der Wissenschaftsvermittlung) im Schülerlabor [Authenticity (of science teaching) in an outreach science lab]. In K. Sommer, J. Wirth, & M. Vanderbeke (Eds.), *Handbuch Forschen im Schülerlabor. Theoretische Grundlagen, empirische Forschungsmethoden und aktuelle Anwendungsbeispiele* (pp. 21–30). Waxmann.

Sommer, K., Wirth, J., & Rummel, N. (2018). Authentizität der Wissenschaftsvermittlung im Schülerlabor – Einführung in den Thementeil [Authenticity of science teaching in the student lab - Introduction]. *Unterrichtswissenschaft, 46*, 253–260. https://doi.org/10.1007/s42010-018-0022-z

Swarat, S., Ortony, A., & Revelle, W. (2012). Activity matters: Understanding student interest in school science. *Journal of Research in Science Teaching, 49*(4), 515–537. https://doi.org/10.1002/tea.21010

Streller, M. (2015). *The educational effects of pre and post-work in out-of-school laboratories (Dissertation)*. Technische Universität Dresden.

Taber, K. S. (2018). The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in Science Education, 48*, 1273–1296. https://doi.org/10.1007/s11165-016-9602-2

Vogt, H. (2007). Theorie des Interesses und Nicht-Interesses [Theory of interest and non-interest]. In D. Krüger & H. Vogt (Eds.), *Theorien in der biologiedidaktischen Forschung* (pp. 9–20). Springer.

Wilde, M., & Bätz, K. (2006). Einfluss unterrichtlicher Vorbereitung auf das Lernen im Naturkundemuseum. *Zeitschrift für Didaktik der Naturwissenschaften, 12*, 77–89.

Wüst-Ackermann, P., Vollmer, C., Randler, C., & Itzek-Greulich, H. (2018). The Vivarium: Maximizing learning with living invertebrates - an out-of-school intervention is more effective than an equivalent lesson at school. *Insects, 9*(3), 1–26, https://doi.org/10.3390/insects9010003

Zhang, F., & Bae, C. L. (2020). Motivational factors that influence student science achievement: A systematic literature review of TIMSS studies. *International Journal of Science Education, 42*(17), 2921–2944. https://doi.org/10.1080/09500693.2020.1843083