Schmid et al. International Journal of STEM Education (2026) 13:53
https://doi.org/10.1186/s40594-026-00643-w

International Journal of STEM Education

RESEARCH

Open Access

The use of school labs as extracurricular STEM programmes and their effects on STEM career intentions

Rahel Schmid[1*], Robbert Smit[1] and Nicolas Robin[2]

Abstract

Background Extracurricular science, technology, engineering, and mathematics (STEM) programmes are very popular and are actively used by teachers and students. Studies evaluating these initiatives show positive effects on cognitive, affective, and motivational student traits, which in turn can influence career choices in STEM. Based on attendance at such programmes, specifically school labs, we measured students' learning gain, the enjoyment experienced during attendance, the change in interest and self-efficacy beliefs in STEM, and how these factors related to STEM career intentions. To this end, 2605 students who had attended a school lab in Switzerland or in the Principality of Liechtenstein were surveyed with a questionnaire.

Results Based on a structural equation model, it could be shown that learning gains and enjoyment of the visit correlated strongly. Furthermore, in the model these two variables did not have a direct effect on STEM career intentions, but an indirect one via the change in self-efficacy beliefs. This shift in beliefs related strongly to STEM career intentions as well as the development in interest in STEM, which was also highly associated with STEM career intentions.

Conclusions Overall, we could demonstrate the importance of four direct and indirect factors resulting from attending a school lab that are important influences on the fostering of students' STEM career intentions.

Keywords Usage analysis, Extracurricular STEM programmes, School labs, STEM career intentions, Structural equation model

Introduction

Over the past 25 years, numerous extracurricular science, technology, engineering, and mathematics (STEM) programmes like Experio Roche in Switzerland, Johannes Kepler University Linz (JKU) Open Lab in Austria, and the DLR_School_Lab Berlin in Germany have been initiated in German-speaking countries. Experio Roche offers various workshops in the fields of computer science, technology, and natural sciences, such as programming Lego robots or chemical syntheses. These take place in its school laboratory (school lab), which is located at the Learning Center of Hoffmann-La Roche AG. The JKU

*Correspondence:
Rahel Schmid
rahel.schmid@phsg.ch
[1]Institute for Science Teacher Education, St.Gallen University of Teacher Education, St.Gallen, Switzerland
[2]Vice-Rectorate for Education, St.Gallen University of Teacher Education, St.Gallen, Switzerland

Open Lab on the campus of the Johannes Kepler University Linz focuses on chemistry and deals with related topics. Additionally, at DLR_School_Lab Berlin, fascinating experiments are carried out in the fields of aviation, space, energy, transport, and digitalization (LernortLabor & IPN Kiel, 2023). These are only three examples from German-speaking countries.

There are various reasons why extracurricular STEM programmes have been introduced. At the turn of the century, science teachers in many countries expressed concern that science education in schools was often outdated and boring, and that it did not teach the skills and ways of thinking that students needed to engage as citizens in the 21st century. In contrast, knowledge transfer at extracurricular learning locations was seen as inspiring and challenging (Millar & Osborne, 1998). Others see poor results in international comparative assessments such as the Programme for International Student Assessment (PISA) or Trends in International Mathematics and Science Study (TIMSS), or the high status of STEM professions as reasons for the establishment of extracurricular STEM programmes (Tillmann & Wegner, 2021). In general, it can be said that these programmes were founded to give students practical insights into the STEM world outside of regular school lessons. One of the aims of extracurricular STEM programmes is to arouse interest, promote motivation, and raise self-efficacy beliefs, as well as have a positive influence on career choices in the STEM field (Kitchen et al., 2018; Laine et al., 2017; LernortLabor & IPN Kiel, 2023; Tillmann & Wegner, 2021). Extracurricular STEM programmes are now an integral part of school education and are widely used. They have also been the subject of intensive research since the early 2000s. However, despite the impact of these extracurricular STEM programmes being of significant interest, their effectiveness has not yet been conclusively clarified (Tillmann & Wegner, 2021). The variability in these effects depends on several moderating factors, including the nature of the informal science programme, student grade level, STEM subject, and publication type and year.

Against this background, this work investigates the impact of visits in school labs on students' career intentions in the STEM field, as well as the moderating factors influencing this relationship. The use of school labs takes into account cognitive, motivational, and affective components. These are assessed in this study as the learning gain from attendance, the enjoyment of the visit, and the change in interest and in self-efficacy beliefs in STEM as a result of attendance. Specifically, we examine how these variables are related. The term "career intentions" implies that a career choice has not yet been made. The theoretical framework of our study is based on the expectancy–value theory developed by Wigfield and Eccles (2000). According to this, expectancy of success and subjective task value influence career choice. Expectancy of success is the belief that one will be successful in a particular area. If students believe that they are good at science, for example, they are more likely to consider relevant career fields. This is a cognitive judgement. Subjective task value refers to the question of why this career field should be chosen. This value is composed of motivational and affective components.

Extracurricular STEM programmes in school labs

An extracurricular STEM programme is a learning space outside the school building where students can learn formally, non-formally, or informally. Formal learning encompasses the entire public education system, from early education in kindergarten to university. Non-formal learning refers to organized learning programmes that take place outside of the regular school curriculum. Informal learning, on the other hand, takes place throughout life and is shaped by influences such as family, work, media, or leisure time. Informal learning is never organized and therefore often spontaneous (Ainsworth & Eaton, 2010). It arises from the learner's involvement in activities that are not undertaken with a learning purpose in mind (Council of Europe, 2025). Extracurricular learning sites enable direct encounters with a learning object and/or a set of facts. The process of learning in such an extracurricular context occurs when there is direct engagement with the learning object or topic. This, in turn, leads to the acquisition of knowledge.

Learning can take place both consciously and unconsciously. This encounter can be authentic if the learning object or subject matter is experienced in its original environment, for example in nature such as by rivers, in meadows, in forests, or on farms. Alternatively, it can also take place in an artificial environment, such as a museum. Extracurricular learning locations differ in terms of their methodological and didactic design. While an old town, for example, often gets by without any specific didactics, facilities such as science centres or school laboratories are specially designed for educational purposes (Ainsworth & Eaton, 2010; Callanan et al., 2011; Chng & Tan, 2024; Messmer et al., 2011). In this study we will focus on school labs.

School labs are specialized facilities that are often located at universities, research centres, companies, museums, or science centres. They offer school class courses that last from a few hours to several days. These courses address topics from the fields of STEM. They focus on activating forms of learning that enable students to work independently with authentic research questions and working methods in the STEM field. School labs are characterized by their high level of commitment, creativity, and originality. They differ in terms of their goals, their personnel and material resources, and their thematic focus, as well as their target audience (Chng & Tan, 2024; Pawek, 2009). The students are supervised and instructed by qualified specialists (LernortLabor & IPN Kiel, 2023).

Various studies with different designs and approaches have been carried out to investigate the impact of a visit to a school lab. The results show predominantly positive effects on cognitive, affective, and motivational characteristics such as learning gains, interest, motivation, self-efficacy beliefs, and the students' emotions (e.g. Kitchen et al., 2018; Laine et al., 2017; Neher-Asylbekov & Wagner, 2023; Xia et al., 2025).

Cognitive effects of school labs

Attending a school lab expands and enriches regular classroom lessons, and supports both subject-specific and interdisciplinary skills development (Tillmann & Wegner, 2021). It needs to be mentioned, however, that in many studies with interventions in school labs there were also some learning gains among students who experienced regular in-school instruction (e.g., conventional lessons, classroom experiments) rather than attending a school lab (i.e., Itzek-Greulich et al., 2014, 2015; Scharfenberg et al., 2007). Goldschmidt et al. (2016) also found gender-specific differences, with female students showing significantly higher learning gains than male students. Huwer (2015) was also able to demonstrate a long-term stable increase in learning in school labs, as evidenced by knowledge gains across different grade levels and topics. In addition, a study by Zehren et al. (2013) noted that students who regularly attended a school lab over a longer period of time developed an improved understanding of scientific contexts. This enhanced understanding was reflected in a higher quality of epistemic questions. Students learned to think ahead and focus on observable and measurable quantities. This helped them formulate more precise predictions. In addition, Kirchhoff et al. (2022) demonstrated that self-perceived competence in experimentation was positively supported in school labs, especially by less competent students.

In summary, it can be said that the results regarding learning gains are mixed. They cannot always be clearly attributed to the visit to a school lab. Nevertheless, school labs enrich STEM education and can contribute to the teaching of STEM content and a more accurate understanding of science. According to the expectancy–value theory by Wigfield and Eccles (2000), this can also have a positive effect on career choices.

Affective effects of school labs

Research on visits to school labs shows that extracurricular learning experiences can evoke strong emotional reactions and promote students' motivation to engage more intensively with scientific topics (Itzek-Greulich & Vollmer, 2017; Röllke et al., 2020). In this section, we will first discuss the affective aspects before moving on to the motivational ones in the next section. Molz et al. (2022) analysed the results of 12 studies from 2004 to 2020 that surveyed enjoyment and general appreciation of school labs. The measured values were consistently high, with results achieving approximately 80% of the maximum possible value. Molz et al. (2022) emphasized that these outcomes applied regardless of country, target group, setting, discipline, or time frame. Emotions therefore play a central role in school labs and have a significant influence on students' motivation, engagement, and learning success. However, one investigation demonstrated no differences in emotional experience when comparing learning in school and school labs (Kirchhoff et al., 2024).

The predominantly positive emotions reported during visits to school labs are also important predictors for career choices (Muñoz-Losa & Corbacho-Cuello, 2025). In addition, according to the expectancy–value theory, motivational effects can also play a significant role in the career choice process, as we will see in the next section.

Motivational effects of school labs

Promoting interest is a central goal of many school labs (Kitchen et al., 2018; Laine et al., 2017; LernortLabor & IPN Kiel, 2023; Tillmann & Wegner, 2021). This is due to the fact that interest in scientific topics is closely linked to students' learning gain and future career choice in this field. Students with a strong interest in science subjects generally perform better in these subjects and are more likely to pursue a career in the STEM field (Krapp, 1992; Taskinen et al., 2013). Numerous studies over the last two decades have shown that both one-off and repeated visits to school labs can promote situational interest in STEM topics (Brandt, 2005; Engeln, 2004; Guderian, 2007; Mokhonko et al., 2014; Pawek, 2009; Simon, 2019). Situational interest refers to short-term interest in a (learning) object that is often stimulated by an external stimulus such as a fascinating experiment (Krapp, 1992; Wilhelm et al., 2011) or related, hands-on activities (Neher-Asylbekov & Wagner, 2023).

School labs generally strive to provide authentic tasks, which in turn is a factor that has a significant influence on students' situational interest (Nachtigall & Rummel, 2021). Only a few works found no increase in interest in science (e.g., Hubricht & Ralle, 2016). It needs to be pointed out that the promotion of situational interest often proved not to be long-term, as the values decreased again over time (Engeln, 2004; Guderian, 2007; Pawek, 2009). However, Guderian (2007) was able to show that each subsequent visit to a school lab can reactivate situational interest. Debriefings after the visit and follow-up lessons at school seem to anchor interest in the long term (Neher-Asylbekov & Wagner, 2023). In addition, Palmer et al. (2017) demonstrated in a longitudinal study that repeatedly aroused situational interest is associated with the development of individual interest in science. Although situational interest does not always necessarily lead to long-term individual interest, it is an essential basis for long-term development (Hidi & Renninger, 2006).

Similar to interest, self-efficacy beliefs also have a strong influence on students' career choices (Bandura et al., 2003). Self-efficacy refers to a person's belief that they can plan and carry out actions based on their own abilities in order to achieve a goal (Bandura, 1977). It is a strong predictor of success in learning science and technology. Self-efficacy not only influences learning processes, but also shapes motivation, interest, and career orientation (Bandura et al., 2003; Catalano, 2024; Yamani & Almazroa, 2024). Therefore, changes in self-efficacy beliefs have often been investigated in studies on school lab visits. Few have found no change (e.g., Hubricht & Ralle, 2016). More frequently, investigations were able to identify positive effects after a visit (Brandt, 2005; Mokhonko et al., 2014; Pawek, 2009; Weßnigk, 2013). Pawek (2009) and Weßnigk (2013) even observed long-term changes.

School labs make a significant contribution in the career choice process. School labs with a focus on career guidance have even placed this goal at the heart of their work. Those based at universities, research institutes, or companies in particular often offer direct entry opportunities into STEM professions. At the same time, other types of school labs like classic school labs or student research centres also create a basis for arousing enthusiasm for these subjects by specifically promoting interest in the STEM field (LernortLabor & IPN Kiel, 2023). As Taskinen (2010) shows, there is a close link between interest and self-efficacy in science and career choice in this field. Both have a strong influence when it comes to deciding in favour of a particular occupation. A large number of studies were able to demonstrate that visits to school labs can have a positive influence on career orientation (Henriksen et al., 2014; Kitchen et al., 2018; Reinhold et al., 2018; Sasson, 2019; Weßnigk, 2013; Zehren et al., 2013). However, Weßnigk (2013) found a lasting effect exclusively among girls. In general, however, there is little evidence to date of long-term effects on later career choices (Nationales MINT Forum e. V., 2018).

Based on their results, Reimann et al. (2020) assume that visits to school labs tend to reinforce students' existing attitudes towards STEM professions rather than fundamentally change them. This means that students with a positive attitude towards STEM professions are encouraged by the visit in their intention to pursue such a profession, while on the other hand those with a negative attitude are confirmed in their rejection of STEM professions. Nevertheless, research on informal STEM learning experiences suggests that such opportunities can contribute to the development of students' STEM identity (Simpson et al., 2025; Sonnert et al., 2025). In turn, STEM identity has been shown to be associated with STEM-related career interests, career intentions, and career choices (Guo et al., 2026; Sonnert et al., 2025). By analysing various investigations, Wang and Degol (2013) concluded that career choices mostly reflect personal interests. Thereby, a gender difference was identified. Women seem to prefer a profession that deals with people and can be practised flexibly, which suits them in terms of parenting responsibilities. Wang and Degol (2013, p. 328) also summarize that current studies indicate that "STEM fields are perceived by women as being object-oriented, male-dominated, and not family friendly". According to Regan and DeWitt (2015, p. 63), in addition to gender, several other factors influence career choice. These include "age, attainment, teaching and learning, school type, influential individuals (parents and teachers), and images of science and scientists".

The question therefore arises as to what extent the use of school labs can influence students' STEM career intentions. Although many causes are known, no attempt has yet been made to represent the possible effects in a comprehensive model. Therefore, in this article we will examine the relationships between cognitive, affective, and motivational factors and STEM career intentions due to the visit. Therefore, the research question is: how are self-assessed learning gain, experienced enjoyment, change in interest in STEM and in self-efficacy beliefs in STEM, and STEM career intentions due to the visit related? We postulate the following explorative hypotheses (as shown in Fig. 1):

1. Higher self-assessed learning gain due to the visit correlates with stronger STEM career intentions.
2. Greater enjoyment of the visit correlates with stronger STEM career intentions.
3. Greater positive change in interest is associated with stronger STEM career intentions.
4. Greater positive change in self-efficacy beliefs is associated with stronger STEM career intentions.

Method

Research design

A cross-sectional quantitative approach was chosen to answer the research question and to test the hypotheses. Selected school labs in German- and French-speaking Switzerland and the Principality of Liechtenstein took part in the study. These school labs are characterized by a didactically sound design, take place in a laboratory context, and are led or supervised by external experts. In German-speaking Switzerland, Experio Roche, go tec!,

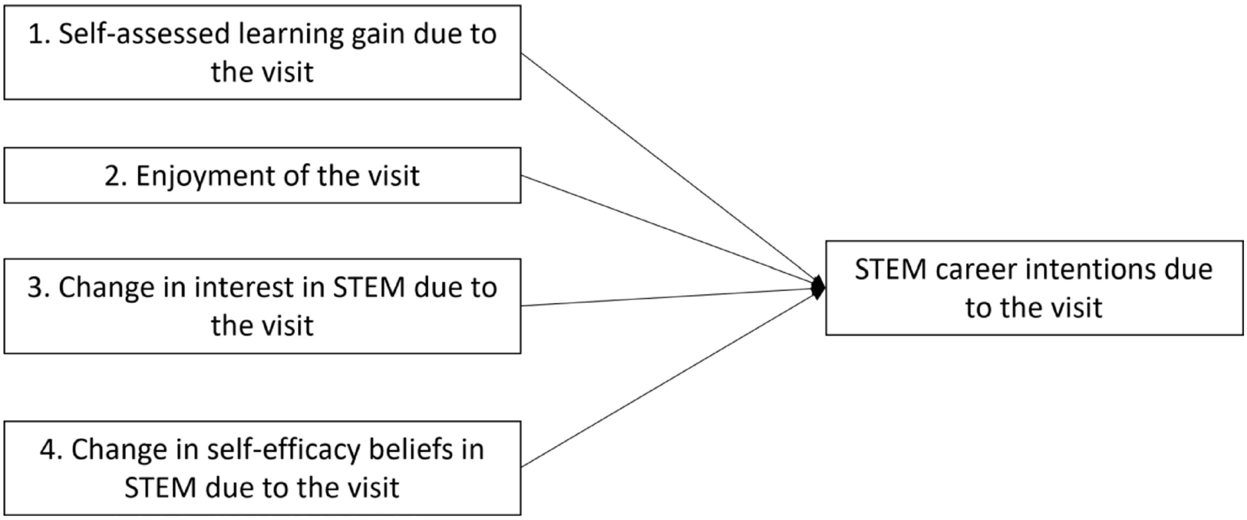

Fig. 1 Assumed factors explaining STEM career intentions based on a visit to a school lab (simplified model)

Table 1 Sample characteristics ($N = 2{,}605$)

School type	Gender				Mean age	Language at home			Part of Switzerland		
Lower secondary education	Male	Female	Non-binary	No answer		German or Swiss German	Other language	No answer	German-speaking Switzerland or the Principality of Liechtenstein	French-speaking Switzerland	No answer
	373 (47.2%)	398 (50.4%)	12 (1.5%)	7 (0.9%)	13.9	565 (71.5%)	218 (27.6%)	7 (0.9%)	776 (98.2%)	14 (1.8%)	–
Upper secondary education	689 (38%)	1,059 (58.4%)	53 (2.9%)	11 (0.6%)	17.2	1,348 (74.4%)	452 (24.9%)	12 (0.7%)	1,612 (89%)	20 (1.1%)	180 (9.9%)

Lower secondary education $n = 790$; Upper secondary education $n = 1812$

PSI iLab, Klassenlabor at the St. Gallen Natural History Museum, Lernlabor of the University of Teacher Education Lucerne, MobiLab, mobiLLab, Smartfeld, Swiss TecLadies, TecDay, and Technorama took part. Scienscope took part from French-speaking Switzerland, and the Principality of Liechtenstein was presented by pepperMINT.

The data were collected over a year from April 2022 to April 2023. The students were surveyed with a questionnaire within two weeks after attending one of the listed school labs. The questions were answered by the students in during school lessons. In order to minimize the loss of teaching time as much as possible, we had to limit ourselves to a post-evaluation. Participation was voluntary and based on informed consent. All data have been anonymized.

Sample

A total of 2,605 students took part in the survey, 790 of whom were in lower secondary education (grades 7–9) and 1,812 in upper secondary education (grades 10–13). Three students did not specify a grade level. Details regarding gender distribution, average age, language spoken at home, and part of Switzerland can be found in Table 1.

Instruments

The students were questioned on whether they enjoyed the visit, as well as about their self-assessed learning gain, their self-assessed change in interest in STEM and their self-assessed change in self-efficacy beliefs in STEM, and possible STEM career intentions due to their attendance. Details on the scales can be found in Table 2. The "enjoyment of the visit" one was adapted from Brandt (2005), Peixoto et al. (2015), and Tulis and Ainley (2011). The four scales "self-assessed learning gain due to the visit", "change in interest in STEM due to the visit", "change in self-efficacy beliefs in STEM due to the visit", and "STEM career intentions due to the visit" were evaluated by the use of the phrase starting with: "I have the impression that now, after the visit …" which was taken from a study by Güdel (2014). The "self-assessed learning gain due to the visit" scale was self-created. The "change in interest in STEM due to the visit" scale was adopted from

Table 2 Sample items for each scale applied

Variable	Sample item	# items	Cronbach's Alpha	Sources
Enjoyment of the visit	The activities were fun.	3	0.88	Adapted from Brandt (2005), Peixoto et al. (2015) and Tulis and Ainley (2011)
Self-assessed learning gain due to the visit	I have the impression that now, after the visit, I have learned something that I didn't know before.	5	0.93	Adapted from Güdel (2014), self-created
Change in interest in STEM due to the visit	I have the impression that now, after the visit, I enjoy scientific and technical subjects more than I did before.	5	0.87	Adapted from Güdel (2014)
Change in self-efficacy beliefs in STEM due to the visit	I have the impression that now, after the visit, I am more confident in solving a scientific-technical problem.	3	0.91	Adapted from Güdel (2014)
STEM career intentions due to the visit	I have the impression that now, after the visit, I can imagine working in a scientific or technical profession.	4	0.93	Adapted from Güdel (2014)

Table 3 Overview of descriptive data

Variable	*N*	M	SD
Enjoyment of the visit	2542	4.31	0.97
Self-assessed learning gain due to the visit	2400	4.35	1.17
Change in interest in STEM due to the visit	2402	3.36	1.13
Change in self-efficacy beliefs in STEM due to the visit	2372	3.33	1.25
STEM career intentions due to the visit	2388	3.20	1.31

Six-point Likert scale with 1 = strongly disagree, 2 = disagree, 3 = somewhat disagree, 4 = somewhat agree, 5 = agree and 6 = absolutely agree; *M* = mean; *SD* = standard deviation

the "assessment of the development of interests" one from Güdel (2014). The "change in self-efficacy beliefs in STEM due to the visit" scale was again based on a scale by Güdel (2014) that focused on self-efficacy beliefs in technical tasks. The "STEM career intentions due to the visit" one was also drawn from a scale from Güdel (2014). To evaluate the items, a six-point Likert scale was used (1 = strongly disagree, 2 = disagree, 3 = somewhat disagree, 4 = somewhat agree, 5 = agree and 6 = absolutely agree).

Data analysis

A descriptive analysis was carried out using SPSS. Internal consistency was tested with Cronbach's alpha. According to Taber (2018), values between 0.87 and 0.93 indicate good internal consistency (Table 3). In order to investigate the influence of the use of school labs on STEM career intentions, a theoretical model based on the expectancy–value theory was established and tested. Based on this first model, several models with and without mediators were assessed utilizing Mplus 7 for reasons of optimizing the fit values. The applied cross-sectional SEM allows us to formulate causal assumptions as a hypothesis that can be tested. However, not rejecting a hypothesis (or, in other words, not rejecting our model) does not mean the causal assumptions in our model are correct (Geiser, 2012). In this sense, we can only speak of correlations between variables as a result. Self-assessed learning gain, change in interest in STEM, change in self-efficacy beliefs and STEM career intentions due to the visit were modelled with latent variables. Enjoyment of the visit was evaluated with manifest variables, as it was only surveyed once in all labs, but three times after each module on the school lab TecDay. An average value was computed here. Missing values were present in the data-set. Since these values were unrelated to the study design, we assumed that they occurred at random. Therefore, we applied the full information maximum likelihood (FIML) method, which allows all available data to be incorporated into the model. In all cases, the proportion of missing values was below 10%, which is considered acceptable (Enders, 2010).

Results

In the following table the descriptive data are presented. Generally, students' enjoyment of the visit, self-assessed learning change in interest in STEM and change in self-efficacy beliefs in STEM, and STEM career intentions due to their attendance were somewhat positive (Table 3).

Starting with a model in which all factors led directly to STEM career intentions, model improvements showed that an indirect model with mediators better explained the relationships. In the final model, STEM career intention was modelled as the outcome variable and the cognitive, affective, and motivational student characteristics as explanatory variables. In the following, causal terminology refers to the theoretically specified model. However, as the analyses are based on correlational data, the findings do not establish causality but merely indicate consistency with the proposed relationships (cf. Bozionelos, 2003). Changes in self-efficacy beliefs and in interest were predicted in this model by self-assessed learning gain and enjoyment of the visit. In other words, change in self-efficacy beliefs and change in interest were mediators in the model (Fig. 2). Age, gender, and school level (lower

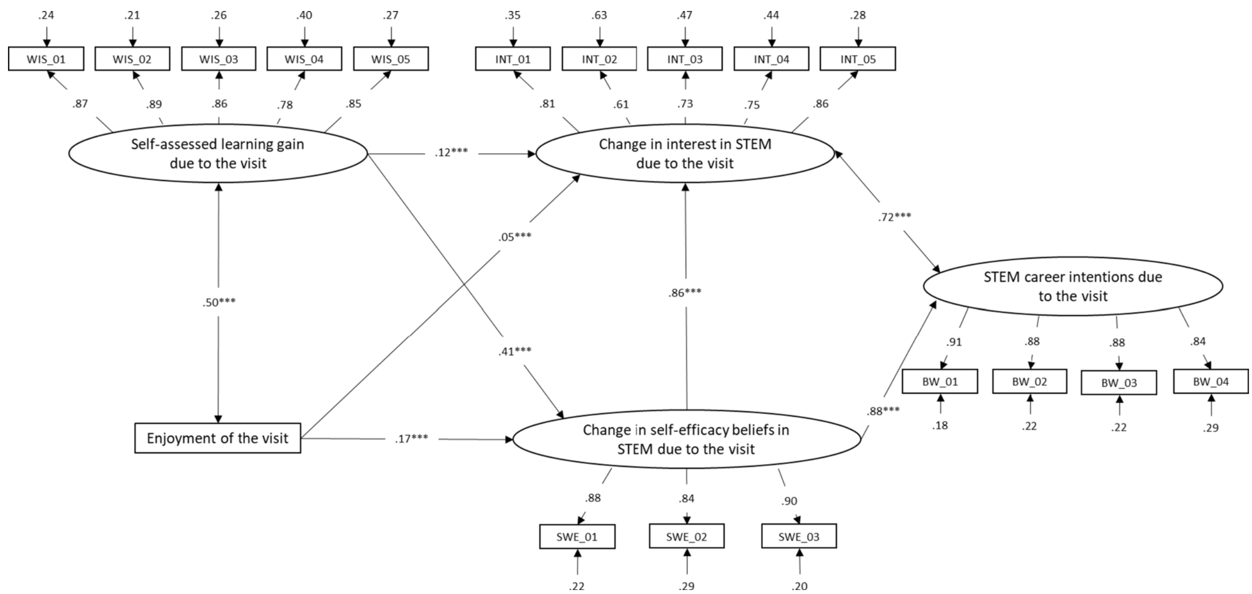

Fig. 2 Interdependencies to explain STEM career intentions (standardized estimates, all paths significant, ***$p < .001$).
Note The model is shown without the control variables age, gender, and school level (lower and upper secondary level).

and upper secondary level) were utilized as control variables. To test whether the structural equation model was appropriate, the fit indices were reviewed against the critical values of Hu and Bentler (1999). The following values were considered a good model fit: $\chi^2 = 1120.34$, $df = 167$, $p < .001$, $\chi^2/df = 6.71$; RMSEA = 0.05, CFI = 0.96 and TLI = 0.95. In addition, multicollinearity was checked using the VIF values. A value of 10 or higher is often considered critical, indicating possible multicollinearity. Since the VIF values of 1.4 for enjoyment, 1.6 for learning gain, 4.2 for change in interest, and 3.6 for change in self-efficacy beliefs are clearly below 10, no multicollinearity is assumed (O'brien, 2007).

In this model, students' STEM career intentions can be explained both directly and indirectly with the following selected variables: self-assessed learning gain due to the attendance, enjoyment of the visit, change in interest in STEM and change in self-efficacy beliefs in STEM, and STEM career intentions due to the attendance. In total, 28.6% of the variance in the change in self-efficacy expectations in STEM, a high 95% of the variance in the change in interest in STEM and a high 79.4% of the variance in STEM career intentions are explained by the model (Fig. 2).

The structural equation model shows that the self-assessed learning gain correlated strongly with the enjoyment of the visit ($\beta = 0.50$, $p < .001$). Students who stated that they had learned a lot also experienced great enjoyment in the school lab. It can also be seen that self-assessed learning gain had a small effect on the change in interest in STEM ($\beta = 0.12$, $p < .001$) and a medium effect on the change in self-efficacy beliefs in STEM ($\beta = 0.41$, $p < .001$). This means that students who felt that they had learned a lot were more interested in STEM after the workshop and were also more confident in successfully mastering scientific and technical tasks in these areas or solving problems.

Enjoyment had a significant but rather small effect on the change in interest in STEM ($\beta = 0.05$, $p < .001$) and a small to medium effect on the change in self-efficacy beliefs in STEM ($\beta = 0.17$, $p < .001$). Students who enjoyed the visit showed slightly more interest in STEM after the visit and were more confident in working on a science and technology topic than students who had less enjoyment.

The variable "change in self-efficacy beliefs in STEM" had a strong effect on the variable "change in interest in STEM" ($\beta = 0.86$, $p < .001$) as well as on STEM career intentions ($\beta = 0.88$, $p < .001$). This means that, for example, students who were more confident about working on a scientific/technical topic after the workshop were also more interested in STEM after the workshop and were also more likely to imagine learning a profession in the STEM field. In addition, the variable "change in interest in STEM" is strongly related to the variable "STEM career intentions" ($\beta = 0.72$, $p < .001$). Students who were more interested in STEM after the visit were also more likely to imagine pursuing a career in the STEM field (Fig. 2).

In the following section, we report some effects of control variables on the five main variables in our model. These effects were not depicted in Fig. 2 in order to maintain clarity. In general, the beta effects of control variables were rather small. Gender had a negligible effect on self-assessed learning gain only (β = −0.07, p = .001). With regard to the school level, a small effect on the self-assessed learning gain (β = 0.11, p < .001) could be demonstrated. In our case, this means that students at upper secondary level assessed their learning growth as slightly higher than students at lower secondary level. The school level also had a small effect on the enjoyment of the visit (β = −0.11, p < .001). In our model, lower secondary school students showed slightly more enjoyment of the visit than upper secondary school ones. Gender also had a small to medium effect on the change in self-efficacy expectation in STEM (β = 0.16, p < .001). The value for the variable "change of self-efficacy expectation" for male students was slightly higher than that for female ones. Age had a rather small effect on the variable "change in self-efficacy expectation in STEM" (β = −0.07, p < .01). Younger students were slightly more confident about working on a scientific/technical topic after the visit compared to older ones. Age, gender, and grade level had no significant effect on the variable "change in interest in STEM". Finally, gender (β = 0.04, p < .001) and grade (β = 0.09, p < .001) had a negligible effect on STEM career intentions.

Looking at both the direct and indirect paths from learning gain to interest growth, the total effect is significant for all paths combined (β = 0.49, p < .001). This effect is explained more strongly through the indirect path from self-assessed learning gain to the change in interest in STEM via the change in self-efficacy beliefs in STEM (β = 0.37, p < .001) than via the direct path from self-assessed learning gain to the change in interest in STEM (β = 0.12, p < .001). This would mean that students who reported a high learning gain also mentioned high self-efficacy and thus high interest in STEM. For enjoyment of the visit the explanation is somewhat similar. The total effect of enjoyment on interest is significant (β = 0.20, p < .001). This effect is largely explained by the indirect path from enjoyment to the change in interest in STEM via the change in self-efficacy beliefs in STEM (β = 0.15, p < .001). The direct path from enjoyment to the change in interest in STEM is significant, but negligibly small (β = 0.05, p < .001).

The differences in STEM career intentions based on the visits can also be explained in more detail using indirect paths. The difference demonstrated by students in STEM career intentions is fully explained by the indirect path from self-assessed learning gain to career STEM career intentions via the change in self-efficacy beliefs in STEM (β = 0.36, p < .001). The total effect of enjoyment on STEM career intentions is also significant (β = 0.15, p < .001), which is completely explained by the indirect path from enjoyment to STEM career intentions. Therefore, contrary to our assumption (Fig. 1), learning gain and enjoyment do not have a direct effect on STEM career intentions, but they have an indirect influence on STEM career intentions via self-efficacy beliefs. Self-efficacy beliefs, on the other hand, exert a substantial influence on STEM career intentions in the model, both through change in interest and directly.

Discussion and conclusion

Based on our research question, we investigated the extent to which the use of school labs might influence students' career intentions in STEM subjects. In this context, we have looked at different variables related to STEM career intentions which can be experienced during a visit, or which can be influenced by a visit to a school lab. These variables were students' self-assessed learning, enjoyment, change in interest in STEM and in self-efficacy beliefs in STEM due to the visit. With respect to our theoretical expectancy-value model, we explored whether students with higher expectancy beliefs and higher values in science are more likely to consider relevant career fields. It was expected that self-assessed learning gain (Hypothesis 1) and enjoyment of the visit (Hypothesis 2), as well as the change in interest (Hypothesis 3) and in self-efficacy beliefs influence STEM career intentions (Hypothesis 4).

We were able to confirm all hypotheses. Learning gain and enjoyment of the visit showed a relationship with change in interest and change in self-efficacy beliefs in STEM. In the SEM model the indirect effects from learning gain to interest via self-efficacy beliefs, and from enjoyment of the visit to interest via self-efficacy beliefs were stronger than the direct effects. Thus, change in self-efficacy beliefs could be identified as a mediator between learning gain and change in interest, and between enjoyment of the visit and change in interest. In addition, self-efficacy acted as a mediator between learning gain or enjoyment and STEM career intentions.

Hypotheses 3 and 4 confirm the assumption of Taskinen (2010) and Priemer and Lewalter (2009) that interest and self-efficacy beliefs strongly influence students' STEM career intentions. Compared to the model in the study by Luo et al. (2021), the beta values here are considerably higher. The self-perceived change in self-efficacy showed a strong relationship with STEM career intentions, but also with the change in interest in STEM. One interpretation could be that students who have altered their self-efficacy beliefs in STEM due to the visit have also changed their interest in STEM and are more likely to consider pursuing a STEM profession. Change in interest in turn had a strong correlation with STEM career intentions. Students who are interested in STEM are more likely to pursue a STEM profession, and students who follow a STEM career path are likelier to be interested in STEM. In addition, learning gain and enjoyment of the visit demonstrate an indirect relationship with STEM career intentions. Both variables might influence STEM career intentions via self-efficacy beliefs. This indirect effect is apparently stronger than the direct one in the SEM model. Self-efficacy beliefs seem to play a central role in these relationships. In sum, it might be assumed that a positively experienced visit to a school lab can have an influence on STEM career intentions. The utilization of school labs by teachers facilitates their presentation of STEM careers to students in a vivid manner as part of the career selection process.

Limitations

There are also some limitations to consider. When we mention change in this study, we are reporting self-assessed growth or self-assessed decline from the perspective of the individual student. It is not a pre–post measurement. In our study, students at the lower secondary and upper secondary levels in the middle of the career choice process were surveyed. Some studies indicate that career interest remains largely stable from the age of 15 (Bergmann & Eder, 2000; Nagy & Husemann, 2010). It is therefore suggested that interventions should also be made with younger students in order to achieve changes in career interests (Nationales MINT Forum e. V., 2018). It should also be noted that STEM career intentions can be influenced by other variables. The factors that explain STEM career intentions for an occupation in the scientific or technical field can be well illustrated in an expectancy–value model (Eccles & Wigfield, 2002). In this model, further explaining factors, such as the opportunity to tinker at home in a workshop, are included. In some works it was shown, for example, that parents or teachers also have a significant influence on students' career choices (Plasman et al., 2020; Smit et al., 2020). According to Regan and DeWitt (2015), in addition to parents or teachers, factors as attainment, teaching, and learning, and images of science and scientists might influence career choice. To sum up, future studies should use a longitudinal design, survey younger students or select other variables to contextualize these results. The change in different variables could be assessed in an intervention study with a repeated-measures design. This would allow for evaluating long-term effects.

One potential issue regarding the results could be the strong correlations between interest, self-efficacy, and career intentions. However, it should be noted that all constructs in our study show correlations below 0.9, indicating a level of discriminant validity that, while approaching a critical threshold, remains within an acceptable range (Cheung et al., 2024). We also tested for redundant indicators; however, none could be removed because all were considered theoretically relevant. In addition, the variables were examined for multicollinearity to ensure that they were sufficiently independent from one another. Nuutila et al. (2021), for example, have also identified strong links between interest and self-efficacy beliefs. They demonstrated that these two variables do not operate in isolation but are closely related during learning processes. It should also be noted here that our sample may well be subject to a positive bias. This is because it can be assumed that teachers who take their classes to school labs are themselves keen on science and have an interest in the subject. It is therefore reasonable to assume that they are also able to inspire their students (Jungert et al., 2020; Keller et al., 2016).

Implications

In terms of implications for practice, this paper showed that school labs are very important because they can promote learning, enjoyment, interest, and self-efficacy. Our study reveals, despite the limitations, that these positive effects of the school labs can influence students' STEM career intentions. Visiting school labs can therefore contribute to a few more talented young people being attracted into the STEM professions. Getting students excited about STEM careers is highly relevant to society given the shortage of skilled workers in this field. STEM careers are important for ensuring technological progress and remaining competitive and innovative. By promoting cognitive, affective, and motivational skills in school labs and thereby facilitating STEM career intentions, these institutions perform an important function in education and labour market policy. It is therefore important that providers of school labs ensure that they offer learning opportunities that are enjoyable but also promote interest and self-efficacy. This will enable them to further strengthen their position as an effective influencing factor in students' career choice process (Kerst et al., 2022; Tytler, 2020).

Acknowledgements
We thank all partners of the school labs who took part in the survey. In addition, we are grateful to the editors and reviewers for their constructive comments to enhance the clarity and coherence of this article.

Author contributions
Rahel Schmid designed the research project, developed the instruments, interpreted the results, and wrote the original draft. Robbert Smit provided methodological advice, supported the interpretation of the data, and assisted with writing. Nicolas Robin was responsible for the funding acquisition and supervised the project.

Funding
Open access funding provided by St.Gallen University of Teacher Education. This work was supported by Metrohm Stiftung.

Data availability
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Competing interests
The authors declare no competing interests.

Received: 2 October 2025 / Accepted: 11 August 2026
Published online: 24 August 2026

References

Ainsworth, H. L., & Eaton, S. E. (2010). *Informal learning is never organized and therefore often spontaneous*. Onate.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, *84*(2), 191–215.

Bandura, A., Barbaranelli, C., Caprara, G. V., & Pastorelli, C. (2003). Self-efficacy beliefs as shapers of children's aspirations and career trajectories. *Child Development*, *72*(1), 187–206. https://doi.org/10.1111/1467-8624.00273

Bergmann, C., & Eder, F. (2000). Geschlechtsspezifische Interessen in der Sekundarstufe II [Gender-specific interests at upper secondary level]. *Empirische Pädagogik*, 255–285.

Bozionelos, N. (2003). Causal path modeling: What it does and what it does not tell us. *The Career Development International*, *8*(1), 5–11. https://doi.org/10.1108/13620430310459469

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

Callanan, M., Cervantes, C., & Loomis, M. (2011). Informal learning. *WIREs Cognitive Science*, *2*(6), 646–655. https://doi.org/10.1002/wcs.143

Catalano, A. (2024). The development and validation of the children's engineering self-efficacy scale (CESES). *Journal of Research in STEM Education*, *10*(1–2), 3–18. https://doi.org/10.51355/j-stem.2024.136

Cheung, G. W., Cooper–Thomas, H. D., Lau, R. S., & Wang, L. C. (2024). Reporting reliability, convergent and discriminant validity with structural equation modeling: A review and best–practice recommendations. *Asia Pacific Journal of Management*, *41*, 745–783. https://doi.org/10.1007/s10490-023-09871-y

Chng, E. H. S., & Tan, T. T. M. (2024). Informal learning of science at science centers and museums: Perspectives, influences, and issues. In Y. S. Ong, T. T. M. Tan, & Y.-J. Lee (Eds.), *A Diversity of Pathways Through Science Education* (pp. 219–244). Springer Singapore. https://doi.org/10.1007/978-981-97-2607-3_13

Council of Europe (2025). *Formal, non-formal and informal learning*. https://www.coe.int/en/web/lang-migrants/formal-non-formal-and-informal-learning

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology*, *53*, 109–132.

Enders, C. K. (2010). *Applied missing data analysis*. Guilford.

Engeln, K. (2004). *Schülerlabors. Authentische, aktivierende Lernumgebungen als Möglichkeit, Interesse an Naturwissenschaften und Technik zu wecken [School labs. Authentic, activating learning environments as an opportunity to awaken interest in science and technology]*. Logos-.

Geiser, C. (2012). *Data analysis with Mplus (Methodology in the social sciences)*. Guilford Press.

Goldschmidt, M., Scharfenberg, F. J., & Bogner, F. X. (2016). Instructional efficiency of different discussion approaches in an outreach laboratory: Teacherguided versus student-centered. *The Journal of Educational Research*, *109*(1), 27–36. https://doi.org/10.1080/00220671.2014.917601

Güdel, K. (2014). Technikaffinität von Mädchen und Jungen der Sekundarstufe I. Untersuchung von Technikinteresse, Selbstwirksamkeitserwartung, Geschlechterrollen und Berufswünschen [Technology affinity of girls and boys in lower secondary school. Investigation of interest in technology, self-efficacy expectations, gender roles and career aspirations] https://archive-ouverte.unige.ch/unige:41471 (29.11.2023).

Guderian, P. (2007). *Wirksamkeitsanalyse außerschulischer Lernorte - Der Einfluss mehrmaliger Besuche eines Schülerlabors auf die Entwicklung des Interesses an Physik Dissertation*, Humboldt-Universität Berlin. https://edoc.hu-berlin.de/handle/18452/16262

Guo, X., Hao, X., Shao, F., Li, X., Dou, S., & Hu, W. (2026). The impact of science learning experiences, science identity, and career exploration on science-related career choice: a sex-based perspective. *IJ STEM Ed*. https://doi.org/10.1186/s40594-026-00596-0

Henriksen, E. K., Jensen, F., & Sjaastad, J. (2014). The role of out-of-school experiences and targeted recruitment efforts in norwegian science and technology students' educational choice. *International Journal of Science Education Part B*, *5*(3), 203–222. https://doi.org/10.1080/21548455.2014.900585

Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist*, *41*(2), 111–127. https://doi.org/10.1207/s15326985ep4102_4

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Hubricht, S., & Ralle, B. (2016). Interessierte Schüler/innen im Schülerlabor identifizieren und fördern. In C. Mauerer (Ed.), *Authentizität und Lernen—das Fach in der Fachdidaktik. Gesellschaft für Didaktik der Chemie und Physik Jahrestagung in Berlin 2015* (pp. 293–295).

Huwer, J. (2015). *Nachhaltigkeit und Chemie im Schülerlabor. Forschendes Experimentieren im Kontext einer naturwissenschaftlichtechnischen Umweltbildung [Sustainability and chemistry in the school laboratory. Research-based experimentation in the context of scientific and technical environmental education]*. Universität des Saarlandes].

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*(1), 3–28. https://doi.org/10.1002/tea.21334

Itzek-Greulich, H., Flunger, B., Vollmer, C., Nagengast, B., Rehm, M., & Trautwein, U. (2014). Effekte der Einbindung eines Schülerlaborbesuchs in den Schulunterricht auf die Lernleistung [Effects of integrating a school laboratory visit into the school curriculum on learning performance]. In S. Bernholt (Ed.), *Naturwissenschaftliche Bildung zwischen Science- und Fachunterricht. Gesellschaft für Didaktik der Chemie und Physik Jahrestagung in München 2013*.

Itzek-Greulich, H., Flunger, B., Vollmer, C., Nagengast, B., Rehm, M., & Trautwein, U. (2015). Effects of a science center outreach lab on school students' achievement. Are student lab visits needed when they teach what students can learn at school? *Learning and Instruction*, *38*, 43–52. https://doi.org/10.1016/j.learninstruc.2015.03.003

Jungert, T., Levine, S., & Koestner, R. (2020). Examining how parent and teacher enthusiasm influences motivation and achievement in STEM. *The Journal of Educational Research*, *113*(4), 275–282. https://doi.org/10.1080/00220671.2020.1806015

Keller, M. M., Neumann, K., & Fischer, H. E. (2016). The impact of physics teachers' pedagogical content knowledge and motivation on students' achievement and interest. *JRST*, *54*(5), 586–614. https://doi.org/10.1002/tea.21378

Kerst, C., Weilage, I., & Gehrke, B. (2022). *Bildung und Qualifikation als Grundlage der technologischen Leistungsfähigkeit Deutschlands 2022. Studien zum deutschen Innovationssystem [Education and qualifications as the basis for Germany's technological performance in 2022. Studies on the German innovation system]*. Expertenkommission Forschung und Innovation (EFI).

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*. https://doi.org/10.3389/fpsyg.2022.882185

Kirchhoff, T., Wilde, M., & Großmann, N. (2024). On the interest-promoting effect of outreach science labs: A comparison of students' interest during experimentation at an outreach science lab and at school. *Research in Science Education*, *54*(3), 459–473. https://doi.org/10.1007/s11165-023-10140-7

Kitchen, J. A., Sonnert, G., & Sadler, P. M. (2018). The impact of college- and university-run high school summer programs on students' end of high school STEM career aspirations. *Science Studies and Science Education*, *102*(3), 529–547. https://doi.org/10.1002/sce.21332

Krapp, A. (1992). Konzepte und Forschungsansätze zur Analyse des Zusammenhangs von Interesse, Lernen und Leistung [Concepts and research approaches for analysing the relationship between interest, learning and performance]. In A. Krapp, & M. Prenzel (Eds.), *Interesse, Lernen, Leistung. Neuere Ansätze der pädagogisch-psychologischen Interessenforschung* (pp. 9–52). Aschendorff.

Laine, E., Veermans, M., Lahti, A., & Veermans, K. (2017). Generation of student interest in an inquiry-based mobile learning environment. *Frontline Learning Research*, *5*(4), 42–60. https://doi.org/10.14786/flr.v5i4.306

LernortLabor. (2023). In (Eds.), *Schülerlabor-Atlas. Schülerlabore in Europa - analog bis digital [School Lab Atlas. School labs in Europe - analogue to digital]*. LernortLabor. Kiel, IPN.

Luo, T., So, W. W. M., Wan, Z. H., & Li, W. C. (2021). STEM stereotypes predict students' STEM career interest via self-efficacy and outcome expectations. *International*

Journal of STEM Education, *8*(1), 36. https://doi.org/10.1186/s40594-021-00295-y
Messmer, K., Raffael, N., Rempfler, A., & Wilhelm, M. (Eds.). (2011). *Ausserschulische Lernorte—Positionen aus Geographie, Geschichte und Naturwissenschaften [Extracurricular places of learning—positions from geography, history and natural sciences]*. LIT.
Millar, R., & Osborne, J. (1998). *Beyond 2000: Science education for the future*. King's College London. https://www.nuffieldfoundation.org/wp-content/uploads/2015/11/Beyond-2000.pdf
Mokhonko, S., Nickolaus, R., & Windaus, A. (2014). Förderung von Mädchen in Naturwissenschaften: Schülerlabore und ihre Effekte [Promoting girls in science: school labs and their effects]. *Zeitschrift für Didaktik der Naturwissenschaften*, *20*, 143–159. https://doi.org/10.1007/s40573-014-0016-2
Molz, A., Kuhn, J., & Müller, A. (2022). Effectiveness of science outreach labs with and without connection to classroom learning: Affective and cognitive outcomes. *Physical Review Physics Education Research*, *18*(2), 1–24. https://doi.org/10.1103/PhysRevPhysEducRes.18.020144
Muñoz-Losa, A., & Corbacho-Cuello, I. (2025). Impact of interactive science workshops participation on primary school children's emotions and attitudes towards science. *International Journal of Science and Mathematics Education*, *23*, 2689–2706. https://doi.org/10.1007/s10763-024-10539-2
Nachtigall, V., & Rummel, N. (2021). Investigating students' perceived authenticity of learning activities in an out-of-school lab for social sciences: a replication study. *Instructional Science*, *49*(6), 779–810.
Nagy, G., & Husemann, N. (2010). Berufliche Interessen vor und nach dem Übergang in die gymnasiale Oberstufe [Career interests before and after the transition to upper secondary school]. In W. Bos, E. Klieme, & O. Köller (Eds.), *Schulische Lerngelegenheiten und Kompetenzentwicklung. Festschrift für Jürgen Baumert* (pp. 59–84). Waxmann.
Nationales, M. I. N. T., & Forum e. V. (2018). *Expertise zu Effekten zentraler außerschulischer*. MINT-Angebote [Expertise on the effects of central extracurricular STEM offerings].
Neher-Asylbekov, S., & Wagner, I. (2023). Effects of out-of-school STEM learning environments on student interest: A critical systematic literature review. *Journal for STEM Education Research*, *6*, 1–44. https://doi.org/10.1007/s41979-022-00080-8
Nuutila, K., Tapola, A., Tuominen, H., Molnár, G., & Niemivirta, M. (2021). Mutual relationships between the levels of and changes in interest, self-efficacy, and perceived difficulty during task engagement. *Learning and Individual Differences*. https://doi.org/10.1016/j.lindif.2021.102090
O'brien, R. M. (2007). A caution regarding rules of thumb for variance inflation factors. *Quality & Quantity*, *41*, 673–690. https://doi.org/10.1007/s11135-006-9018-6
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 [Student labs as interest-promoting extracurricular learning environments for middle and high school students]* (Dissertation, Christian-Albrechts-Universität zu Kiel). https://macau.uni-kiel.de/receive/diss_mods_00003669
Peixoto, F., Mata, L., Monteiro, V., & Sanches, C. (2015). The achievement emotions questionnaire: Validation for pre-adolescent students. *European Journal of Developmental Psychology*, *12*(4), 472–481. https://doi.org/10.1080/17405629.2015.1040757
Plasman, J., Gottfried, M., Williams, D., Ippolito, M., & Owens, A. (2020). Parents' occupations and students' success in STEM fields: A systematic review and narrative synthesis. *Adolescent Research Review*, *6*, 33–44. https://doi.org/10.1007/s40894-020-00136-z
Priemer, B., & Lewalter, D. (2009). Schülerlaborbesuche—eine Bereicherung für den naturwissenschaftlichen Unterricht!? [School lab visits—an enrichment for science lessons!?]., *58*(4), 10–14.
Regan, E., & DeWitt, J. (2015). Attitudes, interest and factors influencing STEM enrolment behaviour - an overview of relevant literature. In E. K. Henriksen, J. Dillon, & J. Ryder (Eds.), *Understanding Student Participation and Choice in Science and Technology Education* (pp. 63–88). Springer Dordrecht. https://doi.org/10.1007/978-94-007-7793-4
Reimann, M., Herzog, S., Parchmann, I., & Schwarzer, S. (2020). Wirksamkeit der schulischen Vor- und Nachbereitung eines Schülerlaborbesuches [Effectiveness of school-based preparation and follow-up of a school lab visit]. *Zeitschrift für Didaktik der Naturwissenschaften*, *26*, 227–240. https://doi.org/10.1007/s40573-020-00121-y
Reinhold, S., Holzberger, D., & Seidel, T. (2018). Encouraging a career in science: a research review of secondary schools' effects on students' STEM orientation. *Studies in Science Education*, *54*(1), 69–103. https://doi.org/10.1080/03057267.2018.1442900
Röllke, K., Maak, A. L., Wenzel, A., & Grotjohann, N. (2020). Experimental workshops in student labs and at school - What influence do location and personality traits have on learners' motivational variables? *Pedagogical Research*, *5*(1).
Sasson, I. (2019). Participation in research apprenticeship program: Issues related to career choice in STEM. *International Journal of Science and Mathematics Education*, *17*, 467–482. https://doi.org/10.1007/s10763-017-9873-8
Scharfenberg, F. J., Bogner, F. X., & Klautke, S. (2007). Learning in a gene technology laboratory with educational focus: Results of a teaching unit with authentic experiments. *Biochemistry and Molecular Biology Education*, *35*(1), 28–39. https://doi.org/10.1002/bmb.1
Simon, F. (2019). *Der Einfluss von Betreuung und Betreuenden auf die Wirksamkeit von Schülerlaborbesuchen. Eine Zusammenhangsanalyse von Betreuungsqualität, Betreuermerkmalen und Schülerlaborzielen sowie Replikationsstudie zur Wirksamkeit von Schülerlaborbesuchen [The influence of supervision and supervisors on the effectiveness of student laboratory visits. A correlation analysis of supervision quality, supervisor characteristics and student laboratory goals as well as a replication study on the effectiveness of student laboratory visits*. Logos-.
Simpson, A., McCann, J., Miroff, L. E., & McGee, T. (2025). The compex STEM identity development of middle school girls in a culturally infused afterschool program. *Journal for STEM Educ Res*. https://doi.org/10.1007/s41979-025-00162-3
Smit, R., Robin, N., & De Toffol, C. (2020). Explaining secondary students' career intentions for technology and engineering jobs using an expectancy-value model. *Frontiers in Education*. https://doi.org/10.3389/feduc.2020.00039
Sonnert, G., Reid, T., Sunbury, S., & Sadler, P. M. (2025). How do formal and informal science learning experiences during high school shape students' career interest and STEM identity? *IJ STEM Ed*. https://doi.org/10.1186/s40594-025-00568-w
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
Taskinen, P. H. (2010). *Naturwissenschaften als zukünftiges Berufsfeld für Schülerinnen und Schüler mit hoher naturwissenschaftlicher und mathematischer Kompetenz [Natural sciences as a future career field for pupils with a high level of scientific and mathematical competence]* (Dissertation, Christian-Albrechts-Universität zu Kiel) https://macau.uni-kiel.de/servlets/MCRFileNodeServlet/dissertation_derivate_00003501/diss_taskinen.pdf (22.10.2024).
Taskinen, P. H., Schütte, K., & Prenzel, M. (2013). Adolescents' motivation to select an academic science-related career: the role of school factors, individual interest, and science self-concept. *Educational Research and Evaluation*, *19*(8), 717–733. https://doi.org/10.1080/13803611.2013.853620
Tillmann, J., & Wegner, C. (2021). Weiterentwicklung eines klassischen Schülerlabors—Darstellung des aktuellen Forschungsstandes [Further development of a classic school laboratory—presentation of the current state of research]., *4*(2), 5–39. https://doi.org/10.25321/prise.2021.1076
Tulis, M., & Ainley, M. (2011). Interest, enjoyment and pride after failure experiences? Predictors of students' state emotions after success and failure during learning in mathematics. *Educational Psychology*, *31*(7), 779–807. https://doi.org/10.1080/01443410.2011.608524
Tytler, R. (2020). STEM education for the twenty-first century. In J. Anderson & Y. Li (Eds.), *Integrated Approaches to STEM Education* (pp. 21–43). Springer. https://doi.org/10.1007/978-3-030-52229-2_3
Wang, M. T., & Degol, J. (2013). Motivational pathways to STEM career choices: Using expectancy–value perspective to understand individual and gender differences in STEM fields. *Developmental Review*, *33*, 304–340. https://doi.org/10.1016/j.dr.2013.08.001
Weßnigk, S. (2013). *Kooperaties Arbeiten an industrienahen ausserschulisdchen Lernorten [Cooperative work at industry-related extracurricular learning centres]* (Doctoral thesis, Christian-Albrechts-Universität zu Kiel) https://macau.uni-kiel.de/servlets/MCRFileNodeServlet/dissertation_derivate_00004630/dissertation_susanne_wessnigk.pdf (22.10.2024).
Wigfield, A., & Eccles, J. S. (2000). Expectancy–value theory of achievement motivation. *Contemporary Educational Psychology*, *25*(1), 68–81. https://doi.org/10.1006/ceps.1999.1015
Wilhelm, M., Messmer, K., & Rempfler, A. (2011). Ausserschulische lernorte - Chance und Herausforderung [Extracurricular learning centres - opportunity and challenge]. In K. Messmer, N. Raffael, A. Rempfler, & M. Wilhelm (Eds.), *Ausserschulische Lernorte - Positionen aus Geographie, Geschichte und Naturwissenschaften*. LIT.

Xia, X., Bentley, L. R., Fan, X., & Tai, R. H. (2025). STEM outside of school: a meta–analysis of the effects of informal science education on students' interests and attitudes for STEM. *International Journal of Science and Mathematics Education*, *23*, 1153–1181. https://doi.org/10.1007/s10763-024-10504-z

Yamani, N., & Almazroa, H. (2024). Exploring career interest and STEM self-efficacy: implications for promoting gender equity. *Frontiers in Psychology*, *15*, 1–12. https://doi.org/10.3389/fpsyg.2024.1402933

Zehren, W., Neber, H., & Hempelmann, R. (2013). Forschendes Experimentieren im Schülerlabor. Kognitive und motivationale Effekte [Research-based experimentation in the school laboratory. Cognitive and motivational effects]. *Der mathematische und naturwissenschaftliche Unterricht*, *66*, 416–423.

Publisher's note