



Predictors of Students' Intrinsic Motivation in a Biotechnological Out-of-School Student Lab

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Out-of-school student labs have been established in the field of STEM (science, technology, engineering, and maths) to support students' motivation regarding science by giving the opportunity for inquiry-based learning in an authentic learning environment. However, previous research most often lacks to explain and investigate determinants of the reported positive effects of such labs on motivation. Therefore, we investigated predictors of students' intrinsic motivation during a visit to the out-of-school student lab. 170 secondary school students (58% female; $M_{age} = 16.55$ years, $SD_{age} = 0.58$ years) from 12 courses took part in this study. Our results revealed students' perceived autonomy and competence as well as their preparation beforehand as predictors of their intrinsic motivation, but not their gender and grade in biology. Out-of-school student labs therefore seem to be an important opportunity to foster intrinsic motivation regardless of individual student characteristics. Since our results show a crucial role of students' perception of autonomy and competence for their intrinsic motivation in the out-of-school lab, opportunities to implement autonomy and competence support are outlined as practical implications.

Keywords: out-of-school student lab, intrinsic motivation, perceived autonomy, perceived competence, gender

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INTRODUCTION

From the beginning of secondary schooling, students' motivation is described as progressively decreasing in science education (Braund and Reiss, 2006). Since motivation has a crucial impact on the outcomes of learning processes and therefore play an important role in the school context, these trends are especially worrying (Osborne et al., 2003; Schiefele and Schaffner, 2015). Moreover, possessing scientific knowledge is of special economic importance (Osborne et al., 2003). However, students seem to hardly develop positive attitudes toward science (Osborne et al., 2003). To foster students' motivation in science education, out-of-school student labs have been established in the field of STEM since the turn of the millennium (Haupt, 2015). In these facilities, students have the chance to work on authentic tasks and to become acquainted with scientific reasoning (Haupt et al., 2013). Since they provide opportunities for performing scientific inquiry, they can supplement and support inquiry-based science education in school (Haupt et al., 2013). The application of scientific inquiry can support the acquisition of scientific literacy (Lee and Butler, 2003) that is an important aim of science education in school (Oliver et al., 2019).

Previous studies in out-of-school labs investigated the impact of a visit to the lab on different motivational variables such as interest, domain-specific self-concept, achievement emotions, and motivation to learn (Engeln, 2004; Brandt, 2005; Guderian, 2006; Glowinski, 2007; Pawek, 2009; Zehren, 2009; Damerau, 2012; Itzek-Greulich, 2014; Huwer, 2015; Streller, 2016). However, one

important motivational variable has up to now received little attention in the context of the out-of-school lab, although it is assumed to be a key variable for long-lasting and in-depth learning processes: Intrinsic motivation in the sense of self-determination theory (Ryan and Deci, 2017). Moreover, the current state of research lacks to explain how the visit to an out-of-school lab leads to the reported positive effects on motivational variables (Nickolaus et al., 2018).

To be able to give recommendations for effectively supporting student motivation in the student lab, the first step must be to find out which factors lead to the positive effects of the student lab on motivational variables. The current study therefore aimed at identifying predictors of students' intrinsic motivation in a model that considers both student variables that cannot be influenced by the learning environment as well as variables that can be influenced by the learning environment. Identifying predictors of intrinsic motivation in the out-of-school lab that can be influenced by the design of learning environments is especially important to give recommendations for the design of visits to out-of-school labs.

THEORY

Motivation in Self-Determination Theory

Self-determination theory (Ryan and Deci, 2017) describes different motivational qualities that individuals exhibit during their actions. In this theory, it is assumed that individuals are intrinsically motivated if they do something self-determined and with complete inner pleasure (Ryan and Deci, 2017). The action itself is the reason for the execution of the action (Ryan and Deci, 2017). In contrast, if incentives determine the execution of an action, the individuals' behavior is extrinsically motivated (Ryan and Deci, 2017). However, extrinsically motivated actions can be regulated in a controlled or self-determined manner (Vansteenkiste et al., 2010; Ryan and Deci, 2017).

For wellbeing and self-determined motivational regulation, innate psychological needs have to be satisfied (Ryan and Deci, 2017). Ryan and Deci (2017) depict three psychological needs: The need for relatedness describes the desire for the acceptance by and belonging to fellow human beings which can be considered as the impulse for the integration of formerly external values into inner regulation processes and the self (Ryan and Deci, 2017). The need for competence is based on individuals' striving to feel effective in their interaction with the surrounding (Ryan and Deci, 2017). To fulfill this need, individuals search for opportunities for the application, improvement, and presentation of their skills (Ryan and Deci, 2017). The need for autonomy describes individuals' endeavor to be the origin of their actions and to control these actions themselves (Reeve et al., 2003). Furthermore, individuals have the desire to act voluntarily and perceive choices before and during their actions (Reeve et al., 2003).

Self-determination theory is a theory that has been used worldwide for a long time and is constantly evolving (Ryan and Deci, 2017). Especially in the educational context, it is frequently

applied, and the constructs anchored in it are often examined (Ryan and Deci, 2017). Most often, these investigations take place in the regular classroom (e.g., Reeve, 2015), whereas studies at the out-of-school lab are largely absent. The motivational variables that have received attention in studies at the out-of-school student lab to date are reviewed in the following section.

Motivation in the Out-of-School Student Lab

Out-of-school student labs make authentic science accessible to learners, for example by performing scientific inquiry in an authentic setting (Haupt et al., 2013). Authentic activities lead to situated knowledge, which is the product of the activity, the context, and the culture in which it was developed as well (Hofstein and Lunetta, 2004). Moreover, the acquisition of knowledge and, thus, the success of learning processes depend on the students' quality of motivation in these settings (Ryan and Deci, 2017). In this context, a distinction must be made between action-related motivation, such as intrinsic motivation and flow-experience (Csikszentmihalyi, 2010; Ryan and Deci, 2017), and object-related motivation, such as interest (Krapp, 2005). Even though action-related motivation was examined in our study, the findings on object-related interest should also be taken into account, especially because these variables are intercorrelated (e.g., Palmer, 2004; Marth and Bogner, 2017). Several studies showed that a visit to out-of-school student labs can affect students' interest in the natural sciences positively (e.g., Brandt, 2005; Guderian, 2006; Streller, 2016). Brandt et al. (2008) further found that students who visit an out-of-school lab report a higher domain-specific self-concept and higher content- and context-related interest than a control group that did not visit the lab. However, after 4 months, the differences between the groups were no longer evident (Brandt et al., 2008). In an out-of-school student lab that focusses on biological topics, Röllke et al. (2020) found no differences in object-related situational interest and action-related flow-experience between students who had an experimental workshop in an out-of-school student lab or in school. However, both groups expressed a high situational interest in the workshop topic, which might have caused ceiling effects (Röllke et al., 2020). Looking at a connection between action-related motivation and object-related interest, Marth and Bogner (2017) found a slight relationship between science motivation and interest in technology.

With a focus on action-related motivation in out-of-school student labs, two studies took the expectancy-value theory into account (Brandt, 2005; Zehren, 2009). Brandt (2005) investigated "intrinsic motivation with regard to the subject chemistry" as a subscale of "emotional-affective aspects of the object" and found a short-term increase. Zehren (2009) used the same items and found positive effects on this specific intrinsic motivation through repeated visits to an out-of-school student lab. Analyzing the effects of a lab-on-tour, Huwer (2015) found an increase in action-related current motivation in younger students, but not in adolescents. For his study, he used a validated scale for the assessment of current motivation by Rheinberg et al. (2001), consisting of the subscales "fear of failure," "probability

of success,” “interest,” and “challenge” (Huwer, 2015). Itzek-Greulich et al. (2017) differentiated state and trait motivation. They assessed achievement emotions, situational interest, and situational competence beliefs for state motivation and assessed dispositional interest, task values (attainment, cost, intrinsic value, and utility), and competence beliefs for trait motivation (Itzek-Greulich et al., 2017). They found that a hands-on practical approach effectively enhances state motivation and to some extent increases trait motivation (Itzek-Greulich et al., 2017). Goldschmidt and Bogner (2016) found a substantial knowledge acquisition in an out-of-school student lab. Moreover, they found that the extent of knowledge acquisition depends on the students’ action-related motivation (Goldschmidt and Bogner, 2016). In this study, the science motivation questionnaire (Glynn et al., 2009) was used, which assesses students’ motivation to learn science with five dimensions (intrinsic motivation and personal relevance, self-efficacy and assessment anxiety, self-determination, career motivation, and grade motivation).

This state of research shows that although intrinsic motivation in the sense of self-determination theory is considered an important variable for successful learning processes, it has rarely been examined in previous studies in out-of-school student labs. Moreover, despite some promising previous results for fostering students’ object-related interest and action-related motivation, it is still unclear how these effects of out-of-school student labs can be explained (Nickolaus et al., 2018). Therefore, the current study aimed at testing different variables as predictors of students’ action-related intrinsic motivation in out-of-school student labs, which can help to identify operating mechanisms. These variables are depicted in the following section.

Predictors of Students’ Intrinsic Motivation in the Out-of-School Student Lab

At first, the degree of psychological need satisfaction can have an impact on the development of intrinsic motivation in out-of-school labs. The importance of these in section “Motivation in Self-Determination Theory” depicted needs for students’ intrinsic motivation, especially the needs for autonomy and competence, has been outlined many times (e.g., Krapp, 2005; Ryan and Deci, 2017). However, previous discussions and studies reveal that characteristics of the individual can have an impact on students’ intrinsic motivation as well (Vallerand and Ratelle, 2002; Ryan and Deci, 2017). Three characteristics of the individual, which cannot be influenced by the learning environment, are focused in our study: students’ gender, their performance in biology and their preparation before the visit to the out-of-school lab.

Gender

The impact of gender on motivational variables regarding the natural sciences has been reported quite often (e.g., Schiepe-Tiska et al., 2016). Studies show that boys perform better in physics and chemistry than girls (Schiepe-Tiska et al., 2016) whereas biology is often assumed to be a girls’ domain (Budde, 2008) since girls show a distinctly higher interest in this subject than boys (Dietze et al., 2005). However, gender differences in

object-related interest depend not only on the subject but also on the topic. Whereas boys show more interest in technical and physical topics, girls prefer natural phenomena and topics that deal with the body (Holstermann and Bögeholz, 2007). However, research regarding the gender-specific differences in inquiry-based learning settings shows heterogeneous results. For example, Röllke et al. (2020) did not find any effects of students’ gender on their object-related situational interest and action-related flow-experience (see also Engeln, 2004; Pawek, 2009). The results of Glowinski and Bayrhuber (2011) support these results for object-related situational interest (see also Heindl and Nader, 2018). In contrast, in a study by Itzek-Greulich and Vollmer (2017), female adolescents reported more favorable emotions in the practical part of an inquiry-based learning setting than male adolescents. Kuo et al. (2020) further revealed that boys had a higher increase in action-related motivation and engagement regarding science when engaging in an inquiry-based learning setting than girls. Since the state of research regarding gender-specific differences in the out-of-school lab is quite heterogeneous, such differences need to be investigated further. In particular, further investigation should be conducted because findings here mainly exist for object-related motivation (interest) and not action-related motivation.

Performance in Biology

Besides students’ gender, the students’ performance in their regular biology lessons might have an impact on their intrinsic motivation in the out-of-school lab. Although the effects of student motivation on performance are investigated most often, the state of research suggests a positive reciprocal relationship between these variables (see Weidinger et al., 2015). Weidinger et al. (2015) explain these effects with the empirical findings on external rewards anchored in self-determination theory and suggest that the choice of tasks and the use of learning strategies can mediate the effects of grades on students’ motivation. However, with regard to out-of-school student labs, Itzek-Greulich and Vollmer (2017) found that students with better grades reported less joy, less object-related situational interest, and higher boredom during the theoretical part in an inquiry-based learning setting, which is contradictory with the assumptions of Weidinger et al. (2015). In a study by Röllke et al. (2020), there was no significant impact of the biology grade on students’ object-related situational interest and action-related flow-experience in an experimental workshop in the out-of-school student lab. Thus, previous studies do not draw a unified picture and the impact of grades on motivational variables in the out-of-school lab therefore needs to be tested further.

Preparation of the Students

A third variable, which might have an impact on students’ intrinsic motivation in the out-of-school student lab, is their preparation before the visit. Teachers connect the visit to an out-of-school learning environment quite seldom with their classes (Griffin and Symington, 1997) although this visit should be well prepared for successful inquiry learning processes (Lee and Butler, 2003). The preparation of the students is, among other things, mandatory for reducing the perceived novelty of the

setting (Fallik et al., 2013). Regarding the effects of students' preparation on different motivational variables in the out-of-school lab, findings are quite homogeneous. Glowinski and Bayrhuber (2011) found a positive relationship between students' object-related interest in the out-of-school student lab and the amount of pre-visit instruction. Streller (2016) supplements these findings by showing a positive effect of online preparation material on the students' object-related situational interest. In addition, Röllke (2019) found a higher action-related intrinsic motivation for the students who had worked with lab preparation notes beforehand in comparison to students who did not work with lab preparation notes before the visit to the out-of-school lab. This might be explained with the need for competence. If students' prepare their visit and gain knowledge about the experiments beforehand, it is more likely that their ability will be in line with the requirements in the out-of-school lab. This can foster the fulfillment of the need for competence, which, in turn, is an important condition for the development of intrinsic motivation (Ryan and Deci, 2017). It is therefore assumed that the more extensive the students' preparation is, the higher is their intrinsic motivation.

HYPOTHESES

The students' intrinsic motivation in the out-of-school student lab is predicted by. . .

- H_{1A} . . . their perception of autonomy.
- H_{1B} . . . their perception of competence.
- H_{1C} . . . their gender.
- H_{1D} . . . their grade in biology.
- H_{1E} . . . their preparation beforehand.

MATERIALS AND METHODS

Sample

In our one-shot case study, 170 secondary school students (58% female) from 12 courses (11th grade *Gymnasium* or 12th grade comprehensive school) took part. On average, these students were 16.55 years old ($SD = 0.58$ years).

Study Design and Procedure

The students took part in a 1-day inquiry-based workshop in an out-of-school student lab. This lab is located in a center for biotechnological research at a university in Germany. We chose biotechnology as this special field of biology is an interdisciplinary area applying chemistry and engineering. That is, the results might give insight in motivation in biology and in the further STEM areas as well. This is a special situation, as interdisciplinary out-of-school labs integrating all natural sciences are quite rare (12.3% of all labs recorded in Germany). They are normally split according to the school subjects biology (24.3%), chemistry (20.3%), and physics (22.3%) (Haupt, 2015). Besides, labs in the fields of technology (12.0%), computer science (3.3%), mathematics (2.3%), and others (2.9%) can be found (Haupt, 2015). The lab consists of eight workstations for up to 24

students and is equipped with micropipettes, test tubes, samples, micro centrifuges, shakers, gel electrophoresis chambers, and a thermal cycler. Two instructors accompanied the students during the visit to the out-of-school lab. The first instructor participated in all workshops. The second instructor was one of six students in a seminar for preservice biology teachers in their bachelor semesters. The preservice biology teachers were prepared to conduct the workshops in this seminar.

At the beginning of the workshop, students were introduced to the context and the theoretical background of the experiments, were prepared for the use of the laboratory equipment, and got a safety briefing. After this standardized presentation from the instructor, the students worked on a specific research question in the field of molecular genetics (e.g., "The meat of which animal species is processed in a sample of sausage?"). The students answered the question by conducting a specific sequence of experiments that are obligatory in the curriculum of German high schools. They extracted DNA, amplified a gene through polymerase chain reaction, restricted DNA by restriction cleavage, and ran a gel electrophoresis. At the end of the workshop, the students interpreted the generated DNA bands in the agarose gel, and the results were discussed in plenum. Afterward, their perception of autonomy and competence as well as their gender, grade in biology, and preparation before the visit were assessed. The participants were informed that the completion of the questionnaire is voluntary.

We decided to provide the students with a research question and the procedure since a molecular genetic analysis consists of diverse steps with many different consumables (e.g., buffers, primers, enzymes, nucleotides). The protocols for each step have to be followed exactly to achieve interpretable results. Moreover, working in a lab requires a high level of knowledge about experimentation and handling the lab equipment that students probably do not possess.

Test Instruments

To assess students' intrinsic motivation, we used three items from the subscale "interest/enjoyment" from the Intrinsic Motivation Inventory (McAuley et al., 1989) as well as three items of the subscale "perceived competence" to measure their perception of competence. These six items have already been validated in the German translation (Short scale of intrinsic motivation; Wilde et al., 2009). The students' perception of autonomy was evaluated with four translated items of the questionnaire *Perceived Self-Determination* by Reeve (2002). To ensure the correctness of the item translations as well as their content validity, all items were first translated to German, adapted, and discussed by four experts in the field (subject didactics and SDT researchers) (experience-led approach; Bühner, 2011). After this discussion, the items were back-translated from German into English by a native speaker with a scientific background. This back-translation was discussed again by the aforementioned four experts in the field against the background of the German items. In order to test the factorial validity of the instrument, we conducted a principal axes factor analysis (see Moosbrugger and Schermelleh-Engel (2012)). The Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) was found to be sufficient (KMO = 0.64;

see Field, 2016). In addition, Bartlett's test of sphericity was significant ($p < 0.001$). In the analysis, one factor was revealed with an eigenvalue of 1.77 and 44.17% of explained variance. To investigate the construct validity of our test instrument, we tested the relationship between students' perceived autonomy and similar constructs (*convergent validity*) and found the expected correlations (*perceived autonomy support*: $r = 0.46^{**}$; *perceived choice*: $r = 0.49^{**}$). Moreover, our study as well as several previous studies give hint for the criterion validity of the German items (**Table 1**; Hofferber et al., 2016; Großmann et al., 2020; Großmann and Wilde, 2020, 2021).

The items of all test instruments were rated on a five-point rating scale from 0 ("I don't agree at all") to 4 ("I completely agree"). **Table 2** summarizes the scales including example items and internal consistency. Moreover, we assessed students' gender (female = 1; male = 2) and grade in biology. In class 11–13 in German secondary schools, the grades are represented as points ranging from 0 points (insufficient) to 15 points (excellent). Furthermore, we asked about three different degrees of preparation ("no preparation" = 0, "read the lab preparation notes" = 1, "discussed the lab preparation notes in class" = 2).

Statistics

After the deletion of outliers as well as the tests for autocorrelation and multicollinearity (see Field, 2016), a multiple linear regression analysis was conducted to investigate whether the students' gender, their grade in biology, the degree of their preparation as well as their perception of autonomy and competence predict students' intrinsic motivation in the out-of-school student lab. For this analysis, the categorical variable "preparation" was dummy coded into three variables (discussion, reading, and no preparation; see Field, 2016). Only the two variables "discussion" and "reading" were entered into the model. We used the HC3 method that is robust to the violation of the homoscedasticity assumption (Hayes and Cai, 2007).

RESULTS

At first, correlations between all investigated variables were investigated (**Table 1**). With regard to students' perception of competence, significant positive correlations can be reported with their preparation (no preparation = 11%, read the lab preparation notes = 37%, discussed the lab preparation notes in class = 52%) and their grade. These correlations indicate that a higher degree

of preparation and better grades lead to a higher perception of competence. At last, significant positive correlations were revealed between the students' intrinsic motivation and their perception of autonomy, their perception of competence, as well as the degree of preparation.

Afterward, the hypothesized predictors for students' intrinsic motivation were tested in a linear regression [$R^2 = 0.37$, $SE = 0.62$, $F(6, 163) = 17.36$, $p < 0.001$]. The students' perception of autonomy and competence could be confirmed as predictors of their intrinsic motivation in this model (**Table 3**). Moreover, their preparation before the visit to the out-of-school lab positively predicted their intrinsic motivation. This prediction could be found for the discussion of the manuscript in class as well as for the reading of the manuscript before the visit. The students' gender and their grade in biology could not be confirmed as predictors.

DISCUSSION

Our study aimed at investigating predictors of students' intrinsic motivation in the out-of-school lab. This investigation is of special importance since out-of-school labs are often described as motivating, but there is still uncertainty about the mechanism that leads to these effects (Nickolaus et al., 2018). In our study, the students' perceived autonomy and competence as well as their preparation beforehand could be confirmed as predictors of their intrinsic motivation in the out-of-school student lab (H_{1A} , H_{1B} , H_{1E}), but not their gender and grade in biology (H_{1C} , H_{1D}).

The results regarding students' perception of autonomy and competence are in line with self-determination theory (Ryan and Deci, 2017) which considers the fulfillment of the psychological needs as essential for the development of intrinsic motivation. If students can act autonomously in the out-of-school lab, they can perceive their psychological needs for autonomy and competence as satisfied and, in turn, experience intrinsic motivation (see Ryan and Deci, 2017; Großmann et al., 2020). However, the satisfaction of these needs depends on the design of the learning environment (e.g., Reeve, 2015). Descriptively, the students perceived more competence than autonomy in the investigated lab. Opportunities to support students' need for autonomy in out-of-school student labs are given later on (section "Practical Implications for Out-of-School Student Labs").

Students' gender was not found to be a predictor of their intrinsic motivation although a gender gap is often

TABLE 1 | Descriptive statistics of and correlations between all investigated variables.

Variables	<i>M</i>	<i>SD</i>	1	2	3	4	5
1 Gender	–	–	–				
2 Grade	10.22	2.77	$r = -0.03$				
3 Preparation	–	–	$Z = -1.93$	$r = -0.03$			
4 Perceived autonomy	2.43	0.67	$r = 0.01$	$r = -0.04$	$r = 0.15$		
5 Perceived competence	2.97	0.62	$r = -0.02$	$r = 0.25^{**}$	$r = 0.24^*$	$r = 0.05$	
6 Intrinsic motivation	3.30	0.48	$r = -0.06$	$r = 0.11$	$r = 0.21^*$	$r = 0.46^{**}$	$r = 0.38^{**}$

* $p < 0.05$, ** $p < 0.01$. Pearson correlations. For the correlation between gender and preparation, a biserial correlation (Mann-Whitney-U) was used.

TABLE 2 | Applied test instruments with example item and internal consistency.

Scale	Example item	Internal consistency
IMI subscale "interest/enjoyment" 3 items	The activities in the workshop were fun to do.	Cronbach's $\alpha = 0.65$
IMI subscale "perceived competence" 3 items	I think I was pretty good at the activities in the workshop.	Cronbach's $\alpha = 0.77$
Perceived self-determination 4 items	With the team in the lab, I had the feeling that I did what I wanted to do.	Cronbach's $\alpha = 0.58$

IMI, *Intrinsic Motivation Inventory*.

TABLE 3 | Results of the multiple linear regression analysis to investigate predictors of intrinsic motivation.

Variable	β	SE	t	p
Gender	-0.09	0.10	-0.90	0.368
Grade	0.02	0.05	0.53	0.600
Preparation (discussion)	0.39*	0.17	2.26	0.025
Preparation (reading)	0.59**	0.17	3.45	0.000
Perceived competence	0.27**	0.06	4.70	0.000
Perceived autonomy	0.37**	0.06	6.26	0.000

* $p < 0.05$, ** $p < 0.01$. Preparation (discussion) = preparation notes were discussed in class; Preparation (reading) = preparation notes were read by the student; reference category: no preparation.

reported in the science-related subjects (e.g., Schiepe-Tiska et al., 2016). In line with our results, several studies revealed no differences between boys and girls in out-of-school student labs regarding their object-related interest and action-related flow-experience (Engeln, 2004; Pawek, 2009; Glowinski and Bayrhuber, 2011; Röllke et al., 2020). In further investigations, it has to be considered that gender differences need to be surveyed differentiated, as they depend on the subject itself, the topic of the subject that is taught in the lab, and the teaching method that is applied in the lab (see Dietze et al., 2005; Holstermann and Bögeholz, 2007; Budde, 2008; Schiepe-Tiska et al., 2016; Kuo et al., 2020).

With regard to the students' grades, we assumed that this variable may have an impact on their perceived competence and, in turn, on their intrinsic motivation (see Ryan and Deci, 2017). Yet, their grade did not have a positive impact on their intrinsic motivation in our investigated model. These findings are in line with previous studies on students' object-related interest and action-related flow-experience (Itzek-Greulich and Vollmer, 2017; Röllke et al., 2020). However, these results are not in line with Weidinger et al. (2015) who assume positive reciprocal effects between motivation and performance. This might be ascribed to the learning environment and needs further investigation.

Lastly, the students' preparation before the out-of-school visit had an impact on their intrinsic motivation. Students who had discussed the lab preparation notes in class and students who had read the lab preparation notes reported a higher intrinsic motivation than those students who had no preparation. These findings are in line with the results of previous studies (Glowinski

and Bayrhuber, 2011; Streller, 2016; Röllke, 2019). We assume that the skills of the students who had a higher degree of preparation of the visit are more in balance with the demands of the tasks in the lab than those of students who had a smaller degree of preparation. According to self-determination theory (Ryan and Deci, 2017), the students with a higher degree of preparation could therefore feel more competent and, in turn, had a higher intrinsic motivation. It had to be mentioned that all students who participated in our study had dealt with molecular genetics in their regular biology lessons. However, they differed with regard to the preparation with the lab preparation notes, which gave insight into the applications of molecular genetics in the specific experiments.

Limitations and Implications

First, besides the investigated predictors in our study, further variables can have an impact on students' intrinsic motivation in the out-of-school lab. Thus, our model does not raise a claim to completeness. For example, Glowinski and Bayrhuber (2011) showed that students' object-related individual interest as well as the quality of instruction have a significant impact on the "interest in experiments," "interest in research and application contexts," and "interest in authentic learning environments." Since object-related interest and action-related motivation are correlated (e.g., Marth and Bogner, 2017; Palmer, 2004), such variables can also have an impact on intrinsic motivation and could be considered in further studies. That said, habitual and more stable types of motivation need to be addressed (see Schiefele and Schaffner, 2015). It might be that besides the investigated predictors in our study, a habitual intrinsic motivational regulation might have an impact on their situational action-related intrinsic motivation (see Vallerand and Ratelle, 2002). That is, students that generally have a higher intrinsic motivation in their biology classes, may have a higher intrinsic motivation during a visit to the out-of-school student lab than students who possess a lower intrinsic motivation in their biology classes.

Second, our results depict the situation in a specific out-of-school student lab in the field of molecular biology. Out-of-school labs can differ with regard to the equipment, their proximity to science as well as their authenticity, and their level of inquiry (Haupt, 2015; Itzek-Greulich and Vollmer, 2018; Nickolaus et al., 2018). Since these variables can also have an impact on intrinsic motivation in the out-of-school lab, our findings cannot be transferred to other labs without limitations.

Third, it has to be kept in mind that although the conception of the visits was identical, one instructor varied. These varying instructors might have behaved differently which might have resulted in different degrees of autonomy and competence that the students perceived. We conducted correlations between these variables and found no hints for such instructor-related effects (perceived autonomy and instructor: $r = -0.01$, $p = 0.931$; perceived competence and instructor: $r = 0.03$, $p = 0.641$).

Fourth, regarding students' autonomy, reference must be made to the assessment of the students' perception of autonomy. The test instrument we used is not a validated test instrument. Nevertheless, evidence for the validity of the test instrument can

be found in our own study and various previous studies (Table 1; Hofferber et al., 2016; Großmann et al., 2020; Großmann and Wilde, 2020, 2021). Future studies could address the validation of this test instrument in order to further investigate the valid assessment of the perception of autonomy in the German-speaking countries.

CONCLUSION

Our results suggest that out-of-school student labs provide a great chance to support all students, independent from individual characteristics. Two important variables that can be influenced by the design of the out-of-school lab visit, namely the perception of autonomy and competence, were shown to have a crucial impact on the students' intrinsic motivation in the out-of-school lab. Moreover, students' preparation before the visit affected their intrinsic motivation. These variables should therefore be considered in the investigation of operating mechanisms in the development of intrinsic motivation in out-of-school student labs that are demanded by Nickolaus et al. (2018). Taking the perspective of self-determination theory was of particular importance in the context of student labs because conditions for the development of motivation as well as measures to foster intrinsic motivation have been well described in this theory and their effectiveness has been confirmed many times (Ryan and Deci, 2017). As shown in our study, the basic psychological needs have to be considered in student labs, in particular, because they can potentially become frustrated in the student lab. To foster the satisfaction of students' basic needs and their intrinsic motivation in out-of-school student labs, well investigated measures anchored in self-determination theory are presented in the following section.

PRACTICAL IMPLICATIONS FOR OUT-OF-SCHOOL STUDENT LABS

The degree of autonomy that a teacher offers has an impact on the students' perception of competence and autonomy and, in consequence, their intrinsic motivation (e.g., Reeve, 2015). In their meta-analysis, Su and Reeve (2011) summarized effective autonomy-supportive measures. Four of them can be implemented particularly well in the out-of-school lab (see also Reeve, 2015). Since the needs for competence and autonomy are intercorrelated, the implementation of these measures can support both students' perception of competence and autonomy (see Ryan and Deci, 2017; Großmann et al., 2020).

First, a meaningful rationale that shows students the relevance of the topics and their actions in class can support their perception of autonomy (see Su and Reeve, 2011). One way to realize a meaningful rationale is to link the contents of the visit to their everyday life. Out-of-school student labs often deal with topics in contexts that relate to students' everyday life and can therefore be used to design this rationale. Further on, the experimental methods in the out-of-school lab are often applied in other contexts and are therefore of more general importance

for the students. Last, rules that are inherent to out-of-school student labs and important for the handling of the usually expensive equipment, for instance, need a meaningful framing to support students' perception of autonomy. That is, the instructor in the lab should explain why these rules are important for the individual student and the whole class.

Second, negative feelings should be acknowledged and accepted (see Su and Reeve, 2011). As out-of-school student labs provide the opportunity for hands-on activities beyond regular class, students might mainly encounter positive feelings. However, it should be taken into account that these learning environments are unfamiliar for the students and might lead to fear. Students might be afraid to embarrass themselves by giving wrong answers, to do something wrong or to damage the mostly expensive equipment. These negative feelings can be taken up by the instructors in that he/she acknowledges, accepts, and legitimizes these feelings (see Su and Reeve, 2011).

Third, non-controlling language should be used that minimizes pressure and intends to give a feeling of flexibility to support students' perception of autonomy (Su and Reeve, 2011). Specifically, instructors can avoid expressions like "you should" and "you must" and instead emphasize choice by using expressions like "if you like to do." By doing so, instructors highlight the voluntariness of the actions in the out-of-school lab. The degree of voluntariness is, however, dependent on the workshop. For example, it is mandatory to pipette exact volumes of samples according to the instruction manuals. By communicating a meaningful rationale for such direct instructions and rules, students can still perceive themselves as autonomous (Reeve, 2015). However, non-controlling language is not only about providing choices, but also about minimizing pressure on the students (Su and Reeve, 2011).

Fourth, providing choice can support students' perception of autonomy as already indicated in the previous section. However, this measure is not only about perceived flexibility, but about real choices. In our study, the workshops were structured very distinct, which is typical for out-of-school student labs in the field of biology (Haupt et al., 2013). Too much freedom in such settings might lead to excessive demands for the students (see Eckes et al., 2018). Therefore, such learning settings have to be sufficiently structured to enable students the perception of competence (see Eckes et al., 2018). Nevertheless, there are opportunities to provide choice in such labs: For example, students can be engaged to choose and arrange the equipment and organize the timetable for experimental steps themselves. However, it has to be kept in mind that choices have to be meaningful to support students' perception of autonomy (Katz and Assor, 2007).

DATA AVAILABILITY STATEMENT

The dataset presented in this article is not readily available because the authors still use this dataset for further studies. The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation. Requests to access the dataset should be directed to KR, kerstin.roellke@uni-bielefeld.de.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Universität Bielefeld, Ethik-Kommission, Geschäftsstelle: Dr. Eva-Maria Berens. Written informed consent from the participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

KR developed the conception and design of the study, organized the database, and wrote the first draft of the manuscript, but not the sections on the statistical analyses and results. NG performed the statistical analyses and wrote the sections on the statistical

analyses and results, and revised the first draft of the manuscript. Both authors read and approved the submitted version of the manuscript.

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