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Do future biology teachers bug out with higher insect-related knowledge and more positive attitudes? A comparison of different education levels

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Introduction: Global species extinction rates are increasing, with a particularly severe impact on insects. Biology teachers are crucial in raising students' awareness of insects' importance for the economy (e.g., food production) and ecosystems. Consequently, it is essential for biology teachers to possess comprehensive knowledge about insects and to maintain a positive attitude toward them.

Methods: Therefore, our cross-sectional study examines the knowledge and attitudes of students across five educational levels with a particular focus on pre-service teachers: levels 1 to 3 represent secondary school students (n = 362) at different stages, while levels 4 and 5 represent pre-service biology teachers (n = 212) in the bachelor's and master's programs.

Results and discussion: Our results show a moderate to strong positive correlation between knowledge and attitudes across all education levels. Participants with a higher educational level have more knowledge on average. Participants in levels 1, 4, and 5 have more positive attitudes than those in levels 2 and 3. No gender differences were observed regarding knowledge but regarding attitudes, with males showing a more positive attitude.

Conclusion: Results indicate that pre-service biology teachers are well prepared, showing good insect-related knowledge and relatively positive attitudes.

KEYWORDS

biology education, knowledge about insects, attitudes toward insects, secondary school students, pre-service biology teachers, gender

1 Introduction

Biodiversity is declining worldwide due to human activities such as overexploitation, habitat destruction, and anthropogenic climate change (WWF, 2018). Educating the public about biodiversity loss and its consequences is essential for promoting informed discussions about human responsibility for environmental issues and fostering societal engagement (Kellert, 1993; Menzel and Bögeholz, 2006; Menzel, 2010). Knowledge (e.g., about diverse species and their way of life) and a positive attitude toward the environment and its creatures are crucial for shaping a sustainable future (e.g., Hines et al., 1987; Härtel et al., 2023). Teachers play a key role in this process: they participate in societal discourse and prepare the younger generation to address future environmental challenges.

Insects are the most diverse group of living creatures and play a central role in ecosystems worldwide, as the importance of co-evolution between insects (especially bees) and plants in the agricultural sector shows (Campbell et al., 2009; European Food Safety Authority et al., 2020; Patel et al., 2021; Siviter et al., 2021). Nevertheless, they receive little attention in the public discourse on raising awareness of biodiversity loss compared to other species, such as mammals (Clucas et al., 2008; Genovart et al., 2013). In biology education studies, insects are also often underrepresented (even in studies focusing on invertebrates), limiting our understanding of knowledge and attitudes toward them (Kellert, 1993; Huxham et al., 2006; Hooykaas et al., 2019; Härtel et al., 2023). Previous results (mainly focusing on vertebrates) indicate a positive correlation between knowledge about an animal species (e.g., birds) and the attitude toward the species (Prokop et al., 2008a; Schlegel and Rupf, 2010; Hooykaas et al., 2019). Still, the relationship regarding insects is not fully understood yet. Older studies also attribute higher knowledge and positive attitudes toward invertebrates to male persons (Kellert, 1993; Bjerke and Østdahl, 2004).

Our study addresses these uncertainties by focusing exclusively on insects. As the teachers mediate the learning process, this study examines pre-service teachers' knowledge about and attitudes toward insects compared to secondary school students. Furthermore, this study is devoted to whether gender differences exist today or have diminished (e.g., due to societal developments).

2 Theoretical background

Research in science education has shown that species knowledge, particularly invertebrate knowledge (Huxham et al., 2006; Härtel et al., 2023), is low but increases with age and education levels (e.g., from primary to secondary school and university; Huxham et al., 2006; Randler, 2010; Randler and Wieland, 2010; Hooykaas et al., 2019). Individual studies also show that people can more easily identify insects at the genus level than at the species level (Härtel et al., 2023) and struggle to name common insects such as bees correctly (Silva and Minor, 2017). In addition to educational effects, studies also report gender-related differences in knowledge and attitudes toward animals. For example, Huxham et al. (2006) reported that male elementary school students have higher knowledge about animals than females. In contrast, Prokop et al. (2008b) showed that Slovakian elementary and lower secondary school girls had higher general knowledge about animal anatomy than boys but, at the same time, appeared to have more misconceptions about invertebrates.

Numerous studies have examined attitudes toward different animal species. Despite the ecological significance of invertebrates, people tend to have rejective (less positive; negativistic) attitudes toward this organismic group (Kellert, 1993; Bjerke and Østdahl, 2004; Schlegel and Rupf, 2010) as they often evoke feelings of anxiety, aversion, or antipathy (Kellert, 1993). Research also has shown a preference for insects perceived as esthetic or ecologically beneficial (e.g., ladybirds, butterflies) over insects categorized as pests or associated with disease (e.g., potato beetles, mosquitos; Kellert, 1993; Bjerke and Østdahl, 2004; Prokop and Tunnicliffe, 2010). In research on species-related attitudes, up to nine dimensions have been identified addressing different attitudinal characteristics. These include, for example, the animals' value to humans, such as their esthetic or utilitarian significance, as well as their ecological importance (Kellert, 1985). In the context of biology education, which aims to promote awareness of biodiversity (using insects as an example), particular attention is given to the naturalistic dimension – representing interest and affectivity in interacting with wildlife and nature – and the ecologistic or ecoscientistic dimension, which encompasses an understanding of ecosystem interrelationships, such as species-habitat interactions and species knowledge (e.g., Kellert, 1985; Prokop and Tunnicliffe, 2010). Furthermore, previous studies have documented gender-related differences in attitudes toward animals, showing that males often exhibit more positive attitudes toward invertebrates. At the same time, females are more likely to express negativistic attitudes, such as disgust or anxiety (Kellert, 1993; Bjerke and Østdahl, 2004; Vanderstock et al., 2022). The *negativistic* dimension, which involves rejection and avoidance of insects, is therefore particularly relevant when examining sensitivity to biodiversity (Kellert, 1985; Prokop and Tunnicliffe, 2010). Accordingly, the naturalistic, ecoscientistic, and negativistic dimensions are frequently addressed in related research (Prokop and Tunnicliffe, 2008; Prokop and Tunnicliffe, 2010), including in our study. There is an indication that higher levels of education are associated with more positive attitudes toward different species (including insects; Kellert, 1993; Bjerke and Østdahl, 2004), but that age could also lead to less positive attitudes (e.g., on the negativistic or ecologistic dimension; Kellert, 1993).

In contrast to research on species-related attitudes, the multi-component model of attitudes is widely used in general education research to describe attitudes. This model posits that attitudes toward an object (e.g., a species) are composed of three interrelated components: the *cognitive* component, which represents thoughts and beliefs about the object; the *affective* component, which refers to emotions associated with the object; and the *behavioral* component, which reflect past behavior related to the object (Konnemann et al., 2012; Haddock and Maio, 2014). The species-related attitudinal dimensions integrate reactions that align with these components, as illustrated by the negativistic dimension: The perception of insects as useless corresponds to the cognitive component, feelings of disgust toward insects align with the affective component, and the intentional act of killing insects reflects the behavioral component. To provide a comprehensive framework for assessing insect-related attitudes, we developed a model that integrates the species-related dimensions with the multi-components model (see Methods section).

Research has demonstrated a positive relationship between species knowledge (e.g., identification skills, perception) and attitudes toward those species, such as affinity (Lindemann-Matthies, 2005; Schlegel and Rupf, 2010). This relationship provides a potential foundation for fostering students' ecological awareness, a responsibility in which biology teachers play a crucial role. To achieve this, teachers' subject matter knowledge about insects and their ecological importance is essential (Backman et al., 2019; Großschedl et al., 2019). Moreover, knowledge and attitudes about a certain topic have been identified as predictors of future behavior, such as engaging in societal discourse or implementing the topic in biology class (Ajzen, 1991; Aptyka and Großschedl, 2022). Studies on pre-service teachers have found that their intentions to implement species-related content into future biology classes are positively associated with their attitudes toward these species (Wagler, 2010). Additionally, demographic factors such as identified gender and age are predictive of species-related attitudes: male and elderly pre-service teachers tend to exhibit more positive attitudes toward unpopular species, such as cockroaches or grasshoppers (Wagler and Wagler, 2015). Age has also been identified as a predictor of the intention to include these species in biology lessons (Wagler and Wagler, 2015). However, as far as we know, no study has specifically examined the knowledge and attitudes of (pre-service) biology teachers' knowledge with a particular focus on insects.

3 Current study and research questions

The present study is a part of the research project "Entomology Education – An International Assessment of Knowledge and Practice," which is a cooperation between different universities worldwide. The presented sub-project was conducted by members of the University of Cologne in Germany and the Charles University in the Czech Republic. The project was previously approved by the ethics committee from Charles University (approval number 2020/22).

Our study examines the extent to which pre-service biology teachers are equipped for teaching, with a focus on their knowledge and attitudes toward insects. We hypothesize that initial teacher training enhances pre-service teachers' insect-related knowledge and fosters more positive attitudes compared to secondary school students. To this end, we investigate the state of knowledge about and attitudes toward insects dependent on education level and gender. Based on the theoretical background, we answer the following research questions (RQ):

1. Do knowledge about and attitudes toward insects correlate positively in different education levels?
2. Do education level and gender affect knowledge about and attitudes toward insects?

4 Materials and methods

4.1 Sample

Our study collected data from $N = 574$ students from North Rhine-Westphalia. The students attended either lower or upper secondary school or university. The lower secondary school represents the first part of secondary school (starting in grade 5). The upper secondary school follows the lower secondary school and corresponds to the ISCED3 level (Eurydice, 2021). In the upper secondary school, students obtain the Abitur qualification, which qualifies them to study at university (comparable to A level). Within the sample, participants were grouped according to their education level, so the following four groups were considered for our analyses: *Level 1 students* (students of the first 2 years of lower secondary school; $n_{Level1} = 82$), *Level 2 students* (students of the final 2 years of lower secondary school; $n_{Level2} = 109$), *Level 3 students* (students of the upper secondary school; $n_{Level3} = 171$), *Level 4 students* (pre-service biology teachers in the bachelor's program; $n_{Level4} = 93$), and *Level 5 students* (pre-service biology teachers in the master's program; $n_{Level5} = 119$). In our sample, students who identify as female ($n_{female} = 365$) were the largest group, followed by students who identify as male ($n_{male} = 190$). Seven students reported being diverse, and 11 stated they did not want to provide any information about their gender. Due to small sample sizes, we compared students who identify as female with those who identify as male in our analyzes regarding gender.

4.2 Research design and procedures

As a part of a cross-sectional study, demographic data, education level, knowledge about and attitudes toward insects were collected. Participation in the study was voluntary, and the data was collected anonymously via a digital tool (*Limesurvey*). The study was conducted during the biology lessons of the school students and different mandatory courses at the university for the pre-service teachers. It lasted 30–60 min, depending on the students' age.

4.3 Measures

We translated the "EntoEdu 2022" instrument (Lucky et al., in review)[1] into German in coordination with the EntoEdu team. One author of this article has translated the questionnaire into German. An external person with expertise in insects then reviewed the translation. The data was processed using a cleaning protocol (e.g., binarization of knowledge items, inversion of attitudes items).

4.3.1 Knowledge about insects

The knowledge about insects scale contains 27 items of the 50 items of the original instrument of Lucky et al. (in review, see footnote 1), resulting in a maximum score of 27 points covering 17 items on insect identification (morphology) and 10 items on lifestyle and importance of insects. The number of items was reduced to adapt the questionnaire to the target group, as individual items would be too difficult for the youngest students (level 1). The items were excluded based on two criteria: Difficult items were statistically identified in terms of their item difficulty for level 1 (threshold < 0.25). Also, all items were reviewed to ensure that their content was appropriate for level 1 students. For example, items requiring knowledge of technical terms that level 1 students do not know (e.g., endosymbiont) were excluded. In order not to compromise the validity of the questionnaire and to keep differences in the different education levels measurable, items with complex content that the level 1 students might also know were retained. Items on insect identification were kept regardless of their statistical item difficulty (see also chapter Results). The knowledge scale shows good to excellent Kuder Richardson reliability for dichotomous items (KR-20) of 0.83 ($M = 16.72$, $SD = 4.87$, range = 1–27).

4.3.2 Attitudes toward insects

The scale on attitudes toward insects covers 24 items on a 5-point Likert scale and contains 12 items from the instrument of Lucky et al. (in review, see footnote 1) and 12 self-developed additional items. The items were selected based on a model for item development that

1 Lucky, A., Janštová, V., Novotný, P., and Mourek, J. (in review). Quantifying ento-literacy: development and validation of an international insect-focused attitude and knowledge survey instrument. Berlin, Germany: International Journal of STEM Education.

we constructed for this study. The model combines the three content-specific dimensions of attitudes (naturalistic, ecoscientistic, and negativistic dimension; Kellert, 1985; Prokop and Tunnicliffe, 2010) and the three components of the multi-component model of attitudes (cognitive, affective, and behavioral component; Konnemann et al., 2012; Haddock and Maio, 2014). This combination of both models led to nine cells, all systematically covered with test items (see Chapter S1 of the Supplementary material for the model for item development). Items on the naturalistic and ecoscientistic dimensions were recoded to equal the items of the negativistic dimension. High scores on the resulting attitudes scale indicate a positive attitude, whereas low scores represent a negative attitude toward insects. The reliability analysis reveals an excellent internal consistency of Cronbach's $\alpha = 0.89$ ($M = 3.31$, $SD = 0.59$, range = 1.33–4.83) for the scale.

4.4 Data analysis

We used SPSS version 29 to evaluate data. Alpha-level was set at 0.05, and preliminary analyses (e.g., Shapiro–Wilk-Test for normality, Levene-Test for homoscedasticity) were conducted to determine appropriate statistical procedures for the analyses. We performed Pearson product–moment correlations to investigate the relation between the two variables, knowledge about and attitudes toward insects. Afterwards, we compared the correlation coefficients of the different education levels via Fisher-z-transformation (RQ1). Furthermore, we ran a two-way MANOVA with the independent variables (education level, gender) and the dependent variables (knowledge about and attitudes toward insects) with subsequent repeated contrast analyses (RQ2). For visualization, we use R version 4.2.2 (R Core Team, 2022) with packages ggplot (Wickham, 2016) and GGally (Schloerke et al., 2021).

5 Results

5.1 Relation between knowledge about and attitudes toward insects

To answer our first research question (RQ1) on the relation between knowledge about and attitudes toward insects, we conducted Pearson product–moment correlations between knowledge about and attitudes toward insects for the total sample and the five education levels. The results revealed a strong positive relation between knowledge and attitudes for the total sample ($r = 0.56$, $p < 0.01$) and also for Level 2 ($r = 0.53$, $p < 0.01$) and Level 3 ($r = 0.55$, $p < 0.01$) students. The results regarding Level 1 ($r = 0.34$, $p < 0.01$), Level 4 ($r = 0.42$, $p < 0.01$), and Level 5 ($r = 0.43$, $p < 0.01$) students showed a moderate positive relation. Comparisons of the correlations between the different education levels via Fisher-z-transformation did not reveal a significant difference in the strength of the relations (see Table 1; Hemmerich, 2017).

5.2 Scores on knowledge about and attitudes toward insects regarding education level and gender

As knowledge and attitudes are substantially correlated variables (cf. above), we used a multifactorial multivariate analysis of variance (two-way MANOVA) to examine the influence of education level and gender on knowledge about and attitudes toward insects (RQ2). The interaction between gender and education level was also explored. The combined effects of gender and education level on the dependent variables were statistically significant for the overall model, Wilks' $\Lambda = 0.03$; $F(2, 544) = 8617.73$, $p < 0.001$, $\eta_p^2 = 0.97$, as well as for the main effect of education level, Wilks' $\Lambda = 0.69$; $F(8, 1{,}088) = 27.99$, $p < 0.001$, $\eta_p^2 = 0.17$, and gender, Wilks' $\Lambda = 0.97$; $F(2, 544) = 8.06$, $p < 0.001$, $\eta_p^2 = 0.03$, but not for the interaction effect, Wilks' $\Lambda = 0.96$; $F(8, 1{,}088) = 1.06$, $p = 0.392$, $\eta_p^2 = 0.01$. This indicates that there are statistically significant differences between the different education levels (level 1 to 5, see Figure 1) as well as between males and females in their combined scores of knowledge and attitudes. Therefore, we conducted post-hoc ANOVAs that revealed significant differences in education level for both knowledge, $F(4, 545) = 40.93$, $p < 0.001$, $\eta_p^2 = 0.23$, and attitudes, $F(4, 545) = 34.52$, $p < 0.001$, $\eta_p^2 = 0.20$ and in students' attitudes regarding gender, $F(1, 545) = 15.88$, $p < 0.001$, $\eta_p^2 = 0.03$; $M_{female} = 3.27$, $SD = 0.57$, $M_{male} = 3.36$, $SD = 0.63$, but not in their knowledge, $F(1, 545) = 2.02$, $p = 0.1.56$; $M_{female} = 16.98$, $SD = 4.72$, $M_{male} = 16.18$, $SD = 5.04$.

We further investigated the differences in education level via subsequent repeated contrast analysis. The analyses exposed the knowledge that level 2 students scored lower than level 3 students, t (547) = −3.42, $p < 0.001$, $r = 0.20$, and the level 3 students scored lower than the level 4 students, t (547) = −4.86, $p < 0.001$, $r = 0.29$. There were no significant differences between level 1 students and level 2 students as well as between level 4 and level 5 students (see Table 2). The results of the subsequent repeated contrast analysis regarding the attitudes showed that level 1 students scored significantly higher than level 2 students, $t = 4.24$, $p < 0.001$, $r = -0.29$.

TABLE 1 Pearson product–moment correlations between knowledge about and attitudes toward insects among students with different education levels.

	Total sample (N = 574)	Level 1 (n = 82)	Level 2 (n = 109)	Level 3 (n = 171)	Level 4 (n = 93)	Level 5 (n = 119)	Comparison of the correlations			
							Level 1 and Level 2	Level 2 and Level 3	Level 3 and Level 4	Level 4 and Level 5
Knowledge and attitudes	0.56**	0.34**	0.53**	0.55**	0.42**	0.43**	$z = -1.59$ $p = 0.112$	$z = 0.23$ $p = 0.820$	$z = 1.31$ $p = 0.191$	$z = -0.09$ $p = 0.931$

Level 1 = early lower secondary school students; Level 2 = late lower secondary school students; Level 3 = upper secondary school students; Level 4 = pre-service teachers (bachelor's program); and Level 5 = pre-service teachers (master's program). **p <0.01.

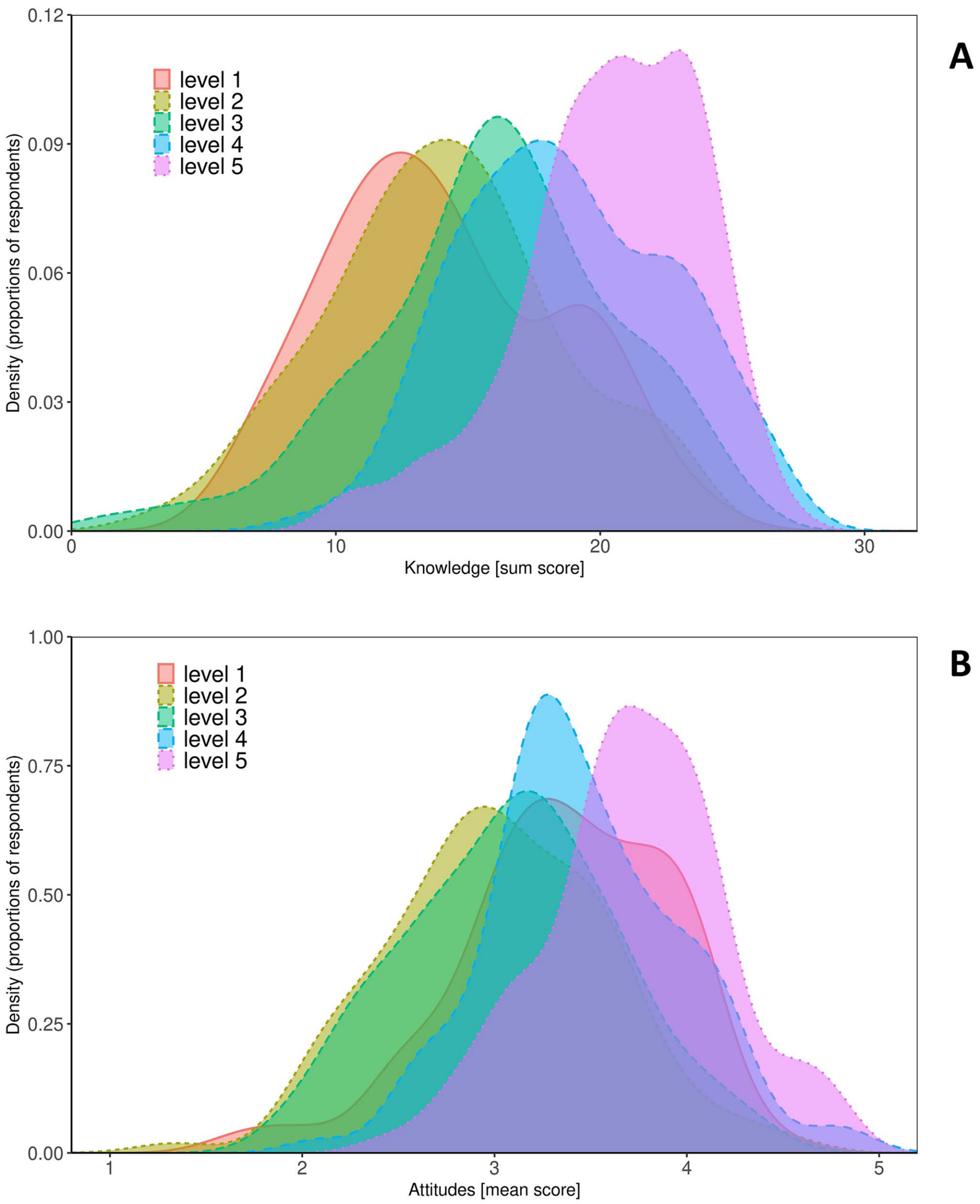

FIGURE 1
Score distribution of knowledge about and attitudes toward insects separated by education level. Visualization of distribution of knowledge (sum score; **A**) and attitudes (mean score, 5-point-Likert scale; **B**) scores. Level 1 = early lower secondary school students; Level 2 = late lower secondary school students; Level 3 = upper secondary school students; Level 4 = pre-service teachers (bachelor's program); and Level 5 = pre-service teachers (master's program).

Furthermore, level 3 students scored significantly lower than level 4 students, $t = -6.27$, $p < 0.001$, $r = 0.32$. No significant differences were found between level 2 and level 3 students as well as between level 4 and level 5 students (see Table 2).

We also analyzed the difficulty of knowledge items on insect identification across education levels. The results of these calculations are shown in Figure 2. We used the results of the youngest students (level 1) as a reference for the assessment of item difficulty. Consequently, we distinguish between easy (item difficulty ≥ 0.8 for level 1 students), difficult (item difficulty < 0.2 for level 1 students), and moderate (item difficulty between 0.2 and 0.8 for level 1 students) items. Overall, the difficulty of most items decreases with the increase in education level. Only one item (grasshopper) shows an inconsistent pattern.

6 Discussion

6.1 Relationship between knowledge about and attitudes toward insects

Regarding our first research question, we found strong positive correlations for the total sample and the older lower and upper secondary school students (levels 2 & 3). However, there were only moderate correlations for the younger lower secondary school students (level 1) and the pre-service teachers (bachelor's and master's programs; levels 4 & 5). The comparatively weaker correlation of the younger lower secondary school students (level 1) is consistent with the findings of Hooykaas et al. (2019), who found a similar correlation for primary

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TABLE 2 Mean and standard deviations for knowledge about and attitudes toward insects and results of the contrast analyses on the differences among students with different education levels.

	Total sample (N = 555)	Level 1 (n = 82)	Level 2 (n = 103)	Level 3 (n = 164)	Level 4 (n = 91)	Level 5 (n = 115)	Repeated contrasts			
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	Level 1 and Level 2	Level 2 and Level 3	Level 3 and Level 4	Level 4 and Level 5
Knowledge	16.71 (4.84)	14.11 (4.32)	14.14 (4.30)	15.93 (4.69)	18.67 (3.95)	20.41 (3.43)	t (547) = −0.03, p = 0.976	t (547) = −3.42, p < 0.001, r = 0.20	t (547) = −4.86, p < 0.001, r = 0.29	t (547) = −1.41, p = 0.160
Attitudes	3.30 (0.59)	3.36 (0.55)	3.02 (0.57)	3.08 (0.55)	3.46 (0.50)	3.72 (0.47)	t (547) = 4.24, p < 0.001, r = −0.29	t (547) = −1.18, p = 0.243	t (547) = −6.27, p < 0.001, r = 0.32	t (547) = −1.10, p = 0.274

Level 1 = early lower secondary school students; Level 2 = late lower secondary school students; Level 3 = upper secondary school students; Level 4 = pre-service teachers (bachelor's program); and Level 5 = pre-service teachers (master's program).

school students regarding species literacy and attitudes toward nature and animals. The moderate correlation among the pre-service biology teachers (bachelor's and master's program) is unexpected but could be due to the selection of the sample. The descriptive statistics show a comparatively slightly lower variance in teachers' knowledge, which could affect the strength of the correlation for these groups. However, the comparisons of the correlations between the different education levels did not show any significant differences.

6.2 Differences in knowledge about and attitudes toward insects regarding education level

The results regarding the first part of our second research question confirmed our expectation that individuals with a higher education level have a higher level of knowledge. Pre-service teachers in the bachelor's program (level 4) showed significantly higher knowledge than upper secondary school students (level 3), and they, in turn, had higher knowledge than older lower secondary school students (level 2). These trends mirror earlier findings that indicate differences in knowledge about insect and bird species for 16 to 65-year-old participants with different education levels (Randler, 2010) and in vertebrate species for primary and secondary school students (Randler, 2008). However, no differences were found between the younger students in the lower secondary school (levels 1 & 2) or between the pre-service teachers in the bachelor's and master's programs (levels 4 & 5). The lack of differences in lower secondary school students' knowledge (levels 1 & 2) may be explained by differences in school curricula. The timing and extent to which this is addressed in lessons can, therefore, vary between schools. Additionally, conscious contact with insects has become increasingly rare in modern everyday life, potentially leading to a diminished perception of insects. A related phenomenon has been described by Wandersee and Schussler (1999) in the context of plants, introducing the concept of *plant blindness*. This term refers to the tendency of individuals to overlook plants, lack awareness of their presence, and fail to appreciate their ecological roles (Wandersee and Schussler, 1999). The phenomenon appears to be particularly prevalent among younger generations (Blue et al., 2023). By analogy, the concept of *insect blindness* could be applied to describe younger students' diminished awareness of insects, which may result in limited knowledge about them. However, this hypothesis is challenged by findings indicating that people sometimes possess more knowledge of exotic animals than about native ones (Huxham et al., 2006). For insects, a lack of media presence may have led to relatively low levels of knowledge, as vertebrates (especially mammals) are usually used as flagship species for campaigns and are more likely to be the main characters in children's books than insects (Huxham et al., 2006; Clucas et al., 2008; Ballouard et al., 2011). An exploratory analysis of the frequency of the various insect groups in German-language media for children (item ranking; low value = less popular insect, high value = more popular insect; see Chapter S3 of the Supplementary material for the suggested ranking) using GPT-4 (see Chapter S2 of the Supplementary material for the used prompt) was correlated with the average item difficulty of insect identification items (low value = difficult item, high value = easy item). The analysis revealed a significantly strong correlation between the two variables (Spearman's $\rho = 0.583$, $p = 0.014$), indicating that items are easier (as reflected by higher item difficulty values) when the respective insects appear more frequently in children's media. This result suggests that a greater presence

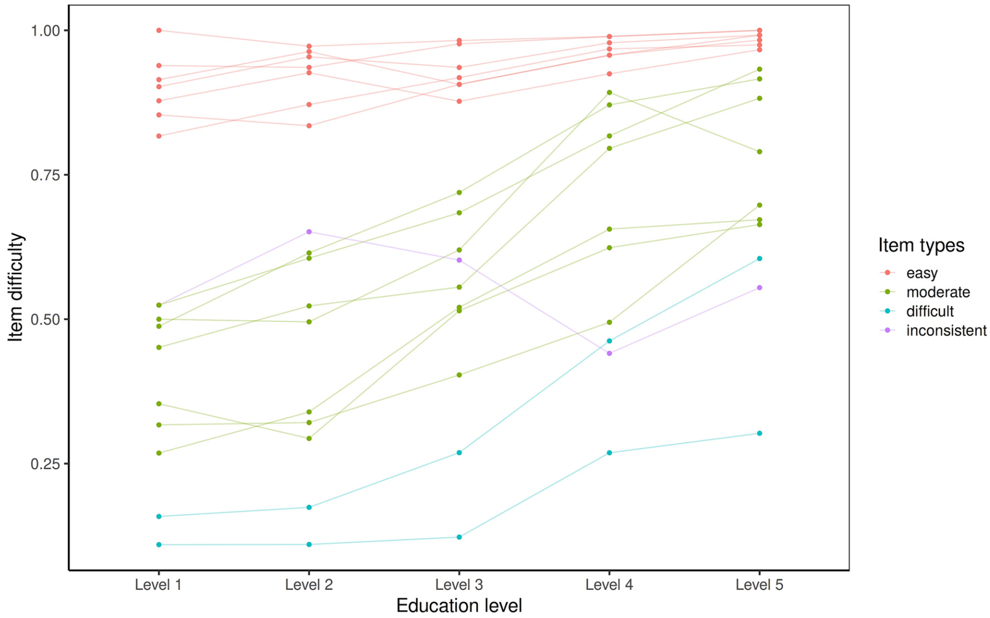

FIGURE 2
Item difficulty of insect identification items. Level 1 = early lower secondary school students; Level 2 = late lower secondary school students; Level 3 = upper secondary school students; Level 4 = pre-service teachers (bachelor's program); and Level 5 = pre-service teachers (master's program). The item types were determined based on the calculated item difficulty for level 1 resulting in the categories easy (item difficulty >0.8), moderate (item difficulty <0.8), difficult (item difficulty <0.2) and inconsistent progression (item difficulty increases from level 2). Based on this classification, the results shown in the figure are in the following order of insects from top to bottom: ant, dragonfly, wasp., moth, bee, ladybug, housefly (easy items), grasshopper (inconsistent item), stick insect, cockchafer, praying mantis, bug, cockroach, flea, louse (moderate items), hercules beetle, and longhorned beetle (difficult items).

of insects in media is associated with easier identification. In order to draw more reliable conclusions, this initial assessment should be further investigated in future studies using appropriate methods, such as those used in bird studies (Randler et al., 2024).

Similar to the trend in knowledge about insects, attitudes toward insects were more positive at higher education levels, with a clear difference between upper secondary school students (level 3) and pre-service teachers in the bachelor's program (level 4). Only the younger lower secondary school students (level 1) deviate from this trend, showing significantly more positive attitudes than the older lower secondary school students (level 2). The more positive attitudes of the pre-service biology teachers (bachelor's and master's program) confirm the findings of Kellert (1993), who found that scientists with a biological focus had more positive attitudes regarding invertebrates than other groups and the general population.

In addition, pre-service teachers may have had more exposure to insects and their ecological and societal importance during their biology teacher education. Kellert (1993) also describes that negative attitudes regarding invertebrates, such as fear, increase with age, which might explain the less positive attitudes for the older lower and upper secondary school students (level 2 & 3) compared to the younger lower secondary school students (level 1).

6.3 Gender differences in attitudes toward insects but not in knowledge about insects

Concerning our second research question, we did not find gender-specific differences in knowledge about insects. These findings are in contrast to previous studies regarding knowledge about invertebrates, which identified a higher level of knowledge in males (Kellert and Berry, 1987; Huxham et al., 2006). However, these differences seem to be disappearing as Hooykaas et al. (2019) found no gender-specific differences in elementary school students but from the age of 12 onwards, and explain this discrepancy with adapting socialization processes between boys and girls.

Male students showed slightly more positive attitudes toward insects. This result follows on from previous findings that indicate that males have more positive attitudes toward animals that are less popular, dangerous, or often perceived as disgusting than female persons (e.g., Bjerke and Østdahl, 2004; Prokop et al., 2008b; Prokop and Tunnicliffe, 2008). It was also assumed that females may be more likely to develop anxiety toward invertebrates (Kellert, 1993). Our findings extend the current state of research by providing more recent results. The small effect sizes suggest that gender differences have diminished in recent generations. Gender-specific education with regard to attitudes toward insects, therefore, seems to have lost much of its relevance for recent generations in Germany.

7 Limitations

When interpreting the results, the exploratory character of this study must be considered. In some analyses, the sample sizes of the subsamples differed considerably when analyzing the additional variables. To avoid falsifying the results through guesswork and thus obtain a reliable measuring instrument, the questionnaire of Lucky et al. (in review, see footnote 1), was adapted to the cognitive abilities (e.g., knowledge about technical terms like endosymbiont) of the students (especially younger lower secondary school students). Also, the attitude scale was adapted and supplemented with additional items to cover a broader range of attitudes (e.g., behavioral dimension). Therefore, the results are only partially comparable with the original study (see chapter Methods for more details on questionnaire adjustments). The aim of this study was to analyze a comprehensive framework of attitudes toward insects with a particular focus on pre-service biology teachers. We intended to cover as many attitude-related aspects as possible that are relevant to pre-service teachers' future teaching practice. To this end, we developed an extended attitudinal model that contains both species-related dimensions (naturalistic, ecoscientistic, and negativistic) as well as cognitive, affective, and behavioral components.

8 Conclusions and implications for education and research

This study aimed to assess the status quo of pre-service biology teachers' knowledge about and attitudes toward insects compared to secondary school students in Germany. We especially wanted to determine whether the biology training of pre-service teachers at university increases knowledge and attitudes as part of their preparation for the teaching profession. This initial assessment indicates a good preparation of pre-service teachers' subject matter knowledge and relatively positive attitudes toward insects. From a scientific point of view, it would therefore be interesting to investigate teachers' intentions to address insects in the classroom (e.g., based on the theory of planned behavior; Ajzen, 1991) – especially as insects are rarely mentioned directly in curricula. The rather positive attitudes of pre-service teachers in our study give a first hint that pre-service teachers might be more likely to implement insect-related content in their biology class (Wagler, 2010; Büssing et al., 2019). A study of pre-service teachers' intentions to implement wolf-related content in their future biology classes, based on the theory of planned behavior, found that attitudes toward wolves were predictive of the pre-service teachers' motivation to protect wolves (Büssing et al., 2019). They also indicate that this motivation is predictive of the attitude of teaching and the perceived behavior control. These findings might be transferred to insects, as wolves are also often seen as controversial (e.g., as a threat to humans) and tend to evoke negative attitudes. Against the background of species extinction and the increasing importance of species conservation, it would therefore be valuable to analyze the motivation to protect insects as an additional construct in future studies. As secondary school students showed rather moderate results in both knowledge about and attitudes toward insects, it is essential to provide pre-service teachers with the skills to teach relevant but unpopular topics (such as insects in the ecosystems) in a way that is conducive to learning. With regard to teacher education, we hope that our results will encourage teacher educators and pre-service teachers to consider unpopular topics (such as insects) in their studies, not only from a scientific point of view but also from a didactic (biology education) perspective.

It was also intended to investigate whether education level or gender proves to be beneficial or detrimental regarding knowledge about and attitudes toward insects. Our study showed the effects of education level on knowledge and attitudes. It also confirms the relation between knowledge about and attitudes toward insects. Gender did not affect knowledge and only had little impact on attitudes. This result indicates that the differences in the socialization process of students of different genders have diminished. However, since this aspect was not the focus of this study, it is only an indication that it should be more precisely classified by considering other personal factors. The relationship between knowledge and attitudes and the effect of the education level should be considered in the teaching of biology in schools. Kellert (1985) already pointed out three stages in the development of the perception of animals. These stages develop from a more emotional interest in animals (up to grade 5), through the development of a cognitive and factual understanding of animals, to the final stage (from grade 8), where ethical and ecological aspects become more important. These stages refer to both a cognitive (knowledge) and an affective (attitudes) development process in school students. Therefore, school students are receptive to different aspects of animal groups and their significance depending on their stage of development.

In order to teach complex biological topics in an age-appropriate way, this aspect should be considered by the teacher and underlines that multifaceted teacher training is essential. In this context, our study provides a good indication of helpful subject matter knowledge in pre-service teacher training, which should be followed by further research on subject-specific didactic implementation (here regarding insects) in the future.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: https://doi.org/10.17605/OSF.IO/W2ZDS.

Ethics statement

The studies involving humans were approved by University of Florida IRB (IRB202002790), Charles University, Faculty of Science (2020/22), Ethics Commission of Bielefeld University on application no. 2021-198 of August 23, 2021, Matej Bél University, nr. 1561/2021. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

RG: Data curation, Formal analysis, Investigation, Writing – original draft, Conceptualization, Methodology, Writing – review & editing. PN: Conceptualization, Formal analysis, Visualization, Writing – review & editing, Methodology. VJ: Conceptualization, Writing – review & editing, Methodology. JG: Conceptualization, Supervision, Writing – review & editing, Methodology.

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Conflict of interest

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

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2024.1477841/full#supplementary-material

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