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# A research instrument to monitor people's competence to sustain insect biodiversity: the Self-Perceived Action Competence for Insect Conservation scale (SPACIC)

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**ABSTRACT**

The loss of insect biodiversity is a major global sustainability issue that is highly relevant to science education. Science education can support and develop learners' competence to take actions to sustain insect biodiversity and empower learners to deal actively with this sustainability issue. However, we currently lack an instrument to assess these aspects of individual competence. This paper aims to fill this gap by introducing the Self-Perceived Action Competence for Insect Conservation scale (SPACIC). This scale allows for investigating learners' action competence by focusing on self-perceived knowledge, confidence, and willingness to take insect conservation actions. The scale is grounded in theory and face-validated by external experts. The piloting with 180 secondary school students showed a good quality of the instrument in terms of reliability and validity, as the reliability analyses and confirmatory factor analysis show. The SPACIC scale is applicable to various formal and informal educational settings. Applying the scale can yield information about the effects of educational approaches and inform learners, educators, and researchers about changes in self-perceived competence. In this way, the SPACIC scale can contribute to the evaluation and design of educational approaches and eventually boost learners' development into becoming active environmental citizens.

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Insect conservation; Scale development; Action competence

## Introduction

The decline of insects is an urgent environmental problem and a major sustainability issue (Cardoso et al., 2020; Dangles & Casas, 2019; Harvey et al., 2020; Van Klink et al., 2020), which makes this topic highly relevant to science education. Insect decline results from an interplay of anthropogenic stressors, such as habitat loss and fragmentation, intensive agriculture, pesticide use, urbanization and climate change (Wagner et al., 2021). This decline affects ecosystems because insects play an important role as prey and predators, as physical decomposers, parasites, and as pollinators (Kawahara et al., 2021). Insect decline also greatly impacts on humankind and societies because insects provide key ecosystem services that are provisional (e.g. nutrition for humans and reared animals, products made out of insects), connected to regulation and maintenance (e.g. waste mediation, pest control, and soil formation), or cultural (e.g. relevance in science, educational value, entertainment,

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aesthetics, spiritual importance) (Ameixa et al., 2018). Most insect species are either harmless or beneficial to humans since only a minority of insect species occur as pests or as vectors for diseases. The pivotal role of insects makes halting insect decline a key aim to achieve sustainability goals (Dangles & Casas, 2019).

Science education can play a crucial role in fostering people's individual competence to cope with the problem of insect decline and take actions that sustain insect biodiversity. However, traditional education focuses mainly on increasing students' knowledge and understanding about insects and their ecological role rather than developing their competence to act (Marselle et al., 2021). Moreover, educational research about students' perspectives on insect declines and insect conservation is generally limited, which means that there is little empirical evidence relating to educational interventions and any impact they may have. A potential reason for this lack of educational research and findings might be the current lack of a reliable research scale to assess learners' competence to deal with this specific sustainability issue, since reliable scales are key to monitor the impact of educational interventions (Waltner et al., 2019).

Therefore, this study aims to fill this gap by proposing a novel research scale, namely the *Self-Perceived Action Competence for Insect Conservation (SPACIC)* scale. The SPACIC scale is grounded in theory and it is to our knowledge the first to combine the content of insect conservation with the educational framework of *action competence* (Jensen & Schnack, 1997; Olsson et al., 2020; Sass et al., 2020). Applying the SPACIC scale in formal and informal educational settings provides new insights into relevant personal dimensions of action taking, hitherto unexplored. The scale also enables assessing and comparing educational approaches about insect conservation. The scale can also be applied in a continuous professional development monitoring, which could contribute to overcoming observable implementation gaps of traditional educational approaches (Marselle et al., 2021). The scale can also provide crucial data to tailor effective educational approaches, which eventually will boost people's competence to take actions that mitigate insect decline.

## Background

In this section, we provide further background information of the issue of insect decline and limitations of current research. We first focus on the problem of insect declines and then address connected educational perspectives and the need for a new instrument to measure people's individual competence to take action to help insects. Finally, we will outline the educational concept of Action Competence, which provides the theoretical frame for the scale development.

### *Insect declines – the gap between awareness and action*

The public awareness of insect decline has been growing in the last decade and there are several educational initiatives, but the public awareness is skewed towards wide spread crop pollinating species such as honeybees (Iwasaki & Hogendoorn, 2021). Hence, this higher awareness of the problem of insect decline is not sufficiently translated into actions that sustain a broad diversity of insects. A recent analysis of pollinator conservation policies identified the need of more effective approaches leading to actions for insect pollinator conservation, because traditional knowledge-centered education is not sufficient (Marselle et al., 2021). This need for approaches focusing on action is underlined by the fact that insect declines remain at a high level (Van Klink et al., 2020), which leads to targets of biodiversity conservation missed (Buchanan et al., 2020). Therefore, conservation scientists continue to call for more actions and to educate a broader public to take actions for insects (Cardoso et al., 2020; Harvey et al., 2020; Kawahara et al., 2021; Wagner et al., 2021).

One explanation for these difficulties to take action is that insect decline is at the core of the major sustainability issue of biodiversity loss. Biodiversity loss can be considered as a *wicked* or even a *super wicked* problem (Lambrechts, 2020; Sharman & Mlambo, 2012). These kinds of problems are difficult to solve because they are complex, not fully understood, involve various stakeholders with different values and perspectives that often lead to conflicting interests (Balint et al., 2011). A conflict of interests can also occur on a personal level, when actions challenge established norms, such as when wildlife friendly gardening conflicts with social norms of tidiness (Burr et al., 2018). As mentioned above, a specific challenge in the context of insect conservation is that public awareness, policies and funding often focus on honeybees, which are a highly managed agricultural species with one of the least risks of becoming extinct and that is inappropriate as an umbrella species for wild insect pollinator conservation (Colla & MacIvor, 2017; Iwasaki & Hogendoorn, 2021). To find a way forward in informing about this (super) wicked problem of insect decline, we need to consider personal social perspectives, such as individuals' experiences, actions, standards, norms, and values (Balint et al., 2011; Toomey et al., 2017).

### *The important role of education and educational research for insect conservation*

Recent studies underline the relevance of considering social perspectives in the context of insect conservation (Hall & Martins, 2020; Marselle et al., 2021; Toomey et al., 2017), particularly in understanding reasons and obstacles for taking conservation actions (Knapp et al., 2021). A diversity of interactions with nature and positive emotions are important predictors of people's pro-pollinator behavior (Knapp et al., 2021; Sturm et al., 2021). Negative attitudes, on the contrary, can lead to a reduced motivation to take action to protect insects (Samways, 2018). Unfortunately, the attitudes towards insects are often negative (Leandro & Jay-Robert, 2019; Shipley & Bixler, 2017), barring few insect groups that are perceived more positively (e.g. butterflies). In general, research on social perspectives in insect pollinator conservation is still underexplored (Knapp et al., 2021). It is also important to bear in mind that most research on social perspectives relates to pollinators, but does not consider the broad diversity of insects and their other functions in ecosystems.

Educational research about students' personal perspectives in the context of insect declines and conservation is very limited as well. Studies about learning through conservation activities usually focus on adult volunteers who already display strong pro-environmental values, as Ruck and Mannion (2021) point out. Their study on pollinator conservation activities at school focused mainly on students' experiences during the project, but did not investigate the students' abilities to contribute to conservation or if this ability changed as a consequence of these activities (Ruck & Mannion, 2021). Another limitation of studies on learning about insects and insect decline at school is that many approaches focus on honeybees, which cannot be translated directly into wild insects. Educational researchers therefore call for including a more diverse perspective to teach about insects, their decline and conservation (Schönfelder & Bogner, 2018; Sieg et al., 2018). Valid instruments for educational research in the field of insect conservation are important to support the assessment and the further development of educational approaches.

### *The need of a new scale for educational research*

Existing tools used in research about personal perspectives of insect conservation are however not sufficient to investigate how learners' competence develops. Tools to investigate attitudes towards pollinators – e.g. semantic differentials (Schönfelder & Bogner, 2018) – do not give insights into learners' competence to conserve insects. Other recently developed instruments focus on existing behavior (Barbett et al., 2020; Knapp et al., 2021), which does not provide information on why people did or did not take actions and is therefore not suitable to investigate how learners' competence develops. These two instruments are also different in their respective scope, which is either more general (pro-nature conservation behavior in Barbett et al. (2020)), or restricted to pollinators (Knapp et al., 2021). Moreover, both instruments were not designed for educational purposes, but for research on adults and therefore contain elements that are not applicable to younger learners. In particular, existing research tools are not adequate in educational research to provide insights into young people's self-reported perceptions of their own competence in the context of insect declines and insect conservation.

We therefore need a reliable research scale to obtain insights into individuals' competence connected to personal actions for insect conservation that is applicable in a wide range of educational settings, age groups and research designs. Such a scale could provide baseline information on personal competence, clarify the effects of existing teaching approaches, and guide the improvement and development of further approaches. Applying this scale could yield information about what is required to make young people take actions to sustain insect biodiversity: do learners need more knowledge of action possibilities, more practical training, or more motivation to take these actions? The concept of *action competence* (Jensen & Schnack, 1997; Sass et al., 2020) provides a theoretical grounding for such a scale development process. Since we are the first to apply the concept of action competence in this context, we outline its assumptions and benefits in the following section.

### *The concept of action competence*

One aim of science education and environmental education from a literacy perspective is to educate students to become active citizens with the ability to deal with current challenges (Hadjichambis et al., 2020; Hodson, 2010). This aim to empower learners to take actions in line with the educational concept of *action competence*, which was developed in the field of health and environmental education (Breiting & Mogensen, 1999; Jensen & Schnack, 1997) and recently redefined for the context of sustainable development (Sass et al., 2020). Action competence describes people's ability to act toward solving controversial problems, which involves knowledge of action possibilities, confidence in one's actions and willingness to take action (Jensen & Schnack, 1997). We can interpret action competence as a latent generic competence that can be fostered through education. In this way, a higher level of action competence can be seen as an outcome of (science) education (Clark, 2016) thus providing an educational ideal for a democratic approach to education (Mogensen & Schnack, 2010).

Education aiming to foster learners' action competence needs to go beyond theoretical knowledge about a problem (Jensen, 2002) and focus on action-oriented knowledge, consider the aspects of confidence in one's actions and willingness to take actions (Jensen & Schnack, 1997). This action-orientation is in line with the claim that learners should get the chance to learn about, through, and from actions to gain practical experience and prepare for active citizenship (Chawla & Derr, 2012). *Action* refers to a specific type of behavior with two main components: (1) *An action is deliberate and intentional* – the person taking the action decides what to do, based on an understanding of the causes of a problem. Hence, action goes beyond mere behavior, because behavior could be copied without understanding or a person could be pushed to a behavior. (2) *An action is targeted at solving a problem*. In this sense, action goes beyond an activity that does not try to solve a problem (Jensen & Schnack, 1997).

These characteristics of action competence highlight differences to other concepts in environmental education. Jensen and Schnack (1997) demarcate action competence from the idea of behavioral change and highlight that behavior modification and action competence are two fundamentally different goals in education. The authors criticize the use of moralizing and manipulating aspects to achieve intended behavioral changes to the 'right' pro-environmental behavior. Rather, fostering action competence aims to support students in making up their own minds and taking their own decisions on how to deal with complex situations (Jensen, 2002; Jensen & Schnack, 1997). The aspect of 'intention' is key for action in the sense of action competence, but not for pro-environmental behavior, which can also be unintentional (see definition of pro-environmental behavior in Steg et al. (2014)). In addition, action competence highlights the importance of indirect actions (see below) that are relevant for solving complex environmental issues, but which are underrepresented in pro-environmental behavior models (see discussion of Kollmuss and Agyeman (2002) in Jensen (2002)).

Action competence is in line with the reasonable person framework developed by Kaplan and Kaplan (2009) which builds on the three main information needs among people for (1) building mental models, (2) being effective, and (3) meaningful actions (see discussion in Olsson et al. (2020)). The first need relates to the knowledge dimension of action competence, since people need knowledge of action possibilities and a vision for the future. The second need relates to the confidence dimension of action competence, since it is important to support peoples' confidence and their feeling of empowerment. This connects to the feeling of self-efficacy, which involves people feeling confident that they can take actions and that these actions matter (Bandura, 2001). Finally, the third need relates to willingness, since people want to engage in meaningful actions.

The concept of action competence fits well with the issue of insect declines, since actions to halt insect decline are key for a sustainable future (Dangles & Casas, 2019), but solving the problem is difficult due to the wicked nature of the issue (see above). Therefore, the general action competence framework (Jensen & Schnack, 1997; Olsson et al., 2020; Sass et al., 2020) was applied to the issue of insect decline as a part of this research project and resulted in the *Action Competence for Insect Conservation (ACIC)* framework (Lampert et al., 2023).

Within this framework of Action Competence for Insect Conservation (Figure 1), actions are seen as divided into *direct* and *indirect* actions, which are the two main categories within action competence (Breiting & Mogensen, 1999; Jensen & Schnack, 1997; Sass et al., 2020). In this context, direct actions aim to sustain insect biodiversity directly in the personal environment, whereas indirect actions aim to encourage others to sustain insect biodiversity. Both types of actions are important from an insect conservation perspective. Direct actions in private gardens can contribute to building stepping-stone habitats in urbanized areas (Hall et al., 2017). Indirect actions provide the opportunity to tackle significant roots of the problem of insect decline (e.g. intensive agriculture using pesticides) that cannot be solved by direct actions (Wagner et al., 2021). Since actions need to be targeted to solve a problem, it is necessary to include the indirect actions that focus on the roots of the problem at stake. We view fostering learners' action competence to sustain insect biodiversity as an educational goal in science education that goes beyond theoretical learning about the issue.

Based on these considerations, the overall aim of this study is to develop a reliable and valid scale to measure students' action competence to sustain insect biodiversity. More specifically, the following research question guides the instrument development:

> How can a reliable and valid instrument, Self-perceived Action Competence for Insect Conservation scale (SPACIC scale), be developed?

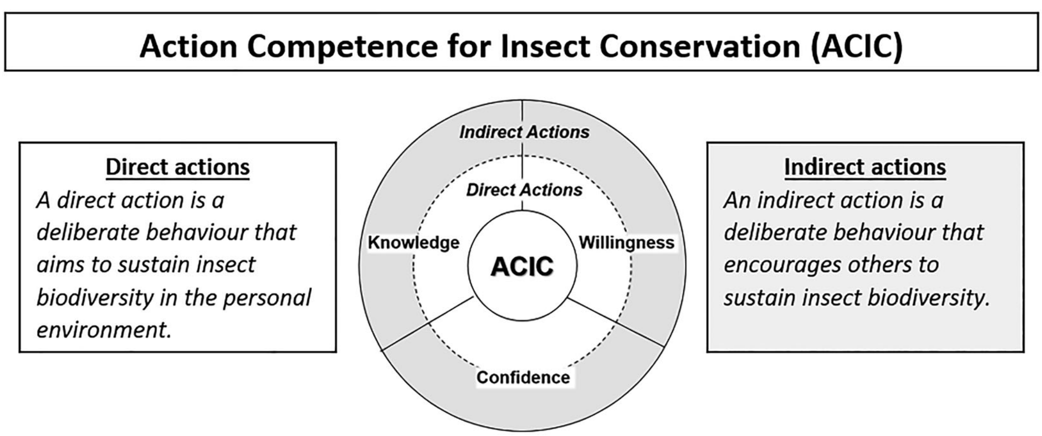


**Figure 1.** Graphical summary of the Action Competence for Insect Conservation (ACIC) framework.

## 3. Materials and methods

In this section, we describe the development of the SPACIC scale that followed the systematic approach for scale development described by Furr (2011). This approach consists of four interrelated steps. Step 1: Articulate construct and context of the scale; Step 2: Choose response format and assemble initial item pool; Step 3: Collect data from respondents; Step 4: Examine psychometric properties and quality (see Figure 2).

We aim to put an additional focus on the reliability and the *construct validity* of the SPACIC scale. *Construct validity* describes the extent to which the new scale represents the construct that shall be measured (Hair et al., 2010). This construct validity consists of four main types of validity: (a) *face validity*, which is the extent to which the content of the items is consistent with the construct; (b) *convergent validity*, which is the extent to which indicators of a construct converge with each other and indicators from other scales; (c) *discriminant validity*, which is the extent to which a construct is truly distinct from other constructs; (d) *nomological validity*, which results from an examination of whether the correlations between the constructs in the measurement theory make sense (Hair et al., 2010).

### *Step 1: Construct & context*

The SPACIC scale is directly connected with the educational framework of Action Competence for Insect Conservation (see background), which serves as the construct. Both, the framework and the SPACIC scale relate to the context of insect decline and insect conservation.

The Action Competence for Insect Conservation framework consists of three dimensions (see Figure 1): (i) Knowledge about actions (K); (ii) Confidence in one's actions (C); and (iii) Willingness to take actions (W). Every dimension (K, C, W) is divided into direct actions (DA) and indirect actions (IA) as sub-dimensions. Hence, there are six sub-dimensions: KDA, KIA, CDA, CIA, WDA, WIA. From a psychometric perspective, the framework and its (sub-)dimensions can be interpreted as a three-order model (see Figure 3). The SPACIC scale takes up this structure through corresponding subscales. The number and content of the items for each subscale were not determined at the beginning of the scale development but resulted from a selection and validation process.

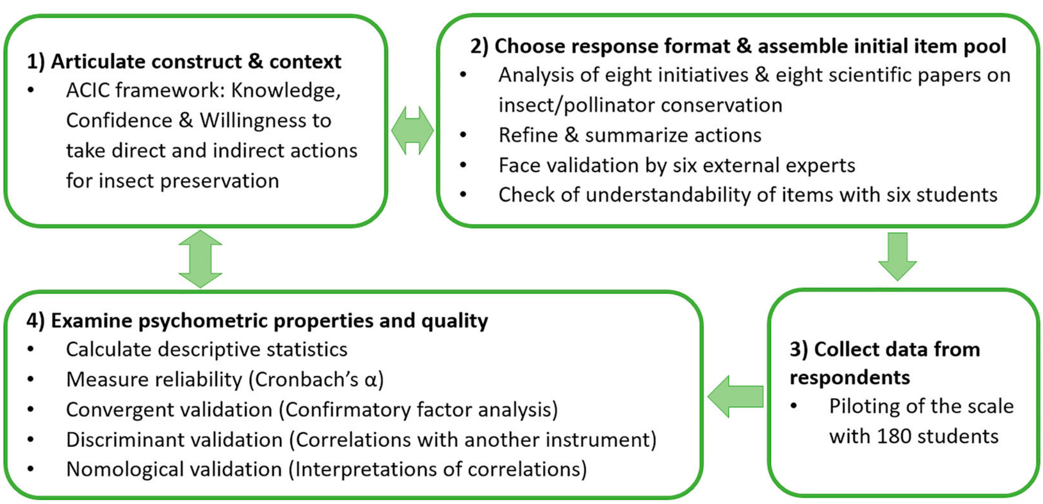


**Figure 2.** Overview of the steps of the scale development process. The arrows describe the (inter)relations of these steps.

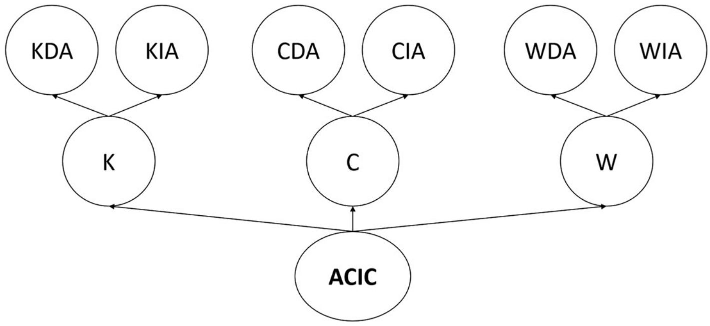


**Figure 3.** Structure of the modeled three-order construct of Action Competence for Insect Conservation. The construct is divided into three sub-constructs K (Knowledge), C (Confidence) and W (Willingness). Each sub-construct consists of direct actions (DA) and indirect actions (IA).

### *Step 2: Response format & assembling the initial item pool*

Our aim was to develop items that allow assessing the *self-perceived* level of ACIC, acknowledging that there is no absolute level of action competence that can be measured (Olsson et al., 2020). All items let respondents themselves decide to what extent they agree with statements about their knowledge (K), confidence (C) or willingness (W) to take actions to conserve insects. We used a five-point Likert-type scale with answer options 'fully disagree', 'disagree', 'neither agree nor disagree', 'partially agree', 'fully agree'.

To allow comparisons between the subscales K, C, and W, we decided to use the same content ( = the same concrete actions) for all items in K, C and W and to pair this content with a specific introduction phrase referring to either K, C, or W dimensions. As an example, if the action is 'create good habitats for insects', this action is included in all three subscales K, C, W, but with different introduction phrases that refer to knowledge, confidence or willingness. The wording of these introduction phrases was based on a recent scale to measure the self-perceived action competence for sustainable development (Olsson et al., 2020).

Based on this response format and scale structure, we started to explore and articulate items on actions related to insect conservation. In a first step, we created a preliminary list of items that refer to concrete actions in the context of insect conservation, including both direct and indirect actions. We created this list based on an analysis of two main types of sources that were also used for the development of the corresponding framework. As a first type of source, we analyzed a selection of eight initiatives[1] ranging from the national level (Sweden, Ireland, UK) to the international level (Europe, North America) to derive their action recommendations. As a second type of source, we included and analysed eight recent scientific papers on insect conservation (Barbett et al., 2020; Harvey et al., 2020; Kawahara et al., 2021; Knapp et al., 2021; Samways et al., 2020; Sharma et al., 2019; Sturm et al., 2021; Wagner et al., 2021) to complement the recommendations of the initiatives.

We then refined these actions into concrete items by summarizing and selecting relevant actions. The actions/items should (1) be feasible for students aged 13–15 and older audiences; (2) include a variety of different action possibilities; (3) include the environmental dimension of the issue, but also consider social and economic aspects; and (4) include at least three direct actions and three indirect actions to have sufficient items to build a latent sub construct (factor) (Hair et al., 2010). This refinement led to a preliminary list for the SPACIC scale consisting of 13 actions (see direct actions 1–6 and indirect actions 9–15 in Table 2).

We used this preliminary list to conduct a *face validation* (Hair et al., 2010) with experts to ensure that the actions included in the SPACIC cover the most relevant aspects of insect conservation. To this end, we selected six acknowledged scientists from four different European countries that have professional expertise in two or more of the following fields: insect conservation, insect monitoring, education and outreach about insect biodiversity, education for sustainable development, and action competence. All experts considered the actions of the preliminary list to be relevant and distinct from each other. Based on the comments of the experts, we made minor changes in the wording of two actions and added two direct actions and one indirect action (see actions 7–8 and action 16 in Table 2). The experts considered that including these actions would provide additional valuable insights into students' competence and add additional contexts for taking actions. In summary, these additional actions added nuances to the scale that aligned with the action suggestions from the initiatives and the scientific papers.

These steps resulted in a final list of 16 actions for the SPACIC scale, including eight direct actions and eight indirect actions. As mentioned above, we included these 16 actions in all three subscales K, C, W, but with different introduction phrases that refer to knowledge, confidence or willingness, which led to the SPACIC scale with 48 items in total. The items vary in scope (from general to concrete), level (from individual to collective), geographical range (from local to community to global), while some items address social and economic aspects of the issue. Since the three types of statements (K, C, W) use similar wordings related to the specific actions (except for the introduction phrase), we included short introduction texts for each of the three sections as pointers to increase the respondents' attention to the differences between K, C and W (see supplementary material).

To check the understandability of the items, we asked six students from the target group (grades 7 and 8, ages 13–15) about their interpretations of the actions and the wording of the items. The aim was to check the general understandability of the items and to see how students distinguish between K, C, and W items. All interviewed students reported good understandability of all items of the SPACIC scale. Moreover, the students reported that they felt that the 16 actions were distinct from each other, and that all actions were potentially feasible. The students gave some concrete examples what certain actions meant to them (e.g. actions 2 and 3: providing flowers for pollinators; action 12: buying ecological products). The students also gave their interpretations of the introduction phrases for the K, C and W sections (see supplementary material). The K items were interpreted by the students as addressing more theoretical knowledge, i.e. their understanding of possible actions to take. The C items were interpreted as more practically oriented, addressing what they felt was possible and/or realistic for them to do in practice. The W items were interpreted as more future-oriented than the other two types, focusing on what they wanted to do in the future. In summary, students' interpretations of the items reflected our intentions and we therefore decided to proceed with the same questionnaire to the quantitative piloting with a larger sample (N = 180).

### *Step 3: Collect data from respondents*

The piloting questionnaire included the SPACIC scale and an established instrument in the field of science and environmental education, namely the two major environmental values scale (2-MEV) (Bogner & Wiseman, 2006) in its Swedish version (Torbjörnsson, 2011). The 2-MEV was included in the piloting to evaluate the validity of the SPACIC scale further. The piloting questionnaire was administered in Swedish (see supplementary material). The English translation of the items for this paper was created by the research group and supported by an independent language expert for Swedish and English.

The sample for the piloting consisted of 180 students from the target group (grades 7–8) from five different schools in Sweden (see Table 1). The students and their legal guardians received information about the general objective of the study, referring to the issue of insect decline, and gave written consent to participate. The students completed the piloting questionnaire online between March and April 2022 on the Survey & Report[2] portal using their school computers.

**Table 1.** The table shows the gender, age and grade distribution of the piloting sample (N = 180).

| Gender | | Age | | Grade | |
|---|---|---|---|---|---|
| | Frequency (percent) | | Frequency (percent) | | Frequency (percent) |
| Female | 98 (54.4%) | **12** | 1 (0.6%) | **Grade 7** | 106 (58.9%) |
| Male | 70 (38.9%) | **13** | 63 (35.0%) | **Grade 8** | 74 (41.1%) |
| Other | 12 (6.7%) | **14** | 81 (45.0%) | | |
| | | **15** | 35 (19.4%) | | |
| Total | 180 (100%) | | 180 (100%) | | 180 (100%) |

**Table 2.** Mean and standard deviation of students' answers (N = 180) to each item of the SPACIC scale.

| | Number of action and content | Knowledge (K) I know how to … Mean ± SD | Confidence (C) I think that I can … Mean ± SD | Willingness (W) I want to … Mean ± SD |
|---|---|---|---|---|
| Direct actions 1–8 | 1: … create good habitats for insects. | 3.28 ± 1.015 | 3.41 ± 1.018 | 3.68 ± 1.107 |
| | 2: … make a garden more insect friendly. | 3.17 ± 1.141 | 3.47 ± 1.075 | 3.46 ± 1.145 |
| | 3: … grow plants (in garden, on balcony or windowsill) to help insects. | 3.49 ± 1.155 | 3.74 ± 1.144 | 3.51 ± 1.189 |
| | 4: … manage a lawn in a way that insects can thrive. | 2.86 ± 1.157 | 3.31 ± 1.068 | 3.28 ± 1.216 |
| | 5: … garden without chemical pesticides. | 3.57 ± 1.282 | 3.84 ± 1.157 | 3.88 ± 1.271 |
| | 6: … provide nesting sites for insects. | 2.96 ± 1.162 | 3.40 ± 1.107 | 3.22 ± 1.169 |
| | 7: … track the diversity of insects in an area (if necessary with a tool). | 2.36 ± 0.938 | 2.76 ± 0.972 | 2.92 ± 1.181 |
| | 8: … make the school yard more insect friendly. | 2.59 ± 1.061 | 2.67 ± 1.098 | 3.04 ± 1.202 |
| Indirect actions 9–16 | 9: … inform other people about how we can help insects. | 2.82 ± 1.063 | 3.10 ± 1.154 | 3.20 ± 1.145 |
| | 10: … raise awareness among friends and family of the problem of insect decline. | 3.01 ± 1.093 | 3.24 ± 1.081 | 3.29 ± 1.147 |
| | 11: … promote a positive attitude to insects among friends and family. | 2.95 ± 1.021 | 3.14 ± 1.077 | 3.34 ± 1.154 |
| | 12: … choose insect-friendly food products when I am shopping. | 2.73 ± 1.213 | 3.23 ± 1.139 | 3.46 ± 1.270 |
| | 13: … support organizations protecting insects. | 2.86 ± 1.109 | 3.06 ± 1.154 | 3.31 ± 1.188 |
| | 14: … contribute to research on insect conservation. | 2.59 ± 1.218 | 2.89 ± 1.179 | 3.16 ± 1.242 |
| | 15: … contact companies to get them to protect insects too. | 2.31 ± 1.048 | 2.64 ± 1.087 | 3.17 ± 1.176 |
| | 16: … support actions taken by family and friends to help insects. | 2.58 ± 1.138 | 2.96 ± 1.027 | 3.24 ± 1.164 |

Notes: The first row includes the introduction phrases for K, C and W that were combined with the actions 1–16 in the left column. The actions 1–8 are direct actions (DA), the actions 9–16 are indirect actions (IA).

### *Step 4: Examine psychometric properties and quality*

The psychometric properties and quality of the SPACIC scale were examined in four main ways, namely (1) calculating descriptive statistics; (2) measuring reliability of the scale with Cronbach's α; (3) examining construct validity through confirmatory factor analysis; and (4) analyzing convergent and discriminant validity by calculating Pearson correlations. The calculations for (1), (2) and (4) were performed using IBM SPSS Statistics version 27. For the confirmatory factor analysis (3), we used the software package Mplus 8 (Muthén & Muthén, 2017).

(1) We calculated descriptive statistics for all items of the scale to get an overview of the distribution of the answers (Field, 2018). This included the calculation of the mean, standard deviation, percentage distribution of the response options. The descriptive statistics not only helped to get a feeling for the data, but also allowed us to detect potential ceiling-effects or bottom-effects.

(2) We measured the reliability of the SPACIC scale, since reliability is an indicator of convergent validity contributing to the construct validity (Hair et al., 2010). We calculated Cronbach's α as

a measurement of reliability on three levels: (a) for the SPACIC scale as a whole; (b) for the three subscales K, C and W; (c) for the subset of eight items referring to direct and indirect action in each subscale (KDA, KIA, CDA, CIA, WDA, WIA). The values of Cronbach's α should be higher than the threshold of .70 (Field, 2018). We also checked for reliability improvements through deletions of items and their effect on Cronbach's α.

(3) We examined the construct validity using confirmatory factor analysis as an established way for construct validation (Hair et al., 2010). The statistical work package Mplus 8 (Muthén & Muthén, 2017) was used for the confirmatory factor analysis and the weighted least squares mean and variance (WLSMV) estimator was used with delta parameterization, since the data were categorical. We also corrected for the nested nature and the hierarchical dependency of the errors of the data through the complex command in *Mplus 8* (Muthén & Muthén, 2017), i.e. student clusters by gender. Multiple fit indices were used to estimate the fit of the data with our theoretical model of ACIC. The values for these indices should be ≥ .95 for the comparative fit index (CFI) and Tucker-Lewis index (TLI) and ≤ .05 for the root mean square error of approximation (RMSEA) (Hair et al., 2010; Hu & Bentler, 1999).

(4) We further examined the convergent and discriminant validity (Hair et al., 2010) of the SPACIC scale using Pearson correlations as a standardized measure of the strength of the relationship between scales. These correlations give insights into relations between subscales and between the SPACIC scale and the two major environmental values scale (2-MEV) (Bogner & Wiseman, 2006), an established instrument in the field of science and environmental education. The 2-MEV scale contains items that are relevant for conservation issues, but the 2-MEV is more general in its scope.

## Results

In this section, we focus on the presentation of the final SPACIC scale and its psychometric properties. This chapter follows the structure of the measures (1)–(4) that were applied to ensure the quality and validity of the scale. Students' level of agreement was coded with numbers from 1 (fully disagree) to 5 (fully agree) for all items.

### *Descriptive statistics (i) and reliability of the scale (ii)*

Table 2 shows all items of the SPACIC scale, including mean and standard deviation of students' responses to each item (a full version of the scale is included in the supplementary material – Summary SPACIC scale English & Swedish).

To get a more general overview of the descriptive statistics of the scale, Table 3 shows the mean and the standard deviation for the subscales and the full SPACIC scale. The table also includes the values for Cronbach's α as a measure of reliability of the scale and its subscales. Based on the results from the descriptive statistics, we did not expect any bottom or ceiling effects.

The values of Cronbach's α are clearly above the threshold of 0.7 and indicate a good reliability of the scale and its subscales. The high value of Cronbach's α for the full SPACIC scale ( = 0.964) fits to a scale containing interconnected constructs (Field, 2018). The results also showed that the reliability of the scale would not improve by deleting single items.

### *Construct validity – results from the confirmatory factor analysis (iii)*

Figure 4 shows the structure and factor weights of the latent constructs of the three order SPACIC scale model used in the confirmatory factor analysis.

The fit indices of the confirmatory factor analysis showed that the theoretical SPACIC model has a good fit to our data. The RMSEA value is 0.05, matching the threshold for a close model fit (Hair et al., 2010; Hu & Bentler, 1999). The values for the CFI ( = 0.985) and TLI ( = 0.984) are clearly

**Table 3.** Mean and standard deviation of students' answers (N = 180) on a subscale level, including Cronbach's α for each subscale.

| Scale / subscale | Nr. of items | Mean ± SD | Cronbach's α |
|---|---|---|---|
| **Knowledge subscale (K)** | **16** | **2.88 ± 0.698** | **0.896** |
| K of direct actions (KDA) | 8 | 3.03 ± 0.756 | 0.830 |
| K of indirect actions (KIA) | 8 | 2.73 ± 0.788 | 0.857 |
| **Confidence subscale (C)** | **16** | **3.18 ± 0.762** | **0.928** |
| C in direct actions (CDA) | 8 | 3.33 ± 0.785 | 0.872 |
| C in indirect actions (CIA) | 8 | 3.03 ± 0.864 | 0.906 |
| **Willingness subscale (W)** | **16** | **3.32 ± 0.953** | **0.963** |
| W for direct actions (WDA) | 8 | 3.37 ± 0.948 | 0.919 |
| W for indirect actions (WIA) | 8 | 3.27 ± 1.015 | 0.948 |
| **SPACIC full scale** | **48** | **3.13 ± 0.691** | **0.964** |

above the recommended value of 0.95 (Hu & Bentler, 1999; Hair et al., 2010). Based on these criteria, the results show a good fit of the data to the theoretical three-order SPACIC model.

The confirmatory factor analysis also provides information for standardized factor loadings of each item and the subscales (see Figure 3). In general, the factor loadings of the items showed differences between the subscales, with the highest values for the willingness scale. Since we planned to use the same actions for all subscales to allow comparisons between the subscales K, C and W, we decided to keep all items in the scale.

### *Convergent and discriminant validity – correlations between scales (iv)*

The Pearson correlation analysis provides indicators for both convergent validity and discriminant validity. As described in the methods section, we calculated correlations between (a) the SPACIC scale and its subscales, (b) correlations between these subscales, and (c) the 2 Major Environmental Values (2-MEV) scale. Table 4 summarizes these Pearson correlations.

The correlations indicate a good convergent validity of the SPACIC scale: (a) All subscales are significantly related with the full SPACIC scale with large effect sizes ($r > 0.7$). (b) All subscales are significantly related to each other, which underlines that the subscales converge to a certain extent, although differences in the effect sizes exist. (c) The positive correlations with the preservation subscale of the 2-MEV shows that the instrument relates to an established instrument measuring personal attitudes to sustain nature. The absence of significant correlations with the utilization subscale of the 2-MEV aligns also with the expected differences in the answering behavior.

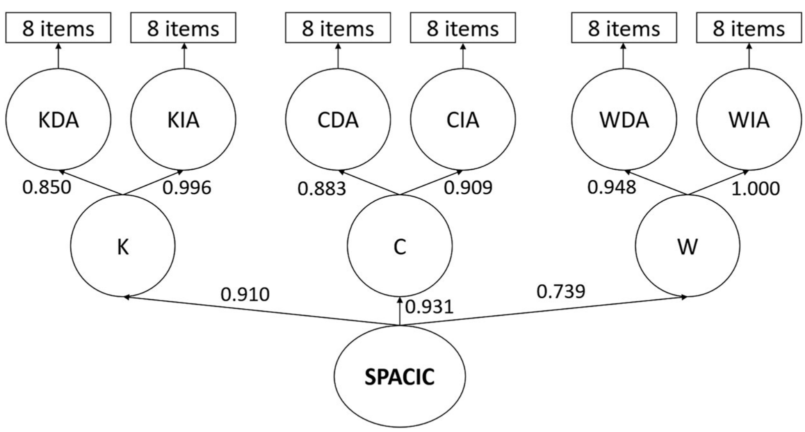


**Figure 4.** Structure diagram of the SPACIC scale including the factor weights from the confirmatory factor analysis.

**Table 4.** Pearson correlations between the full SPACIC scale and its subscales, and the two dimensions of the 2 Major Environmental Values scale of Preservation (P 2-MEV) and Utilization (U 2-MEV).

| | SPACIC | K | KDA | KIA | C | CDA | CIA | W | WDA | WIA | *P* 2-MEV |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **K** | .837** | | | | | | | | | | |
| **KDA** | .727** | .900** | | | | | | | | | |
| **KIA** | .785** | .908** | .635** | | | | | | | | |
| **C** | .859** | .640** | .540** | .616** | | | | | | | |
| **CDA** | .776** | .592** | .581** | .492** | .916** | | | | | | |
| **CIA** | .810** | .591** | .424** | .640** | .932** | .708** | | | | | |
| **W** | .874** | .574** | .489** | .549** | .599** | .521** | .584** | | | | |
| **WDA** | .840** | .539** | .476** | .498** | .579** | .531** | .539** | .969** | | | |
| **WIA** | .856** | .575** | .473** | .565** | .584** | .482** | .592** | .973** | .885** | | |
| ***P* 2-MEV** | .608** | .376** | .347** | .332** | .537** | .527** | .468** | .617** | .625** | .574** | |
| **U 2-MEV** | .074 | .041 | .099 | -.023 | .048 | .089 | .005 | .093 | .100 | .081 | .104 |
| | **SPACIC** | **K** | **KDA** | **KIA** | **C** | **CDA** | **CIA** | **W** | **WDA** | **WIA** | **P2-MEV** |

Notes: **Correlation is significant at the 0.01 level (2-tailed).

The correlations also indicate a sufficient discriminant validity: (a) The different effect sizes between the full SPACIC scale and its subscales show that the subscales contribute to a different degree to the SPACIC scale as a whole. (b) The effect sizes of the correlations between the subscales range from medium to large, which indicates that the respondents answered slightly different in each subscale. (c) The correlation with the preservation subscale of the 2-MEV show medium to large effect sizes, with the highest values for the willingness subscale. Evidently, the correlations with the utilization subscale of the 2-MEV are not significant. These results indicate that the SPACIC scale measure a construct that is related but distinct from the construct measured by the 2-MEV.

## Discussion and conclusions

The results show that the presented SPACIC scale is a reliable and valid instrument to investigate the self-perceived knowledge, confidence, and willingness to take actions sustaining insect biodiversity. The scale is to our knowledge the first instrument to assess these aspects of individual competence and it is applicable in a wide range of educational settings and research designs.

### *Reliability and validity of the scale*

The development of the SPACIC scale followed a psychometric approach in four steps as described by Furr (2011) and the scale expresses high reliability and validity. The measurements for reliability showed a good reliability of the SPACIC scale and its subscales. Cronbach's α was well above 0.70 (Field, 2018) for all subscales and 0.964 for the full scale, which indicates a high level of internal consistency. This high level of reliability is also an indicator of convergent validity (Hair et al., 2010). The fit indices of the confirmatory factor analysis provided further support for the construct validity. A multi-index evaluation of the calculated fit-indices showed a good fit of the hypothesized theoretical three-order model.

The Pearson correlations between the subscales and with the 2-MEV scale provide additional support for the validity of the SPACIC scale. The correlations between the subscales K, C, and W range from 0.4 to 0.7, indicating that the scales measure constructs that are related but not the same (Field, 2018). Likewise, the correlations with the preservation subscale of the 2-MEV (Bogner & Wiseman, 2006) support the theoretical assumptions that the two scales are related, but differ in their scope and the measured construct. The Pearson correlations reflect these theoretical assumptions, because all correlations were significant and ranged from 0.332 to 0.625. The correlation between the full SPACIC scale and the preservation subscale of the 2-MEV is $r = 0.608$. This means that only about 37% ($r^2 = 0.3696$) of the SPACIC is predictable on the basis of the preservation subscale of the 2-MEV, which clearly underlines the discriminant validity. The lack of significant correlations with the utilization subscale of the 2-MEV also matches the expectations.

The descriptive statistics show that students' self-perceived knowledge and confidence are both lower than the self-perceived willingness. This indicates a potential gap between what students want to do (willingness), and their self-perceived knowledge of actions and confidence in being able to take these actions. Interestingly, the students had higher values for the self-perceived confidence than for the self-perceived knowledge. This result can be interpreted to indicate that students are fairly optimistic in being able to take actions if they get the opportunity, even if they currently lack some theoretical knowledge about actions. This is supported by students' interpretation of all actions as potentially feasible for them in the interviews. The scale mainly consists of actions that do not require specific practical skills, which could be a further reason for students being fairly confident to take actions in practice. In summary, the self-perceived confidence scores can be interpreted as an indicator of the perceived feasibility and self-efficacy to put actions into practice, which is in line with the theoretical conception of the confidence in one's actions (see background).

### Applications and benefits of the SPACIC scale

A first obvious application of the scale is in formal education, specifically in science and biology teaching at school or university level, because the SPACIC scale makes the latent competence of students visible. This assessment of learners' competence to deal with this sustainability issue is highly important to monitor the impact of education (Waltner et al., 2019). The SPACIC scale allows measuring the action competence in a class before and after a teaching intervention to see the impact of the teaching on students' competence. This could be particularly valuable for schools or university courses with a focus on sustainability, conservation, biology or with a general environmental focus. Another way of applying the scale is to compare the action competence in different school grades, or follow a group of students longitudinally to get an approximate idea of how action competence develops without any additional intervention. We recommend an application of the scale with students that are as young as our target group (13-15 year-olds) or older. We designed the items in a way that is relevant outside of the school context and only one action refers to school explicitly.[3]

The scale can also be applied in science outreach, initiatives/campaigns or informal learning places (botanical gardens, zoos, museums) working with both children and adults. Until now, there has not been a scale available to compare how the many initiatives/campaigns affect learners in terms of competence to take actions for insects. Applying the scale can provide crucial information on how initiatives contribute to building confidence in society to take actions for insect biodiversity and also to identify initiatives that are particularly good in fostering certain aspects of learners' action competence to share with others. With this information provided by the SPACIC scale, it is also possible to tailor initiatives or outreach programs that meet participants' needs more effectively, thus responding to the call for more effective educational approaches (Marselle et al., 2021).

The SPACIC scale provides information of three educational relevant individual dimensions (knowledge, confidence, willingness) at the same time. In this way, the SPACIC scale can inform about potential obstacles to take certain actions, which are invisible when focusing on one dimension alone. However, the SPACIC scale should not be used in the sense of how people 'perform'. The setting of application should not put pressure on the respondents, since the scale builds on an honest reflection on self-perceived competence. Used in a trustful setting, the SPACIC scale can highlight the existence of any action 'gaps' in knowledge, confidence, or willingness to act, which can inform the further development of teaching. It could also be valuable to use the SPACIC scale as a formative instrument for students to monitor their personal development, making their own learning progress visible. In this way, the scale can support learners' development into becoming active environmental citizens (Hodson, 2010).

When the SPACIC scale is applied in a pre–post setting, the scale provides insights into how K, C, and W change. Higher levels of K after an educational intervention would indicate that students perceive that they have gained theoretical knowledge of actions and of how to perform them. Higher levels of C would indicate that the students perceive themselves to be able to take actions in practice and have a higher sense of self-efficacy to do so. Higher levels of W would indicate that students have a higher willingness to perform actions in the future. The SPACIC scale can also be used in a cross-sectional design to investigate existing levels of K, C, and W between different groups. The analysis of the SPACIC scale can focus on action competence in general (full SPACIC scale), on the subscales (K, C, W), on differences between direct and indirect actions for each subscale, or even on an item level. As an example of a concrete application, we are currently using the SPACIC scale in a pre–post design follow-up study to measure the effects of a teaching approach focusing on insect conservation.

### Conclusion and outlook

Insect decline is a crucial current problem and many calls for educating and engaging a broad public exist (Cardoso et al., 2020; Harvey et al., 2020; Kawahara et al., 2021). Science and environmental education can play a major role in fostering people's competence to cope with such problems and to become active environmental citizens who take action (Hodson, 2010). For a scientifically guided development and assessment of educational measures, we need research instruments to guide this process (Waltner et al., 2019). The SPACIC scale can potentially fill this gap by providing insights into people's self-perceived knowledge, confidence and willingness to take specific actions that contribute to sustaining insect biodiversity. These insights can be used to assess, improve, or design educational measures that fit learners' needs.

Applying the SPACIC scale in various contexts and populations can contribute to progress in educational research in the currently underexplored field of insect decline and conservation (Hall & Martins, 2020; Ruck & Mannion, 2021; Schönfelder & Bogner, 2018). We therefore encourage our fellow researchers and practitioners to use the SPACIC scale (see supplementary material) to investigate how the instrument performs in different contexts, populations, research designs, and how the development of the self-perceived action competence relates to the development of other competences, self-reported behavior, or attitudes.

We support the claim of conservation scientists that we must act now (Harvey et al., 2020) – we need more educational research and a transformation into action-oriented education on insect decline and insect conservation now! We need to educate a critical society with the relevant competence to take actions to sustain insect biodiversity as well as to be active environmental citizens. Applying the SPACIC scale across educational contexts and research designs will contribute to boost educational research on this crucial current issue and provide relevant evidence for the effectiveness of educational approaches.

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## Notes

1. We have analysed the following eight initiatives on insect/pollinator conservation. All online-sources were accessed before 7.12.2022.

   ***EU Pollinators initiative:*** https://wikis.ec.europa.eu/display/EUPKH/Citizens?preview=/25559573/28869041/Citizens%20engagement_Factsheet_A4_1007.pdf ***Pollinator Partnership:*** https://www.pollinator.org/7things ***Xerces society:*** https://xerces.org/bring-back-the-pollinators ***X-Pollination:*** https://xpollination.org/ ***Naturvårdsverket:*** https://www.naturvardsverket.se/amnesomraden/pollinering#E102812064 ***Pollinera Sverige (SURR I Skolan):*** https://pollinerasverige.se/surr-i-skolan/ ***Operation: Rädda Bina*** (Naturskyddsföreningen): https://www.naturskyddsforeningen.se/kampanj/radda-bina/ ***All-Ireland Pollinator plan:*** https://pollinators.ie/wp-content/uploads/2018/05/Pollinator-Plan-2018-WEB.pdf

2. https://www.artologik.com/en/survey-report
3. In action 8, the term 'school' can easily be substituted by 'university' or 'workplace'.

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No potential conflict of interest was reported by the author(s).

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## Ethical approval

The project received ethical approval of the researchers' institution (Karlstad University Ethics Committee, approval number HNT 2022/187).

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