INQUIRY & INVESTIGATION

# Promoting Metacognitive Awareness and Self-Regulation of Intuitive Thinking in Evolution Education

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**Abstract**

*Students' intuitive thinking often proves helpful in different contexts, such as everyday life, but can be an obstacle to learning about evolution. Thus, enhancing students' evolutionary understanding is often challenging, with intuitive conceptions of evolution still existing after instruction. Consequently, it is necessary to address students' intuitive conceptions explicitly. Thus, we present two metaconceptual learning activities that make students metacognitively aware of their intuitive conceptions and enable them to self-regulate these in the context of evolution: (a) a self-assessment of one's conceptions and (b) instruction on the context-dependency of conceptions. Both activities have been found more effective in enhancing students' evolutionary understanding than traditional instruction focusing solely on scientific conceptions and are, thus, recommended to supplement evolution instruction.*


**Key Words:** *evolution; natural selection; student conceptions; metacognition; self-regulated learning.*

## ○ Introduction

Evolution is the unifying theme in biology (Dobzhansky, 1973) and is considered one of the "overarching core concepts" (American Association for the Advancement of Science, 2009, p. 9) of biology. Further, natural selection, in particular, is described as one of the "disciplinary core ideas" (NGSS Lead States, 2013, p. 75; see also College Board, 2019). Students should be enabled to "construct explanations […] of natural selection and evolution" (NGSS Lead States, 2013, p. 57), for example, by referring to scientific concepts such as variation, heritability, and differential survival/reproduction (College Board, 2019; Gregory, 2009). However, understanding and explaining evolution has proved challenging for students at different levels (Bishop & Anderson, 1990; Hartelt et al., 2022; Kuschmierz et al., 2020). One reason is that students' intuitive thinking influences their reasoning about evolution, and particularly, natural selection (Barnes et al., 2017; Coley & Tanner, 2015; Richard et al., 2017). Programs such as AP Biology state that it is important that students use precise language and avoid drawing on intuitive thinking when explaining evolutionary changes (College Board, 2019).

In the literature, various terms are used to describe student conceptions that are not in line with scientific conceptions, such as "misconceptions," "alternative conceptions," "preconceptions," or "intuitive conceptions" (see also Maskiewicz & Lineback, 2013). To describe the origin of many student conceptions of evolution and value students' conceptions, the terms "intuitive conceptions/ideas/thinking" will be used in this paper. Many of students' conceptions of evolution originate in cognitive biases/construals, in other words, "intuitive, often implicit, way[s] of thinking about the world" (Coley et al., 2017, p. 2). An intuitive way of thinking about the world might be "a set of assumptions, a type of explanation, or a predisposition to a particular type of reasoning" (Coley et al., 2017, p. 2). While these intuitive ways of thinking are valuable in many contexts (e.g., in everyday life), they can also hinder the acquisition of scientific knowledge, especially conceptual knowledge about evolution (González Galli et al., 2020; Shtulman, 2017; Shtulman & Calabi, 2012).

Three intuitive ways of thinking are particularly relevant in evolution education (Coley & Tanner, 2015; Gregory, 2009; Shtulman, 2006): teleology, anthropomorphism, and essentialism. A teleological bias (i.e., reasoning based on the assumption of a goal, purpose, or function) can lead to a goal-directed, purposeful understanding of evolution. An anthropomorphic bias (i.e., reasoning about non-human species or processes by analogy to humans) can lead to an understanding that species modify their characteristics intentionally during evolution. An essentialist bias (i.e., reasoning based on the assumption that group members share an immutable essence) can lead to neglecting or underestimating within-species variation, and consequently, to the assumption that species change as a whole from generation to generation.

These intuitive ways of thinking are pervasive, persistent, and context-dependent (Hartelt & Martens, 2024a): pervasive because they are core features of human cognition and exist across cultures, ages, and educational backgrounds (Coley et al., 2017; Kelemen, 1999; Medin & Atran, 2004); persistent because they often persist despite formal education, are resistant to change, and often coexist with scientific conceptions after instruction (Kelemen et al., 2013; Opfer et al., 2012; Shtulman & Valcarcel, 2012); and context-dependent because they prove helpful in some contexts but problematic in others (Coley & Tanner, 2012; González Galli et al.,



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2020; Shtulman & Calabi, 2012). In particular, it can be differentiated between everyday vs. scientific context, different scientific contexts, and different social contexts. For example, it may be appropriate to explain human actions in an everyday context in a teleological, goal-directed way but not evolutionary changes (González Galli & Meinardi, 2011; Kampourakis, 2014, 2020). Further, an essentialist bias, and thus, focusing on the similarities of a group, may be helpful when making predictions about an organism's ontogenetic development or when classifying organisms but not when explaining evolutionary changes due to natural selection (Shtulman & Calabi, 2012). Regarding the social context, it depends on the prior knowledge of the addressee how they may interpret an evolutionary explanation. For example, a speaker may have an appropriate understanding of evolution and use anthropomorphic language metaphorically, but a non-expert may interpret this anthropomorphic language inappropriately literally, and thus, intuitive conceptions may be reinforced in the addressee (Betz et al., 2019; Kallery & Psillos, 2004; Tempelmann et al., 2024; Thulin & Pramling, 2009).

Taking these considerations into account, it seems neither possible nor preferable to eliminate students' intuitive conceptions since these are resistant and also often appropriate. However, intuitive conceptions can be an obstacle in learning evolution and, thus, need to be addressed. Traditional instruction that focuses on teaching scientific concepts has been shown to have limited success in developing an appropriate understanding of evolution and reducing students' intuitive conceptions (Legare et al., 2018; Shtulman & Calabi, 2013; Tibell & Harms, 2017). When learning scientific concepts, students often do not see that these conflict with their intuitive conceptions, of which they are generally not metacognitively aware (Wingert et al., 2022). In consequence, they often integrate scientific concepts into their existing intuitive thinking, resulting in a coexistence of intuitive and scientific conceptions (Opfer et al., 2012).

Researchers and educators have suggested that instructional approaches based on self-regulated learning and metacognition can enhance students' conceptual knowledge about evolution (González Galli et al., 2020; Perez et al., 2022; Shtulman, 2022). When these instructional approaches focus on students' intuitive conceptions on a metacognitive level, they can also be described as "metaconceptual" (Yürük et al., 2009). A body of work provides evidence that metaconceptual instruction supports students' acquisition of conceptual knowledge and is superior to traditional ways of teaching where students' conceptions are not explicitly addressed (Kirbulut, 2012; Sabancı et al., 2020; Wiser & Amin, 2001; Yürük, 2007; Yürük et al., 2009, 2011). In particular, explicitly addressing students' intuitive thinking can promote their conceptual knowledge about evolution (Perez et al., 2022; Pickett et al., 2022; Wingert et al., 2022).

This paper aims to present metaconceptual learning materials for evolution education that attempt to make students metacognitively aware of their intuitive conceptions and enable them to self-regulate these in a context-dependent way: (a) a self-assessment of one's conceptions and (b) instruction on the context-dependency of conceptions (see Supplemental Material files 1–5a, b, which can be found in the online version of this article). The self-assessment can make students metacognitively aware of their conceptions as they engage in evaluating their current intuitive and scientific conceptions (Hartelt & Martens, 2024a, 2025; see also Andrade, 2019). The instruction on the context-dependency of conceptions can support students in becoming aware of the demands of different contexts and self-regulating their intuitive thinking depending on the context (Hartelt & Martens, 2024a; see also González Galli et al., 2020). In a recent study conducted by the authors of this article, evidence for the effectiveness of these specific instructional approaches in enhancing students' conceptual knowledge about evolution has been provided (Hartelt & Martens, 2024a; see section "empirical evidence for the effectiveness of the presented metaconceptual approaches").

## ○ Description of the Metaconceptual Learning Materials

### *General Remarks*

The metaconceptual learning materials have been developed for and evaluated with upper secondary education students (class levels 10–13). However, the metaconceptual learning materials may also be adapted by educators for lower secondary or post-secondary education. Learning materials for two metaconceptual instructional approaches have been designed: (a) a self-assessment of one's conceptions and (b) instruction on the context-dependency of conceptions. The progress of one instructional sequence using the metaconceptual learning materials is suggested in Figure 1. However, the materials may be used by teachers differently and at different phases of evolution instruction. For example, the self-assessment may be used at the beginning of evolution instruction to make students aware of their preexisting conceptions (preferably if they already have some basic understanding of natural selection), in the middle of evolution instruction when students already should have developed a more thorough understanding of evolution, at the end of evolution instruction to let students self-evaluate their learning outcome, or at all of these phases to make the learning development visible to the students. For teaching the scientific concepts of natural selection prior to an instructional sequence using the presented instructional approaches (see Figure 1), suitable learning materials have already been published (e.g., Hartelt & Martens, 2024b; Jördens et al., 2018; Mohammadi et al., 2020).

The metaconceptual learning materials (see Supplemental Material files 2a, b and 4a, b) can either be distributed digitally or printed out. If printed out, the printing of Supplemental Material file 2a, b should be done in color, as the colors are essential in the self-assessment activity, and pens in different colors (matching the colors of the different concepts in the self-assessment) should be available to the students.

### *Metaconceptual Learning Material (a): Self-Assessment of One's Conceptions*

In the introductory phase (Supplemental Material file 1a, b), the question is raised as to how cheetahs' ability to run fast developed during evolution (for a similar question to provoke students' conceptions of evolution, see Bishop & Anderson, 1990). To activate students' prior knowledge and allow a subsequent self-assessment, students are then asked to explain the evolutionary changes in the speed of cheetahs in written form (for the worksheet, see Supplemental Material file 2a, b, p. 1). For example, one student answered this question in a recent study conducted by us in the following way (see also Hartelt & Martens, 2024a; underlying concepts added in brackets):

*Cheetahs became faster and faster because the other animals also improved more and more, and the cheetah, as an end consumer,*

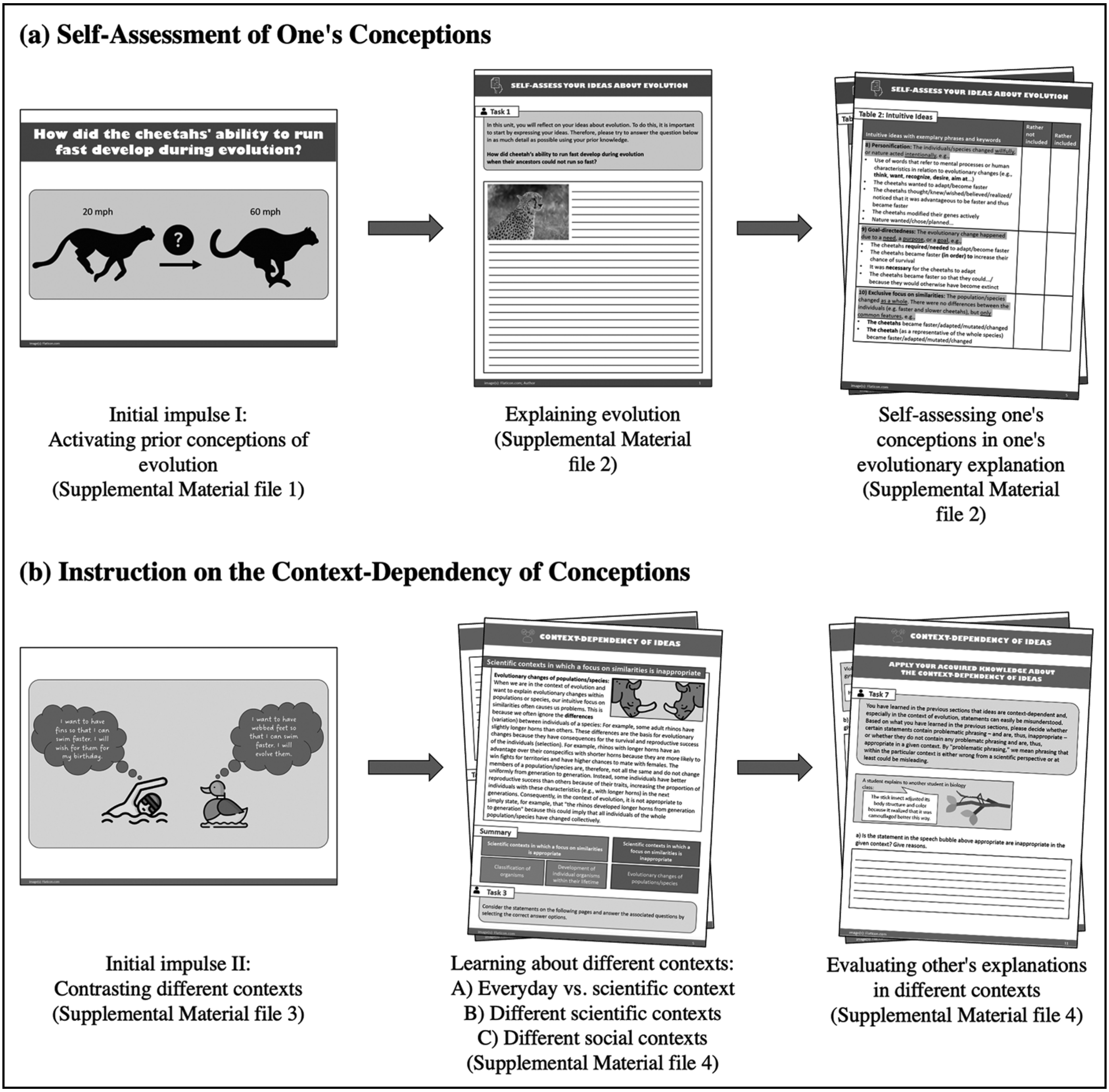


**Figure 1.** Suggestion for an instructional sequence using the metaconceptual learning materials (a) and (b).

*Note. Figure development by the authors. Single parts of this figure are based on icons from Flaticon.com.*

> *wants to keep its position in the food chain [anthropomorphism]. […] Therefore, during evolution, it was essential for survival to be able to run short but incredibly fast, which is why only these cheetahs [variation] and their children survived because of this selection advantage [differential survival/reproduction].*

As this quote illustrates, students often have coexisting intuitive and scientific conceptions of evolution. This student, for example, expressed in their explanation of evolutionary changes an intuitive conception based on anthropomorphism and the scientific concepts of variation and differential survival/reproduction. It is important that students express their various conceptions in this task because the constructed explanation is the object of the following self-assessment.

For conducting the self-assessment itself (for the worksheets, see Supplemental Material file 2a, b, p. 2–6), students receive a list of seven scientific concepts of natural selection (e.g., variation, inheritance, differential survival/reproduction, etc.; Nehm et al., 2010) and a list of three intuitive ways of thinking (teleology, anthropomorphism, and essentialism; please note that we avoided these technical terms throughout the learning materials and used substitutes instead, e.g., "goal-directedness" for teleology). Exemplary phrases and key terms are provided in the lists for each scientific and intuitive conception to support the self-assessment. The students are asked to examine their prior explanation of evolutionary changes by color-coding in their explanation and checking off in the lists intuitive and scientific conceptions used. Taking up the previous

"Cheetahs became faster and faster because the other animals also improved more and more, and the cheetah, as an end consumer, wants to keep his position in the food chain."

**Table 2: Intuitive Ideas**

| Intuitive ideas with exemplary phrases and keywords | Rather not included | Rather included |
|---|---|---|
| **8) Personification:** The individuals/species changed willfully, or nature acted intentionally, e.g.,<br>• Use of words that refer to mental processes or human characteristics in relation to evolutionary changes (e.g., **think, want, recognize, desire, aim at...**)<br>• The cheetahs wanted to adapt/become faster<br>• The cheetahs thought/knew/wished/believed/realized/ noticed that it was advantageous to be faster and thus became faster<br>• The cheetahs modified their genes actively<br>• Nature wanted/chose/planned... | | X |
| ... | | |

**Figure 2.** Example for the self-assessment regarding anthropomorphism/personification.

student's explanation, the student may self-assess their phrase "the cheetah as an end consumer wants to keep his position in the food chain" as anthropomorphic (respectively personifying), color the phrase in the respective color for anthropomorphism, tick off the box for anthropomorphism in the criteria list (see also Figure 2), and continue similarly for the other intuitive and scientific conceptions that are asked to be self-assessed. Depending on students' prior knowledge and self-assessment experience, or when teachers notice that students struggle with self-assessing their conceptions, teachers may consider going through the list of intuitive and scientific conceptions and assessing the exemplary explanation presented above together with the students before students individually conduct the self-assessment. Further, teachers may decide to reduce the number of scientific concepts that should be self-assessed to the most fundamental concepts of natural selection (Nehm et al., 2010): variation, inheritance, and differential survival/reproduction (number one to three in Table 1 in the worksheets; see Supplemental Material file 2a, b). To enhance the accuracy of the self-assessments, teachers may also encourage students to exchange their completed self-assessments with their peers and provide and receive feedback (see also the respective task in the worksheets), and/or teachers may collect students' self-assessments and provide feedback themselves. Based on the self-assessment (and potential feedback), students should set goals regarding future explanations of evolutionary changes as part of self-regulated learning. In total, working on this metaconceptual learning material should take around 40 minutes.

### *Metaconceptual Learning Material (b): Instruction on the Context-Dependency of Conceptions*

To introduce the issue of the context-dependency of conceptions, the teacher shows a presentation slide (Supplemental Material file 3a, b). In this slide, anthropomorphic statements in two different contexts (everyday life context and evolutionary context) are shown. While the statement in the context of everyday life ("I want to have fins so that I can swim faster. I will wish for them for my birthday.") can be considered appropriate, a similar statement in the context of evolution ("I want to have webbed feet so that I can swim faster. I will evolve them.") would be inappropriate as organisms cannot willfully change their traits during evolution. Teachers can ask the students to compare and contrast the two statements. Based on initial students' responses, for example, that animals do not evolve new traits intentionally but that humans can produce and use objects intentionally, teachers can systematize the responses regarding what both statements share (a personifying view focusing on intentionality), and what differs between both statements (the context: everyday life vs. scientific context). Based on that, teachers can discuss with their students why one statement may be appropriate and the other not. Through the following instruction, students should become aware of the context-dependency of conceptions. To reach this goal, students read informational texts and work on different tasks (for the worksheets, see Supplemental Material file 4a, b; for sample solutions, see Supplemental Material file 5a, b). The learning materials focus on the following differentiations between contexts: (A) everyday life vs. scientific context, (B) different scientific contexts, and (C) different social contexts. Regarding (A) everyday life vs. scientific context, students are asked to explain why teleology and anthropomorphism may be appropriate in everyday life but not in the context of evolution by contrasting statements in both contexts. Regarding (B) different scientific contexts, students are asked to decide for different statements whether these are appropriate or not. This should be done based on provided information in which contexts an essentialist bias can be helpful (e.g., ontogenetic development and classification of organisms) and in which it could be problematic (e.g., evolution through natural selection). Regarding (C) different social contexts, students receive information on why it is important to consider the addressee of an explanation and their prior knowledge. They are asked to explain how a given statement about evolutionary changes may be misunderstood by someone with little prior knowledge and how these misunderstandings could be avoided. In a concluding activity, students decide and justify whether different statements regarding evolutionary changes are appropriate in a certain context. Discussions with a partner and other small tasks complement the worksheets. Teachers are free to decide whether and at which points they would like to review the tasks with the whole class. A discussion with the whole class can be very productive, especially for the evaluation of the various statements as "appropriate" or "inappropriate" as these evaluations can be discussed in a nuanced way in class. Further, teachers may decide to substitute some of the informational texts or tasks with presentations by themselves or with further class discussions. Without adjustments, working on this metaconceptual learning material should take around 70 minutes.

## ○ Assessment

To assess the outcome of the metaconceptual instructional approaches, students' ability to explain evolutionary changes can be assessed by using open response tasks, for example, "How would a biologist explain how the ability to dive for long periods evolved in seals when their ancestors could not dive for such long periods?" (see also Nehm et al., 2012). The quality of students' explanations can be assessed by the degree to which students use appropriate scientific conceptions and inappropriate intuitive conceptions. Teachers can use the listed conceptions in the self-assessment sheet to categorize students' intuitive and scientific conceptions. Depending on students' prior knowledge and educational level, it may also be sufficient to focus only on the intuitive conceptions and the three most fundamental scientific concepts of natural selection (variation, inheritance, and differential survival/reproduction) instead of all seven listed scientific concepts. Depending on the educational level, thresholds for good explanations may also vary. For second-semester biology college

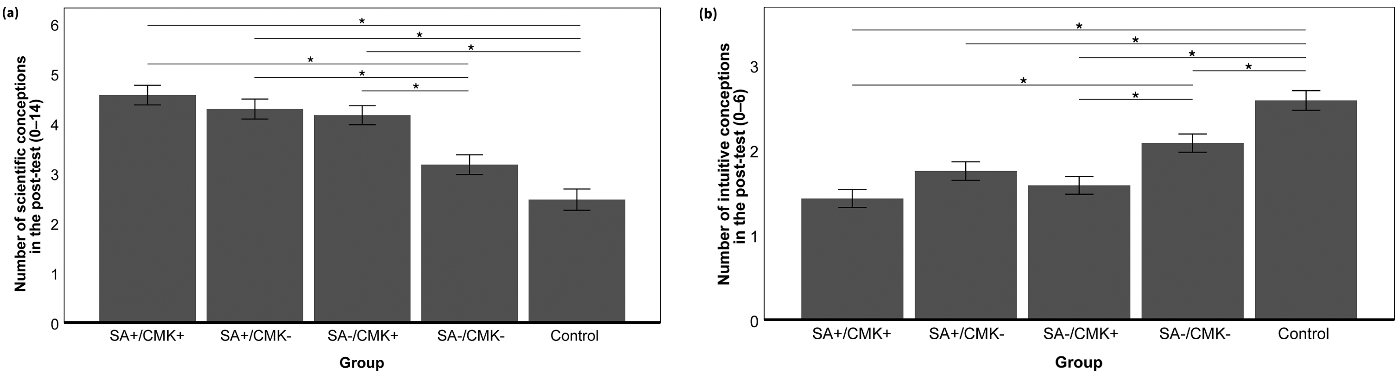


**Figure 3.** Students' use of intuitive and scientific conceptions across two evolutionary explanations in the post-test after receiving instruction with/without the metaconceptual learning materials. **(a)** Number of scientific conceptions (0–14). (**b)** Number of intuitive conceptions (0–6). Figure based on Hartelt & Martens (2024a). CC BY 4.0.

*Note.* Mean scores are displayed in the figure, and error bars represent standard errors; * = $p < .05$. SA = self-assessment of one's conceptions; CMK = instruction on the context-dependency of conceptions; plus sign (+) = the group received the respective intervention; minus sign (-) = the group did not receive the respective intervention but traditional instruction focusing on the scientific concepts of evolution; Control = group that did not receive any instruction on evolution or another topic at all.

majors, Nehm and Reilly (2007) suggested that students using four or more scientific concepts of natural selection (out of seven) should receive a "passing score," regardless of the number of inappropriate conceptions. If students use no inappropriate conceptions, even one scientific concept should be enough for a "passing score" (for details, see Nehm & Reilly, 2007). However, teachers may use considerably different thresholds based on their learners' characteristics.

The proposed summative assessment could also be transformed into a formative self-assessment if another self-assessment follows this task. For this, the exemplary phrases of the self-assessment worksheet (regarding cheetahs' speed) would have to be adjusted to the assessment task, e.g., seals' diving ability. This way, students could become metacognitively aware of and monitor their progress and changes in their conceptions, which could promote their self-regulated learning.

## ○ Empirical Evidence for the Effectiveness of the Presented Metaconceptual Approaches

The effectiveness of the metaconceptual approaches presented in this paper has been investigated in an experimental intervention study with $N = 730$ upper secondary school students. The methods and results of this study are described in detail in Hartelt & Martens (2024a, c) and readers are encouraged to consult these papers for detailed information beyond the main information provided in this section. Using a 2x2 factorial, pre-post-follow-up-test design, students were randomly assigned to four different groups that received either one/both metaconceptual instructions or traditional instruction focusing solely on the scientific concepts of evolution. A further fifth group received no instruction at all between the pre- and post-test, thus, differing from the other groups that received traditional instruction focusing on scientific concepts if they did not receive metaconceptual instruction. The effectiveness of the interventions was measured in terms of intuitive and scientific conceptions used by the students in two evolutionary explanations (contexts: evolutionary gain of a trait in a familiar species; evolutionary loss of a trait in an unfamiliar species). The questions prompting students to provide evolutionary explanations were phrased similarly to the question proposed as an assessment tool (see section "assessment"; see also Nehm et al., 2012). The questions included different species at the various measurement points (e.g., for the gain of a trait in a familiar species: anteaters' tongue, seals' diving ability, and hyenas' dentition) to reduce fatigue effects. Explaining the evolutionary changes of the species used as examples across the measurement points has been found equally difficult in a pre-study. The students' conceptions (for each evolutionary explanation: three intuitive conceptions and seven scientific conceptions) were coded by two experienced raters ($\kappa = .843$; almost perfect interrater reliability; Landis & Koch, 1977) based on the coding guide of Nehm et al. (2010). Considering the students' conceptions across both evolutionary explanations, it was found that students who conducted the self-assessment used more scientific conceptions compared with the students who did not conduct the self-assessment, while the use of intuitive conceptions did not differ between the groups. The instruction on the context-dependency of conceptions resulted in a higher use of scientific conceptions and a lower use of intuitive conceptions compared with the traditional instruction focusing solely on the scientific concepts of evolution (for the detailed results, see Figure 3). Moreover, a combination of both metaconceptual instructional approaches has proven to be especially successful in enhancing students' conceptual knowledge of evolution in the long term (for a detailed description and analysis of the follow-up test results, see Hartelt & Martens, 2024a). A further important finding was that making students metaconceptually aware of their intuitive conceptions led to more accurate beliefs about their abilities (for a detailed description and analysis of the intervention effects on students' self-efficacy and self-efficacy bias, see Hartelt & Martens, 2024c). Together, these findings provide strong arguments for implementing these metaconceptual instructional approaches in evolution instruction.

## ○ Conclusion

The metaconceptual learning materials presented in this paper represent a practical approach to address students' intuitive thinking in evolution education as the materials (see the various Supplemental Material files) are ready to use for implementation by teachers but can also be adapted by teachers for diverse student groups. The learning materials provide students with the opportunity to distinguish between intuitive and scientific conceptions, to become metacognitively aware of their conceptions, to self-regulate their conceptions depending on the context (e.g., inhibit intuitive conceptions when they are not appropriate in the context of evolution), and, in consequence, develop a profound understanding of evolution respectively natural selection. As there is robust empirical evidence for the effectiveness of the presented metaconceptual learning materials (Hartelt & Martens, 2024a), teachers can expect more scientific conceptions and less inappropriate intuitive conceptions of evolution—compared with non-metaconceptual instruction focusing solely on the teaching scientific conceptions—when implementing the metaconceptual learning materials in their evolution instruction. Further, we recommend including additional metaconceptual learning activities following the presented activities, e.g., by letting students identify explanations based on intuitive thinking in authentic media contents or encouraging classroom discussion on a metaconceptual level when a student again draws on intuitive thinking.

It has been demanded that teachers should be supported in "diagnosing and responding to students' problems in mastering new concepts" (National Research Council, 2012, p. 312) and that it should be investigated "what instructional intervention […] can move students along a path from their initial understanding to the desired outcome" (National Research Council, 2012, p. 313). With the metaconceptual learning materials presented, we have addressed these issues, as they have been investigated for their effectiveness in enhancing students' understanding by addressing their intuitive preconceptions (Hartelt & Martens, 2024a), and provide students with the opportunity to diagnose their conceptions themselves and learn how to self-regulate their intuitive conceptions in the context of evolution.

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ABT AUTHORS & PHOTOGRAPHERS

# Guidelines

We encourage our readers, biologists with teaching interests, and biology educators in general, to write for *The American Biology Teacher.* This peer-reviewed journal includes articles for practitioners at every level, with a special focus on high school and post-secondary biology instruction.

Revised May 2023

## Article Categories

A note about article word count: Please recognize that tables, figures, and photographs add to the overall length of the article. One page of text has approximately 1,000 words, therefore a 1/4-page graphic will count for 250 words. More extensive graphics should be budgeted accordingly. References are also included in the final article word count.

**Feature Article** (up to 4,500 words) includes topics of general interest to readers of *ABT*. Consider the following examples of content that would be suitable for the feature article category:

- Research on teaching alternatives, including evaluation of a new method, cooperative learning, concept maps, learning contracts, investigative experiences, educational technology, simulations and games, and biology and life science education standards
- Social and ethical implications of biology and how to teach such issues as genetic modification, energy production, agriculture, climate change, health care, nutrition, and cultural responsiveness
- Reviews and updates of recent advances in the life sciences in the form of an "Instant Update" that brings readers up-to-date in a specific area
- Imaginative views of the future of biology education and suggestions for adjusting to changes in schools, classrooms, and student populations
- Other timely, relevant, and interesting content such as discussions of the role of the Next Generation Science Standards in biology teaching, considerations of the nature of science with implications for the classroom, considerations of the continuum of biology instruction from K–12 to post-secondary teaching environments, or contributions that consider the likely/ideal future of science and biology instruction

**Research on Learning** (up to 5,000 words) includes reports of original research on innovative teaching strategies, learning methods, or curriculum comparisons. Studies should be based on sound research questions, hypotheses, discussion of appropriate design and procedures, data and analysis, discussion on study limitations, and recommendations for improved learning outcomes.

**Inquiry and Investigations** (up to 4,000 words) is the section of *ABT* that features discussion of innovative laboratory and field-based strategies. Strategies in this section should be original, engaging, practical, and related to either a particular program such as AP and/or linked to standards such as NGSS. Submissions should also be focused at a particular grade/age level of student and must include all necessary instructions, materials list, worksheets, and assessment tools. Other appropriate contributions in this category are laboratory experiences that engage students in inquiry.

**Tips, Tricks and Techniques** (up to 1,700 words but may be much shorter) features a range of suggestions useful for teachers including laboratory, field, and classroom activities; motivational strategies to assist students in learning specific concepts; modifications of traditional activities; new ways to prepare some aspect of laboratory instruction; etc.

**About Guest Commentaries** In each issue we include a short (900-word) essay on some topic of importance or current interest to the biology teaching community. These essays are invited, authored by the NABT president, or submitted by a reader. If you would like to propose a guest commentary essay, please contact the ABT Editor for more information (ABTEditor@nabt.org).

## Writing & Style Guidelines

The *APA Style (current edition)* is the guide for questions of punctuation, abbreviation, and style. List all references in alphabetical order on a separate page at the end of the manuscript. Use first person and a friendly tone whenever appropriate. Use concise words to emphasize your point rather than capitalization, underlining, italics, or boldface. Use the SI (metric) system for all weights and measures.

Themed issues of the ABT traditionally occur in February (Evolution) and April (Ecology).

## Preparing Tables, Figures, and Photographs

### General Requirements

- When your article is accepted, we will require that figures be submitted as individual figure files in higher resolution format. See below for file format and resolution requirements.
- Color is limited within the printed version of the journal. All artwork, figures, tables, etc. must be legible in black and white. If color is important to understanding your figures, please consider alternative ways of conveying the information.

#### Article Photographs

Digital files must meet the following guidelines:

- Minimum resolution of 300 DPI, 600 DPI is preferred
- Acceptable file formats are TIFF and JPEG
- Set to one-column (3.5″ wide) or two-column size (7″ wide)
- If figure originates from a website, please include the URL in the figure caption. Please note that screen captures of figures from a website are normally too low in resolution for use.

#### Tables and Figures

- Minimum resolution of 600 DPI, 1200 DPI is preferred
- Acceptable file formats are TIFF, BMP, and EPS
- Set to one-column (3.5″ wide) or two-column size (7″ wide)

**If you have any questions, contact Valerie Haff at managingeditor@nabt.org.**

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## Submission Guidelines

**All authors must be current members of NABT or a charge of $100 per page is due before publication.**

**All manuscripts must be submitted online at https://abt.scholasticahq.com/for-authors**

- Authors will be asked to register the first time they enter the site. Upon receiving a password, authors can proceed to upload their manuscripts through a step-by-step process. Assistance is available using the "Help" button found on the bottom right corner of most pages. Additional assistance is available from the Managing Editor (managingeditor@nabt.org).
- Manuscripts must be submitted as Word or WordPerfect files.
- Format manuscripts for 8.5 × 11-inch paper, 12-point font, double-spaced throughout, including tables, figure legends, and references.
- Please place figures (including photos) and tables where they are first cited in the text along with appropriate labels. Make sure to include figure and table citations in the text, as it is not always obvious where they should be placed. At the time of initial submission, figures, tables and images should be low resolution so that the final file size remains manageable.
- If your article is accepted, the editors will require that figures be submitted as figure files in higher resolution form. See section on *Preparing Tables, Figures, and Photographs*.

## Supplemental Materials

In order to maintain the word count for individual articles, we are pleased to facilitate publication of supplemental materials accompanying the online issue. If authors have materials (figures, examples, worksheets, appendices, multimedia files, etc.) that support but are not essential to the printed text of the article, authors can include those as separate files with their article submission.

## Editorial Procedures

- Communications will be directed only to the first author of multiple-authored articles.
- Typically, three individuals who have expertise in the respective content area will review each article.
- The editors attempt to make decisions on articles as soon as possible after receipt, but the process can take six to eight months, with the actual date of publication to follow. Authors will be emailed editorial decisions as soon as they are available.
- Accepted manuscripts will be forwarded to the Copy Editor for editing. This process may involve making changes in style and content. However, the author is ultimately responsible for scientific and technical accuracy. Page proofs will be sent to authors for final review before publication at which time only minor changes can be made.

## Submitting Images

### Cover Images

Submissions of cover photographs from NABT members are strongly encouraged. Covers are selected based on the quality of the image, originality, composition, and overall interest to life science educators. *ABT* has high standards for cover image requirements and it is important for potential photographers to understand that the required size of the cover image generally precludes images taken with cell phones, point-and-shoot cameras, and even some older model digital SLR cameras.

Please follow the requirements listed below.

- Email possible cover images to Julie Minbiole at jminbiole@colum.edu.
- *ABT* covers feature an almost-square image with a slight vertical orientation.
- Choose an image with a good story to tell. Do not crop the subject too tightly. It is best to provide an area of background around the subject.
- Include a brief description of the image, details of the shot (i.e., circumstances, time of day, location, type of camera, camera settings, etc.), and your biographical information in an email message.
- Include your name, home and email addresses, and phone numbers.
- Please ensure that the image meets the minimum standards for publication listed below and has not been edited or enhanced in any way. The digital file must meet the minimum resolution of 300 pixels per inch (PPI)—preferred is 400 PPI— and a size of 8.5 x 11.25".
  **We accept TIFF or JPEG images only.**

Thank you for your interest in *The American Biology Teacher.* We look forward to receiving your manuscripts.

William McComas, Editor-in-Chief
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