Chapter 8
Pre-service Teachers' Determination of Butterflies with Identification Key: Studying Their Eye Movements

Tanja Gregorčič and Gregor Torkar

Introduction

Science curricula that integrate more research and research like experiences are getting internationally increased support from preschool to university level (e.g., Bybee, 2011; NAAEE, 2019; NRC, 2012; OECD, 2018). The National Research Council (NRC, 2012) is emphasizing process skills, i.e., asking questions, defining problems, conducting investigations, interpreting and using evidence, constructing explanations and designing solutions. These ways children and adults develop their understanding of surrounding environments, it helps them build a strong foundation of skills and knowledge for further exploration of the world and develop deeper conceptual understandings that environmental literacy needs (NAAEE, 2019). Research into student's development of science concepts exposed a great need for studies on how observation and other scientific process skills develop. Similarly, as intuitive (spontaneous) concepts are gradually replaced by scientific concepts, intuitive observations are replaced with more selective, sophisticated, and theory-driven observations that lead to the development of scientific explanations (Duschl, 2000; Tomkins & Tunnicliffe, 2007).

Skills of Observation

Dallwitz et al. (2002) wrote that the observation and identification of organisms is a process in determining which taxon species belong to and represents a basic skill for understanding nature. The way that students observe differences in nature, in

T. Gregorčič · G. Torkar (✉)
Faculty of Education, University of Ljubljana, Ljubljana, Slovenia
e-mail: gregor.torkar@pef.uni-lj.si

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observed behavior and perceived function is fundamental to developing scientific thinking (Tomkins & Tunnicliffe, 2007). Observations are motivated and guided by and acquire meaning about questions or problems about natural phenomena (Lederman, 2018). For an experienced observer, observation plays a key role throughout the entire investigation process, whereas everyday observer uses observation mainly for data collection (Eberbach & Crowley, 2009). Garcia Moreno-Esteva et al. (2020) provided a couple of examples of how personal identification processes of a biologist and non-biologist vary when they are carrying out a task concerning the observation of species-specific characteristics of two bird species. Observations and investigations of the environment enable students to identify and answer questions that trigger their curiosity about the world around them. Observation is an important initial skill in early years (Johnston, 2009) that helps students find and organize patterns in the observed natural world, which is crucial for scientific activity (Klemm & Neuhaus, 2017). Student's skills of observation develop with age (Johnston, 2011) and influence the development of other scientific skills (Johnston, 2009). Observations are more than just seeing things. Most students initially start observing using multiple senses at once (Johnston, 2011, 2013). Once they develop perceptions of objects, using their sight, sound, smell, feel, and/or taste, they rapidly start to construct a concept of identity for an object (Tomkins & Tunnicliffe, 2015). Simple explanations of observations gradually develop into complex interpretations (Johnston, 2009). They start recognizing similarities and differences between objects, observing patterns, identifying sequences and events in their surroundings, and interpreting observations (Johnston, 2011).

Identification Keys

In biology, an identification key is a tool that aids the identification of biological entities (e.g., plants, animals, animal tracks). Thus, one of the most fundamental objectives in biology teaching is to strive for developing students' skills and abilities to use biological identification keys (Randler & Zehender, 2006). For these purposes simplified identification keys are used. Bajd (2016) explains that with simplified identification keys primary and secondary school students are taught to observe organisms closely and classify them, to use biological terminology, to use the identification keys (the skill that can help them later use scientific identification keys) and about biodiversity.

Each identification step in simplified identification key requires from learner to choose between two options (dichotomous keys) or multiple ones (polytomous keys); consisting of text, graphics, or both. Simplified keys mostly contain organisms from the student's local environment and which allows them to get to know these organisms more closely through identification (Bajd, 2016). There is an increasing number of studies (e.g., Anđić et al., 2019; Laganis et al., 2017; Stagg et al., 2015; Randler, 2008; Bromham & Oprandi, 2006; Randler & Bogner, 2006) investigating the effectiveness of identification keys. Most of these studies were done with primary and secondary school students.

The results of Randler and Bogner (2006) indicate that using identification keys in biology teaching is an effective educational tool to explain scientific principles. Through the process of determination with identification key students improve their observational skills and terminology (Laganis et al., 2017), and can work independently, without the teacher's help (Bromham & Oprandi, 2006). Students are more motivated for learning about plants when working with identification keys, although botanical content is not attractive for students (Silva et al., 2011).

Nowadays, loads of identification keys are available, usually using words, illustrations, and/or photographs that guide a learner through the identification of the organism. For a review on the use of images in field guides and identification keys see Leggett and Kirchoff (2011). Authors exposed best practices in an image used in guides and keys, based on their review e.g., multiple images should be included to illustrate the taxon descriptions (characters indicated with arrows to direct the user's attention); an observed organism in the photograph should be pointed out from the backgrounds, where possible, the background should be of a standard color; the use of drawings is more reasonable than photographs when representing a typical example of an organism; when used, illustrations should be prepared by professional botanical illustrators, and clearly labeled. However, little is known what type of visual representations (illustrations or photographs) users prefer to use.

Eye-Tracking Technique

Eye-tracking is a technique for studying various visualizations because it makes it possible to monitor cognitive processes due to the links between eye movements and cognition. Eye movements indicate where attention is being directed and total fixation time (i.e., cumulative duration of fixations within a region) is considered as a sign of the amount of total cognitive processing engaged with the fixated information. Data gathered with eye tracing provides information about the cognitive process of the student, such as reading, scene perception, visual search, and other information on processing the problem (Rayner, 1998, 2009). The eye-tracking technique has been used in many studies, analyzing the learning process and problem-solving (e.g., Lai et al., 2013; Pavlin et al., 2019; Torkar et al., 2018). For detecting information about students' procession of various visualizations, the eye-tracking is also efficiently used (e.g., Ferk Savec et al., 2016).

Research Problem and Research Questions

Concerning this fact, collecting eye movements can provide important information in investigating students' identification of organisms with simplified identification keys. In the present study, we focus our attention on pre-service teachers, who are going to teach students to use simplified identification keys in primary and lower secondary school and their task is also to develop student's scientific skills. The goal of the present research was to observe pre-service teacher's eye movements during the determination of butterfly species with a simplified dichotomous key containing illustrations, photographs, and written descriptions that guide a learner through the identification step.

The research questions underlying this research were:

1. Do pre-service teachers use statistically significantly more illustrations or photographs in identification keys?
2. Are there statistically significant differences in the identification process between students who identified organisms correctly or incorrectly?
3. Are there statistically significant differences in the identification process between students with more or less prior experiences with identification keys and butterflies?
4. Are there statistically significant differences in results about the identification process, success in the identification process and experiences with identification keys and butterflies between biology major and non-major pre-service teachers?

Method

Participants

Slovenian pre-service teachers ($n = 58$) participated in the study: pre-service biology teachers ($n = 26$) and pre-service primary school teachers ($n = 32$). Seven males and fifty-one females. They are going to teach science or biology subjects in primary or lower secondary school. Education staff at the school level have to hold relevant educational qualification (ISCED 7 for primary school and lower secondary school teachers) and they have to pass the state professional examination for education staff (Eurydice, 2019). Even though the curriculum varies among universities, pre-service teachers typically take content knowledge courses, pedagogical content knowledge courses, and general education courses. Pre-service teachers learn how to create and use simplified identification keys in general biology or science courses. Pre-service biology teachers also learn to use scientific identification keys in zoology and botany courses. Participating pre-service teachers were in the second, third, or fourth year of studies at the University of Ljubljana's Faculty of Education. They all learned how to make and use simplified dichotomous identification keys before the study.

Through the curriculum for the pre-service primary school teachers and pre-service biology teachers at the Faculty of Education, University of Ljubljana, there is a great emphasis on learning how to use and create simplified identification keys. Pre-service primary school teachers, in the first year of study, at the subject of Natural Sciences—biology, learn about the importance of observational skills for classification of organisms. Throughout the activity of classifying fruits and vegetables by one criterion, i.e., they use their observational skills (using different senses) to determine the criteria for classification. Further, students are acquainted with a simplified schematic dichotomous identification key for organisms from students' local environment (they have to identify snail, spider, earthworm, etc. with the key). They also create their own simplified schematic dichotomous identification key for plants in the context of making herbarium. With created identification key the plants included in an herbarium can be determined. At the tutorials pre-service primary school teachers also learn to use simplified textual dichotomous identification key for determining ground animals (Bajd, 1998), and winter branches of woody species (Bajd, 1997). On the seacoast, they also use a simplified identification key for marine snails and shells (Bajd, 2012). Throughout curricula described above, pre-service primary school teachers learn to use and create simplified dichotomous identification keys for children in primary school and understand the importance of including identification keys in primary school science subjects' curricula.

Pre-service biology teachers learn to use and create simplified dichotomous keys at the Didactics of Biology from their first year of study. They learn about the variety of identification keys. The theoretical, empirical, schematic, graphic, textual, dichotomous, polytomous, digital, paper-based (book) identification keys are presented. They experience using digital dichotomous identification key for woody plants and also designing digital dichotomous identification key for common animals. Pre-service biology teachers also learn to use scientific biological identification keys at the Systematic Botany, the Zoology of Invertebrates, the Slovenian flora and fauna. Besides the use of identification keys and adaptation of them for teaching and learning biology subjects, students also learn about the diversity of species.

Procedure and Instruments

Eight tasks for butterfly species identification were presented on a computer screen in the form of text and images. Each task was presented with one identification step: two different written descriptions (A and B), an illustration and a photograph of an organism (for example see Fig. 8.1). Illustrations and photographs were taken from existing identification keys (Polak, 2009; Tolman, 2008). Students had to identify which description (A or B) correctly describes the organism on the images. On four out of eight tasks illustrations were placed on the left side and photographs on the right side of the slide. The remaining four slides had the opposite pattern.

To detect students' identification process an eye-tracker device was used. In present study the screen-based Tobii Pro X2-30 eye-tracker apparatus with Tobii Studio Enterprise for recordings and analyses of students' eye movement when using identification key was used. Gaze data were captured at 30 Hz with an accuracy of 0.4 degrees of visual angle at distances ranging between 40 and 90 cm. With an eye-tracker device eye movements can be detected, such as fixations of the gaze to the specific area of the computer screen during a specific activity. Also, students'

Fig. 8.1 An example of a student focusing on illustration, placed on the left side when identifying the butterfly species (represented with a heat map)

visual attention toward different elements of the task on the computer screen, the total amount of time (total fixation duration, TFD) and number of fixations (fixation count, FC) spent in particular areas of interest (AOI) was measured (Tsai et al., 2012; Havanki & VandenPlas, 2014).

Also, a short questionnaire was used to gather information about students' experiences with identification keys and butterflies (questions are presented in Table 8.2).

Data Analysis

To determine students' visual attention toward different elements of the slides while identifying species, we focused on the total amount of time (total fixation duration - TFD) spent in particular areas of interest (AOI). The tasks displayed on the computer screen were divided into several AOIs with regard to the placement of the images/texts investigated. Fixations refer to maintaining the visual gaze on a certain location (Fig. 8.1), and fast eye movements from one location to another are called saccades (Fig. 8.2). The identification of saccades or fixations is based on the motion of gaze. When both the velocity and acceleration thresholds (in our case: 30 degrees per second and 8,000 degrees per second squared) are exceeded, a saccade begins; otherwise, the sample is labeled as a fixation. Besides, how often participants used, in addition to text, just an illustration or a photograph was analysed. The limit of TFD in AOI was set at half a second (this was overall the lowest total time on AOI for illustration and photograph). If those participants spent less than half a second

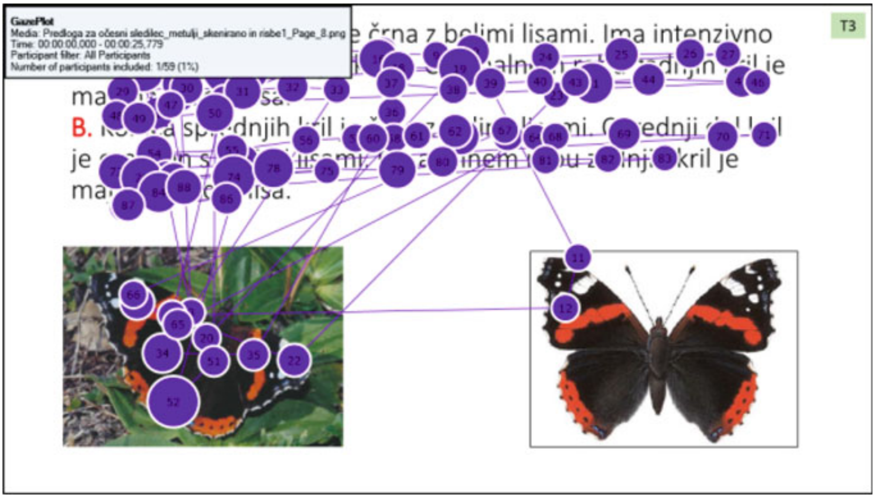

Fig. 8.2 An example of a student focusing on the photograph of the organism, placed on the left side, when identifying the butterfly species (represented with gaze plot). Through the representation of the gaze plot, the many integrations between images and text could be observed

on AOI illustration or photograph, we considered that the illustration or photograph was not used in the identification process.

Data entry and analysis were conducted using the Statistical Package for the Social Sciences (IBM SPSS 22.0). Basic descriptive statistics for numerical variables (mean, standard deviation, and frequency) were employed. The inferential statistical methods used were the Pearson product-moment correlation and the Student's *t*-test. In addition, effect sizes Cohen's *d* was calculated. Cohen's *d* statistic is a common measure to estimate effect size for independent samples *t*-tests (Cohen, 1988).

Results

Results show that 41.4% of pre-service teachers solved correctly all eight tasks, 27.6% seven, 22.4% six, 6.9% five, and 1.7% four tasks. Table 8.1 shows students' success in the identification of butterflies. On average they identified seven (SD = 1.04) butterfly species correctly.

Students were asked about their experiences with butterflies and identification keys (Table 8.2). A great amount of them (79.3%) said that they like observing butterflies in nature, but only 6.9% of students have sampled and determined butterflies so far. Most of the students (84.5%) mistakenly thought that butterfly species *Lycaena virgaureae* has yellow-colored wings. Also, only 5.2% of students would recognize butterfly species clouded yellow *Colias croceus*. Students also reported about their knowledge on the biodiversity of butterflies. Only one of the participants

Table 8.1 Correctly and incorrectly solved tasks

Tasks (*species*)	Task solved correctly		Task solved incorrectly		Total	
	f	*f*%	*f*	*f*%	*f*	*f*%
Task 1 (*Anthocharis cardamines*)	49	84.5	9	15.5	58	100.0
Task 2 (*Inachis io*)	52	89.7	6	10.3	58	100.0
Task 3 (*Vanessa atalanta*)	41	70.7	17	29.3	58	100.0
Task 4 (*Maniola jurtina*)	56	96.6	2	3.4	58	100.0
Task 5 (*Lycaena phlaeas*)	52	89.7	6	10.3	58	100.0
Task 6 (*Vanessa cardui*)	51	87.9	7	12.1	58	100.0
Task 7 (*Polygonia c-album*)	58	100.0	0	0.0	58	100.0
Task 8 (*Pararge aegeria*)	47	81.0	11	19.0	58	100.0

Table 8.2 Self-reported experiences with keys and butterflies

Self-reported experiences with identification keys and butterflies	Experienced		Not experienced	
	f	*f*%	*f*	*f*%
I like observing butterflies in the meadow.	46	79.3	12	20.7
I could recognize a butterfly species yellow clouded *Colias croceus*.	3	5.2	55	94.8
I have sampled and determined butterflies more than three times.	4	6.9	54	93.1
Butterfly species *Lycaena virgaureae* has yellow wings.	9	15.5	49	84.5

assessed her knowledge about butterfly species diversity as good (1.7%), 37.9% as average, 43.1% as fair, and 17.2% as poor.

They spent on average 18.19 s ($SD = 6.95$) for each task (tasks 1–8) presented on separate slides. When identifying butterflies, they devoted on average 26.17% of the total fixation duration (TFD) time to images and the rest of the time on written descriptions of butterfly species. They used on average 13.86% ($SD = 4.33$) of TFD on illustrations and 12.31% ($SD = 4.18$) of TFD on photographs of butterflies. The difference is statistically significant ($t = 1.966$, $df = 114$, $p = .050$). The effect size for this analysis ($d = .364$) was found to exceed Cohen's (1988) convention for a small effect ($d = .20$). In most cases students used at the same time photographs and illustrations (83.3%) in the identification process. Details are presented in Table 8.3.

Results in Table 8.4 show that the number of correctly identified butterfly species is not significantly correlated with self-reported prior experiences with identification keys and butterflies ($r = -.063, p = .637$). The number of correctly identified butterfly species is also not significantly correlated with average TFD for identifying butterflies ($r = -.236$, $p = .075$) neither with the average percent of TFD on illustrations ($r = -.056$, $p = .677$) and photographs ($r = -.204$, $p = .125$). It is also seen that

Table 8.3 Number (f, $f\%$) of times TFD in AOI < 0.5 s for illustrations and photographs

		Illustration		Photograph		Total	
Task	N	*f*	*f%*	*f*	*f%*	*f*	*f%*
1	57	4	6.9	5	8.6	9	15.8
2	58	10	17.2	2	3.4	12	20.7
3	58	5	8.6	0	0.0	5	8.6
4	58	3	5.2	9	15.5	12	20.7
5	58	2	3.4	4	6.9	6	10.3
6	58	0	0.0	6	10.3	6	10.3
7	58	6	10.3	7	12.1	13	22.4
8	58	1	1.7	3	5.2	4	6.9
Total	463	31	6.7	36	7.8	77	16.6

Table 8.4 Correlations between the number of correctly solved tasks, self-reported experiences with identification keys and butterflies, and eye-tracking results

	(1)	(2)	(3)	(4)	(5)	(6)
Number of correctly solved tasks (1)	1					
Self-reported experiences with identification keys and butterflies (2)	−.063	1				
Average TFD for each task (3)	−.236	.083	1			
Average TFD% on images (4)	−.144	−.040	$.340^{**}$	1		
Average TFD% on illustrations (5)	−.056	−.124	$.283^{*}$	$.894^{***}$	1	
Average TDF on photographs (6)	−.204	.056	$.325^{*}$	$.887^{***}$	$.586^{***}$	1

Note $*p < .05$, $**p < .01$, $***p < .001$

average TFD for identifying butterflies is not significantly correlated with students' experiences with identification keys and butterflies ($r = .083$, $p = .533$). The same is true for the percent of TFD on illustrations ($r = -.124$, $p = .353$) and photographs ($r = -.056$, $p = .674$) (Table 8.4).

Student's *t*-test indicated that pre-service primary school teachers had less prior experiences with identification keys and butterflies than pre-service biology teachers ($M = 2.75$, $SD = .95$; $M = 3.85$, $SD = .88$), $t(56) = 4.513$, $p < .001$, $d = 1.201$ (Fig. 8.3). The effect size for this analysis was found to exceed Cohen's (1988) convention for a large effect ($d = .80$). However, there are no statistically significant differences in a number of correctly solved tasks between pre-service primary school teachers and pre-service biology teachers ($M = 7.03$, $SD = 0.97$; $M = 6.96$, $SD = 1.14$), $t(56) = .251$, $p = .803$, $d = .066$. Pre-service biology teachers spent on average less TFD in identification process than pre-service primary school teachers ($M = 17.75$, $SD = 6.14$; $M = 18.53$, $SD = 7.62$), $t(56) = .425$, $p = .672$, $d = .113$. An average percent of TFD spent for observing images (illustrations and photographs) of butterfly species is smaller among pre-service biology teachers ($M = 25.22$, $SD =$

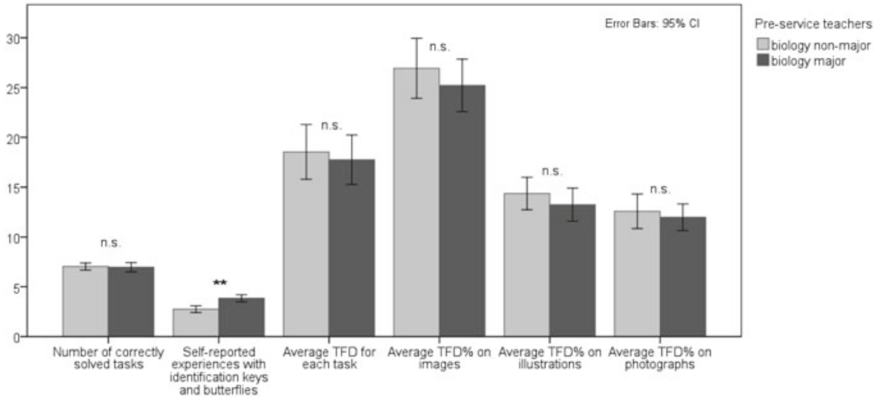

Fig. 8.3 Differences in results between biology major and non-major pre-service teachers (*Note* **p < .001; n.s.—not a statistically significant difference)

6.53) than among pre-service primary school teachers ($M = 26.93$, $SD = 8.36$), $t(56) = .854$, $p = .397$, $d = .228$. Cohen's d value above 0.2 suggest small effect (Cohen, 1988). Consequently, pre-service biology teachers average percent of TFD spent for observing illustrations of butterfly species is also smaller among pre-service biology teachers ($M = 13.24$, $SD = 4.11$) than among pre-service primary school teachers ($M = 14.36$, $SD = 4.49$), $t(56) = .980$, $p = .331$, $d = .260$. And pre-service biology teachers average percent of TFD spent for observing illustrations of butterfly species is smaller among pre-service biology teachers ($M = 11.98$, $SD = 3.32$) than among pre-service primary school teachers ($M = 12.57$, $SD = 4.81$), $t(54.68) = .553$, $p = .582$, $d = .143$.

Discussion

Pre-service primary school and biology teachers report having very little prior experiences with identifying keys for butterflies. The use of identification keys in teaching and learning biology is a great opportunity to develop students' scientific skills of observation and classification (Randler & Bogner, 2006), familiarize them with biodiversity, biological terminology, and the use of identification keys (Bajd, 2016). Identification keys can be simplified to make it more fitting for educational purposes. The main goal of the present research was to observe the determination of butterfly species with a simplified dichotomous key containing illustrations, photographs, and written descriptions, and to explore what type of visual representations (illustrations or photographs) pre-service teachers prefer to use and are more effective in the identification process. The findings of the present research suggest that pre-service biology and primary school teachers spent on average one-quarter of a total fixation duration on images (illustration and/or photograph of a butterfly) while identifying species of butterflies. Students used more illustrations than photographs for the determination of butterfly species, but the size of the effect is small. A possible explanation of the result is that students disliked photographic backgrounds because they distract them from the subject (Leggett & Kirchoff, 2011). Leggett and Kirchoff (2011) recommend that backgrounds should be of the standard color, which is also a common practice in scientific identification keys (e.g., Johnson, 2004; Svensson, 2010). A finding of the present research suggests that students rely more on illustration prepared by professional biological illustrators in comparison to a photograph even though later depicts butterfly more realistically. Drawings that are prepared by a trained botanical illustrator show specimens typical of the species and focus on and emphasize their specific features (Meicenheimer, 2007, 2009) which help learners identify organisms.

Before the study, all participating pre-service primary school teachers learned how to use and develop simplified dichotomous identification keys and besides that, pre-service biology teachers learned to use scientific identification keys in botany and zoology. As expected, pre-service biology teachers reported having more experiences with identification key and butterflies than pre-service primary school teachers, this had no significant effect on success in the identification process. Those students that reported having more experiences with identification keys and butterflies were not more successful in identification in comparison to less experienced students. These results can be explained in two ways. First, with the simplicity of examples presented in the tasks (as seen from Table 8.1), where a large majority of participants correctly determined the species. This is also one of the limitations of the present study, therefore, in future studies, complex examples and also scientific identification keys should be used, to make sure that tasks are sufficiently difficult for learners to differentiate them more. Secondly, Eberbach and Crowley (2009) explained that specific scientific skills of observation are developed within a disciplinary framework. Meaning, that being able to observe and identify plants does not help you much within disciplines such as entomology or ornithology.

Studying students' eye movements and total fixation durations in AOIs gave us information on their process of identification. Namely, the average total fixation duration time was slightly shorter, but not significantly, among students who provided more frequently correct answers. The same conclusion can be made for their total fixation duration on illustrations and photographs. Pre-service biology teachers used less percentage of time to observe images, probably due to better knowledge of the biological terminology used in the texts or higher confidence in a determination. Most students looked both images—photographs and illustrations (for example see Fig. 8.2) in the identification process which speaks in favor of Wisniewski's (2002) recommendation that taxon written descriptions should be supported with multiple images to help students visualize the presentative features of an organism. Furthermore, it is interesting finding that the number of students who used only illustration or photograph was lower within tasks that were most correctly answered. This is something to be further explored in future studies.

Conclusion

The present research provides some useful information about the determination of species with identification keys. Pre-service teachers reported having very little prior experiences with identification keys for butterflies, but still, they were very successful in the determination of eight butterfly species with provided simplified identification key. This speaks in favor of using identification keys for learners to autonomously observe and identify taxon. Eye-tracking technology proved to be useful in the present research, but it is hardly a standalone research method. Analysis of the eye movements showed that students preferred illustrations over photographs of butterflies in the identification process, but the effect size is small and needs to be further tested. Furthermore, students mostly looked at both images (photographs and illustrations) in the identification process, therefore, multiple images are recommendable in identification keys to help learners to observe the presentative features of a taxon. Due to relatively small numbers of incorrectly solved tasks, it is difficult to make solid conclusions on the effect of visual attention toward different elements of identification keys. The findings of the present study also contribute to the support of those who see identification keys as the way to enable school students to learn about biodiversity independently of a teacher's help.

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Tanja Gregorčič Ph.D. student, is a teaching assistant for biology education at the University of Ljubljana, Faculty of Education, Slovenia. Her research focuses on the field of students' conceptions about animals, system thinking of natural complex system such as the human body system and on implementing new technologies (augmented reality, eye-tracking) in biology teaching and learning.

Gregor Torkar, Ph.D. is an Associate Professor for biological education at the Faculty of Education, University of Ljubljana, Slovenia. His research field in general is biology and environmental education within the primary, secondary and undergraduate level of education. His current research focus is ecology, evolution and conservational education. He is using eye-tracking technology in his research for evaluating textbooks and science education in general. He is involved in several national and international research projects on science education and nature conservation.