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Effectiveness of Digital and Paper-Based Identification Keys for Plants with Slovenian Pre-service Teachers

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Abstract: Teaching about biodiversity and its conservation could be an effective way to teach the importance of different species and human dependence on ecological support systems. This study compares the effectiveness of a digital and a paper-based dichotomous identification key for teaching pre-service teachers about plant species diversity. Twenty-four Slovenian teachers in pre-service training used a digital version of the key on tablet computers and twenty-nine used a paper-based version to identify woody species in the garden near their university faculty. Both keys contained the same species, identical photographs and the same sequence of steps to identify the species. The accuracy and time taken to identify the five species were measured. The participants also completed a questionnaire about the usability of the identification key. Overall, both versions of the key were equally good for determining species names. The digital version of the key was found to be more time-effective than the paper version only when multiple identification steps were required to identify species. The results confirm that those who scored better on the identification tasks have a better general opinion about the usability of the key; especially students using digital version of the key. Implications for teachers using or creating identification keys are discussed in the conclusion.

Keywords: *Identification key, plants, pre-service teacher, plant determination, usability of identification key.*

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Introduction

There is a growing awareness of the importance of biodiversity conservation for the survival of humanity (Millennium Ecosystem Assessment [MEA], 2005). Barney et al. (2005) stress the importance of communicating biodiversity to raise public awareness of the importance of nature conservation. It can be concluded from this that classroom teaching should give appropriate attention to learning about species in order to achieve the goals of biodiversity conservation. Species identification has become increasingly less important in schools (Lawler, 2016), resulting in incomplete or non-existent species identification skills in schoolchildren, students and adults. (Bebbington, 2005; Bell, 1981; Randler & Bogner, 2002). Kos and Jerman (2015) emphasised that children should be encouraged to notice the many variables and details when observing plants. They found that five- to ten-year-old children pay most attention to obvious features: first colour, then shape, and then size. This declining interest in knowledge about species diversity and identification skills is partly the result of an increased focus on 'higher order cognitive goals' throughout the educational system, which is shifting towards more ecologically oriented approaches (Randler & Bogner, 2002). Additional limitation to knowing species diversity is taxonomic impediment, inability to survey and identify all species due to the lack of good taxonomists. Only a few taxonomic groups are sufficiently surveyed (Vinarski, 2020). Taxonomic impediment reduces the initial opportunity to develop specific skills to identify lesser-studied species groups and to capture the full biodiversity of an area.

Studies have shown a low level of knowledge about plants (Bebbington, 2005; Fančovičová & Prokop, 2011; Patrick & Tunnicliffe, 2011). In many countries, including Slovenia (e.g. Huang et al., 2010), school activities of studying plants are mostly limited to the classroom. The ability to name at least the most common species would improve a teacher's ability to do biology fieldwork (Bebbington, 2005). Lindemann-Matthies et al. (2017) investigated how well pre-service teachers are prepared for the implementation of species identification in school. They emphasized the crucial role of the teacher preparation system in familiarizing graduates with local organisms and with appropriate approaches to

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species identification later in school. The main aim of the present study is to test the usability of a digital and a paper-based dichotomous identification key for plant species with pre-service teachers and to familiarize them with this teaching and learning approach that could be used for species identification in schools.

Literature Review

An identification key is a tool that facilitates the identification of biological entities (e.g. plants, animals, fungi or animal tracks). Images and/or words can be used in identification steps that guide a learner through the identification process. Identification keys can be used with single or multiple access. According to the number of alternatives, keys are divided into dichotomous keys (two alternatives in each identification step) or polytomous keys (more than two alternatives in each step). For each identification step in the simplified identification key the learner has to choose between two options (dichotomous keys) or more (polytomous keys) consisting of text, graphics or both. Bajd (2016) explained that simplified identification keys are contextualized to the user's level of knowledge. They usually contain organisms from the learner's local environment, which allows the learner to learn about these organisms through identification (Bajd, 2016). Today, there are a variety of identification keys, usually accompanied by words, illustrations and/or photographs, that guide the learner through the identification of the organism. For an overview of the use of images in field guides and identification keys see Leggett and Kirchoff (2011). The authors presented the best practices in an image used in the guides and keys, based on their review of e.g., multiple images should be included to illustrate the taxon descriptions (characters indicated with arrows to draw the user's attention); an observed organism in the photograph should be highlighted from the backgrounds, with the background preferably a standard colour; the use of drawings is more appropriate than photographs when it is a typical example of an organism; illustrations, when used, should be prepared by professional botanical illustrators and clearly labelled.

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). Identification keys are a well-established method and are one of the keys used in field trips (Wood, 2004). In Slovene primary school students learn how to use simplified identification keys (Skvarč et al., 2011) in which simple features (characters) are used in identification steps to facilitate the identification process (Wood, 2004). Simplified identification keys usually consist of a small number of biological entities (e.g., common species in a local pond) and use basic scientific terminology. The assumption is that digital dichotomous identification keys are more time-effective for learners when using a simple identification key with a large number of biological entities.

There is an increasing number of studies (e.g. Anđić et al., 2018, 2019, 2020; Bromham & Oprandi, 2006; Dolenc-Orbanić et al., 2016; Jeno et al., 2017; Laganis et al., 2017; Stagg et al., 2015 Randler, 2008; Randler & Bogner, 2006) that investigate the effectiveness of identification keys. Most of these studies were conducted with primary and secondary school students. The results of Randler and Bogner (2006) indicate that the use of identification keys in biology lessons is an effective pedagogical tool for explaining scientific principles. Through the process of determination with identification keys, students improve their observation skills and terminology (Laganis et al., 2017) and are able to work independently without the help of the teacher (Bromham & Oprandi, 2006). Laganis et al. (2017) also showed that using a digital dichotomous key to identify plants successfully improves secondary school students' knowledge about species diversity and its characteristics (characters) both indoors and outdoors. A recent study by Unger et al. (2020) showed that university students who used the smartphone application iNaturalist to identify organisms increased their ability to identify local biodiversity and their engagement in biological sciences. Šorgo (2006) reports that students who independently construct dichotomous identification keys achieved higher order cognitive knowledge levels because the construction of such keys is based on analysis, synthesis and assessment. Similarly, Dolenc-Orbanić et al. (2016) find the usefulness of combining mobile learning with digital identification keys and fieldwork in the process of teaching biodiversity. Students are more motivated to learn more about plants when they work with identification keys, although botanical content is usually not attractive to students (Silva et al., 2011).

Methodology

The research design was quantitative. A quasi-experiment was used to compare the usability of a digital and a paper-based dichotomous identification key for teaching pre-service teachers about diversity of plant species.

Research Goal

The goal of the present research is to compare digital and paper versions of the key with the same content and format of the images in order to obtain objective results.

Hypothesis (H)

H1: Pre-service teachers will have more difficulty identifying a plant species when more identification steps are needed.

H2: There will be a significant difference in the correctness of identification of species between the digital and paper version of the key.

H3: Pre-service teachers will need significantly less time to correctly identify selected woody species with digital identification keys.

H4: Pre-service teachers that obtain better results on the identification tasks will have a significantly better opinion about the key's usability for learning about plants.

Sample and Data Collection

A total of fifty-three preservice primary school teachers from the University of Ljubljana's Faculty of Education took part in the research. The students were randomly divided into groups for digital versions or paper versions. Twenty-four pre- service teachers used a digital version of the key on tablet computers and twenty-nine used a paper version of the key. The group who used the digital version is smaller, as some students reported that they had problems with their Internet connection; they were therefore excluded from the data analysis. Eight pre-service teachers were male and forty-five were female, eighteen to twenty-four years old. They were all familiar with the identification keys before the research was conducted. Nevertheless, the students were shown how to use the identification key before starting the research, using the practical example of the identification key for marine gastropods and bivalves.

The research was conducted in April/May 2017 and 2018. The pre-service teachers used an identification key for woody species in the garden near the Faculty of Education. They used digital dichotomous key the *Interactive Guide to Indigenous and Introduced Woody Plants* (Nimis et al., 2008, 2013) or a paper version containing the same species, identical photos of the same size and the same sequence of identification steps. The key can be used to identify fifty-five different woody plants in Slovenia.

First, the identification process with the key was briefly presented to the pre-service teachers. It was explained to them that they would use an identification key, whereby they had to choose one of two alternatives at each step. The students had familiarised themselves with the identification keys before the experiment, so only a quick trial was carried out, showing them the first few identification steps with the key to get an idea of how it works.

Figure 1: Examples of identification steps from the dichotomous identification key (Slovenian version).

The students had five minutes to identify each of five woody species: the wayfarer tree (*Viburnum lantana*), the Japanese barberry (*Berberis thumnbergii*), the northern white cedar (*Thuja occidentalis*), the Serbian spruce (*Picea omorika*), and the common privet (*Ligustrum vulgare*). The researcher, who accompanied the pre-service teachers, stopped the identification process after five minutes in each case. If a pre-service teacher has identified a plant within the deadline, he or she has written plant species name on the worksheet. They also noted on the worksheet if they had any difficulties in the identification process. Then the pre-service teacher was accompanied to the next plant in the garden, and the five-minute identification process was repeated. After each identification of the plants, the researcher recorded the time the pre-service teacher took to identify them.

The identification of five woody plants was immediately followed by a 5-point Likert- type scale (1- totally disagree, 2- disagree, 3- neutral, 4- agree, 5- totally agree) (Likert, 1932), which was used to obtain their opinion on the usability of the key: whether they felt that the key had helped them to observe the plants better and find additional information about the plants, their characteristics, scientific names and diversity (Laganis et al., 2017). Cronbach's alpha coefficient for the resulting instrument was .79. They were also asked whether they knew any of the species identified before the experiment.

Analyzing of Data

Basic descriptive statistics were used to obtain the frequencies and average values of pre-service teachers' ratings and responses. A Shapiro-Wilk Test was used to test the normality distribution. The assumption of homogeneity of variance was not violated (p >.05). Levene's test for equality of variances was conducted. The independent Student's t-test, χ^2 test and the Pearson correlation coefficient were used as inferential statistical methods. The effect size was calculated (Cohen, 1988) to investigate the relationship between treatment groups.

Results

Twenty-four pre-service teachers used the digital dichotomous key and twenty-nine students used the paper version of the same key. The students reported that they did not know any of the species identified before the experiment. Table 1 shows that pre- service teachers had the greatest difficulty in identifying *Ligustrum vulgare*, where the number of identification steps in the key was 11. The number of incorrectly identified species increased with the total number of identification steps. The number of steps is predetermined and is identical in both versions of the key. There were no significant association between the expected and observed frequencies in each category for *Viburnum lantana* ($\chi^2(1)$ = .232, p = .630), *Berberis thumnbergii* ($\chi^2(1)$ = 2.071, p = .150), *Thuja occidentalis* ($\chi^2(1)$ = .587, p = .444), *Picea omorika* ($\chi^2(1)$ = 1.127, p = .288) and *Ligustrum vulgare* ($\chi^2(1)$ = 1.113, p = .292). This means that the ratio of correctly identified plants with the digital version does not differ significantly from the ratio of correctly identified plants with the paper version of the identification key.

Table 1: Frequencies for correctly identified species.

Species	N	Number of steps	Correct identification					
			Total		Digital version (n = 24)		Paper version (n = 29)	
			f	f (%)	f	f (%)	f	f (%)
Viburnum lantana	53	8	28	54.7	14	58.3	14	51.7
Berberis thunbergii	53	7	30	56.6	11	45.8	19	65.5
Thuja occidentalis	53	4	50	94.3	22	91.7	28	96.7
Picea omorika	53	6	45	84.9	19	79.2	26	89.7
Ligustrum vulgare	53	11	16	30.2	9	37.5	7	24.1

Only the time needed to correctly identify the selected species was used to calculate the average identification time. The results presented in Figure 2 show that the digital version of the key proved to be more useful than the paper version in terms of the time needed to identify the species only when several identification steps were used for identification. Time used to successfully identify the plant *Viburnum lantana* with the digital version (M = 125.57, SD = 61.20) was significantly shorter than with paper versions (M =186.47, SD = 80.32) of the identification key, $t(27)$ = −2.28, p = .03, Cohen's d = .91. Similarly, time spent with the digital version (M =154.11, SD = 73.09) was significantly shorter than with paper versions (M = 263.57, SD = 24.44) of the key for the identification of *Ligustrum vulgare*, $t(14)$ = −3.78, p = .002, d = 2.00. Values of Cohen's d between groups of pre-service teachers suggests large significance (Cohen, 1988).

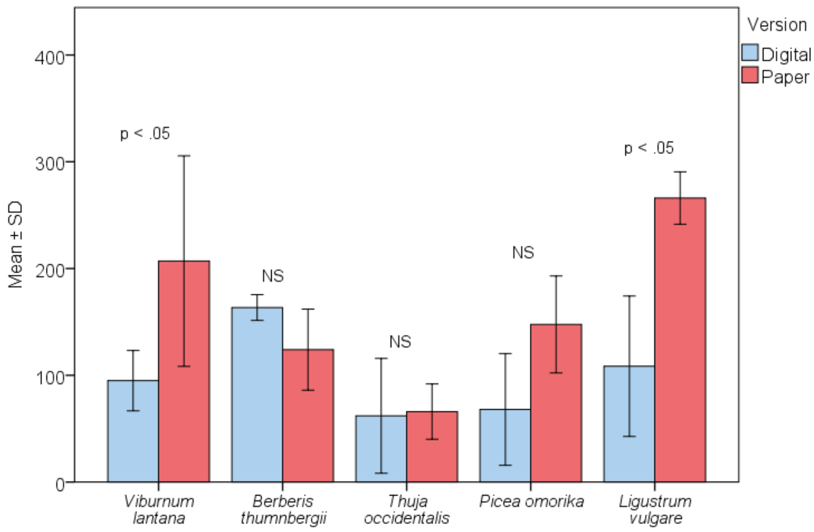

Figure 2: Comparison of time (in seconds) used to successfully identify the plant species with the digital and paper versions of the identification key (p < .05 = statistically significant difference, NS = statistically not significant).

Detailed results on the pre-service teachers' opinions about the usability of the key for learning about plant species are presented in Table 2. They were most positive about the use of the identification key to become more aware of the diversity of plants living in nature, to develop their observation skills and to learn about plant species in an interesting way. The values of the items in italics were reversed. The results do not show a statistically significant advantage of the digital dichotomous key (M = 3.44, SD = .58) over the paper version (M = 3.58, SD = .57) in the opinion about the key for learning about plant species, $t(51) = -1.02$, p = .31, d = 0.26.

Table 2: Pre-service teachers' opinions about the identification key.

	Digital version (n = 24)		Paper version (n = 29)		Total (n = 53)	
Items	***M***	***SD***	***M***	***SD***	***M***	***SD***
By using the identification keys, I develop precise observation skills; I recognize similarities and differences.	4.04	.751	4.17	.89	4.11	.82
By using the identification key, I learned about plant species in an interesting way.	4.00	.85	3.79	.98	3.91	.90
By using the identification key, I became aware of the diversity of plants living in the wild.	4.14	.99	3.71	,96	3.94	.98
I plan to use this identification key in my future work in school.	3.71	1,20	3.79	.94	3.75	1.05
I liked using the identification key because it helped me become more familiar with plants.	3.83	.71	3,58	.93	3.72	.82
When using the identification key, I did not remember the names of species I identified.	3.38	.97	3.41	1.09	3.40	1.02
I very often had difficulty identifying organisms.	3.39	1.12	3.24	.99	3.27	1.02
While identifying an organism, I easily followed the identification steps.	3.08	1.14	3.38	.90	3.25	1.02
The identification key is easy to use.	3.29	1.27	3.21	1.11	3.21	1.16
The identification key is not useful for me because I do not know enough biology to use it to identify plants.	2.17	1.01	2.03	.73	2.09	.86

The results presented in Table 2 show that the students had some difficulties in using the key and the identification steps. Qualitative data were collected on the reported difficulties pre-service teachers had in the plant identification. They noted them on the worksheets after each plant identification. The most commonly reported problems were difficulties in distinguishing between leaves and leaflets (6 individuals), leaf arrangements (opposite or spiral) (3 individuals), pinnately and palmately compound leaves (3 individuals), size of a plant species (3 individuals), plant smell (1 individual) and a term flower petal (1 individual). Some also reported occasional difficulties with the Internet connection. In some cases they were therefore excluded from the data analysis.

The knowledge score was calculated using the following formula: (number of correctly identified species times ten) + (total available time for identification of one species [300s] – average time (in seconds) used for successfully identified species) / 30 * number of correctly identified species. Those who scored better on the identification tasks had more positive opinion about the usefulness of the key for learning about plants and its usefulness for their future work as teachers ($r(51)$ = .33, p = .017). Figure 3 also shows that students successfully using digital version of the key had significantly more positive opinion about the usefulness of the key for learning about plants and its usability for their future work as teachers ($r(24)$ = .42, p = .039) while students using paper version showed no significant correlation ($r(29)$ = .14, p = .485).

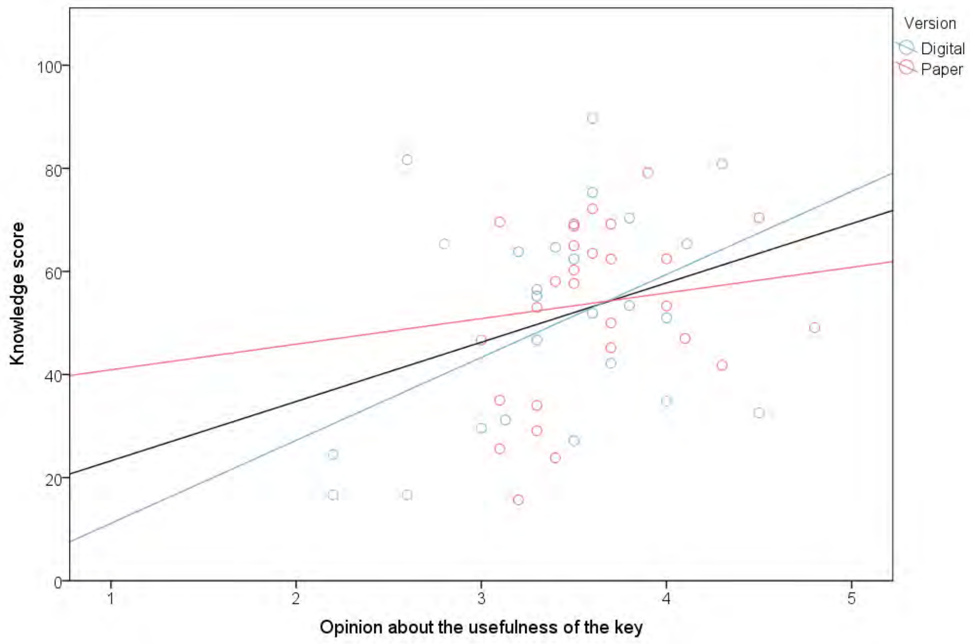

Figure 3: Correlation between knowledge score on the identification tasks and average opinion about the usability of the digital and paper-version identification keys

Discussion

The usability of a digital versus paper-based dichotomous identification key in teaching pre-service teachers about diversity of plant species was compared. The simple identification key itself has an illustrative and explanatory power for learning plant names, their physical properties and new information, and is also easy to use (Laganis et al., 2017). When using keys, students must be attentive and learn the scientific terms on which the keys depend (Bajd, 2016; Kirchoff et al., 2014).

In the research, the hypothesis was put forward (H1) that pre-service teachers will have greater difficulty in identifying a plant species if more identification steps are required. The results confirmed the hypothesis that the correctness of identifying plant species decreases with an increasing number of identification steps. The results imply that more identification steps increase the possibility that they make mistakes in the identification process. A key with fifty-five different species was used in this study (Nimis et al., 2013). The pre-service teachers had to use a maximum of eleven determination steps. The use of keys requires a certain knowledge of botanical terms and some field experience, which students often lack (Silva et al., 2011). In addition, they reported in their worksheets problems with some identification steps, such as the distinction between leaves and leaflets. Laganis et al. (2016) reported similar difficulties in a previous study.

The results disproved the second hypothesis (H2) because the digital dichotomous key on tablet computers and the traditional paper version of the dichotomous key were equally effective in improving their knowledge of plant species names. This confirms that the key provides a user-friendly layout for students to familiarize themselves with wildflowers (Wood, 2004; Jacquemart et al., 2016) and is an effective educational tool (Silva et al., 2011; Laganis et al., 2016), both in the paper and digital versions. Most recent study by Anđić et al. (2020) showed that digital identification key for plants is more suitable than a paper version for learning botany in primary schools when implementing a constructivist approach.

The third hypothesis (H3), that pre-service teachers will need significantly less time to correctly identify selected species with the digital identification key, was partially confirmed. In two out of five cases, teachers using the digital dichotomous key needed significantly less time to identify the selected plant species. The results are statistically significant in favour of the digital version in cases where teachers had to apply more identification steps. They were positive about the use of identification keys, which could have a positive effect on the students' interest in botany, something that has been repeatedly described as problematic in previous research (e.g. Bebbington, 2005; Fančovičová & Prokop, 2011; Tunnicliffe & Reiss, 2000; Wandersee & Schussler, 2001). The pre-service teachers involved in the research expressed a very positive attitude towards the use of the key, which makes it a suitable teaching and learning method in biology lessons.

The last hypothesis (H4) was that the pre-service teachers who achieve better results in the identification tasks will have a much better opinion about the usability of the key for learning about plants. The results confirm that those who scored better on the identification tasks have a better general opinion about the usability of the key for learning about plants. This was especially true for the group of students using digital version of the key. They also expressed their likelihood of integrating the key into their future teaching practice. Similarly, Jacquemart et al. (2016) showed that university students from Belgium appreciated the identification key; the majority of them reported that it helped them in the practice of plant identification.

Conclusion

Earlier studies (e.g. Anđić et al., 2020; Dolenc-Orbanić et al., 2017; Laganis et al., 2017; Randler & Bogner, 2006) found the usability of the digital identification key, but the present study showed that overall, both versions of the key were equally good for the identification of species names. The digital version of the key proved to be more useful than the paper version in terms of the time needed to identify species when multiple identification steps are used. The result can be interpreted in the light of the findings of Ackerman and Goldsmith (2011) that learners still prefer to study text from printed print-outs rather than computer screens.

Recommendations

The research suggests that teachers should consider using or creating a digital version of a dichotomous key when a large number of biological units are contained in the key; more identification steps increase the possibility of errors in the identification process and the time required for identification. Teachers should also pay attention to how the identification steps are formulated and what scientific terms are used when creating a new identification key or applying an existing key. The scientific terms used in the key should be discussed with students before using the key and, when necessary, changed. Also identification steps could be reorganized. However, the purpose of a dichotomous identification key is also to encourage students to actively learn and use scientific terms and therefore teachers should not avoid including new terms in identification keys as long as the terms are explained to students. In addition, when deciding on the number of biological units to be included in a newly created identification key, factors such as age, reading and writing ability of students and their previous experience with identification keys should be taken into account. Finally, identification keys help students to develop observation skills. With simplified identification keys they learn to observe and classify organisms accurately. All these proposals should be further evaluated in future research. Additional research should be conducted to determine how and when in-service teachers use identification keys in schools and what they think about the use of identification keys in biology teaching.

Limitations

The results should not be generalized to all pre-service teachers because of the sampling limitations described above. Only one type of digital identification key was used in the study, so we should not generalize the results to all forms of digital identification keys. In fact, identification keys that use biometrics (e.g., Pl@ntNet) to map plant characteristics from a photograph become very accurate and accessible to users. These types of keys would likely lead to different learning outcomes.

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References

Ackerman, R., & Goldsmith, M. (2011). Metacognitive regulation of text learning: On screen versus on paper. *Journal of Experimental Psychology: Applied*, *17*(1), 18–32. https://doi.org/10.1037/a0022086

Anđić, B., Cvijetićanin, S., Maričić, M., & Stešević, D. (2018). The contribution of dichotomous keys to the quality of biological-botanical knowledge of eighth grade students. *Journal of Biological Education*, *53*(3), 310–326. https://doi.org/10.1080/00219266.2018.1469540

Anđić, B., Cvjetićanin, S., Lavicza, Z., Maričić, M., Novović, T., & Stešević, D. (2020). Mobile and printed dichotomous keys in constructivist learning of biology in primary school. *Research in Science & Technological Education*, 1–28. https://doi.org/10.1080/02635143.2020.1763290

Andjić, B., Cvijetićanin, S., Hayhoe, S., Grujičić, R., & Stešević, D. (2019). Dichotomous keys in the botanical learning of non-visual (blind) people. *Journal of Baltic Science Education*, *18*(5), 668–680. https://doi.org/10.33225/jbse/19.18.668

Bajd, B. (2016). Jednostavni biološki ključevi [Simplified biological keys]. *Biology Education: Journal of Biology Education/ Educatio Biologiae: Časopis Edukacije Biologije*, *2*(1), 91–99.

Barney, E. C., Mintzes J. J., & Yen C. (2005). Assessing knowledge, attitudes, and behavior toward charismatic megafauna: The case of dolphins. *The Journal of Environmental Education, 36*(2), 41–55. https://doi.org/10.3200/JOEE.36.2.41-55

Bebbington, A. (2005). The ability of A-level students to name plants. *Journal of Biological Education*, *39*(2), 63–67. https://doi.org/10.1080/00219266.2005.9655963

Bell, B. F. (1981). When is an animal, not an animal? *Journal of biological Education, 15*(3), 213–218. https://doi.org/10.1080/00219266.1981.9654381

Bromham, L., & Oprandi, P. (2006). Evolution online: Using a virtual learning environment to develop active learning in undergraduates. *Journal of Biological Education, 41*(1), 21–25. https://doi.org/10.1080/00219266.2006.9656052

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Erlbaum.

Dolenc-Orbanić, N., Cotič, N., & Furlan, P. (2016). Mobilno učenje na primeru spoznavanja biodiverzitete [Mobile learning about biodiversity]. *Didactica Slovenica -Pedagoška Obzorja/Pedagogical Horizons, 31*(1), 86–99.

Fančovičová, J., & Prokop, P. (2011). Children's ability to recognize toxic and non-toxic fruits. *Eurasia Journal of Mathematics, Science & Technology Education*, *7*(2), 115–120. https://doi.org/10.12973/ejmste/75186

Huang, Y. M., Lin, Y. T., & Cheng, S. C. (2010). Effectiveness of a mobile plant learning system in a science curriculum in Taiwanese elementary education. *Computers & Education*, *54*(1), 47–58. https://doi.org/10.1016/j.compedu.2009.07.006

Jacquemart, A. L., Lhoir, P., Binard, F., & Descamps, C. (2016). An interactive multimedia dichotomous key for teaching plant identification. *Journal of Biological Education*, *50*(4), 442–451. https://doi.org/10.1080/00219266.2016.1150870

Jeno, L. M., Grytnes, J. A., & Vandvik, V. (2017). The effect of a mobile-application tool on biology students' motivation and achievement in species identification: A Self-Determination Theory perspective. *Computers & Education, 107*, 1–12. https://doi.org/10.1016/j.compedu.2016.12.011

Kirchoff, B. K., Delaney, P. F., Horton, M., & Dellinger-Johnston, R. (2014). Optimizing learning of scientific category knowledge in the classroom: The case of plant identification. *CBE—Life Sciences Education*, *13*(3), 425–436. https://doi.org/10.1187/cbe.13-11-0224

Kos, M., & Jerman, J. (2015). Observing natural objects: characteristics of flowering plants perceived as important by 5- and 10-year-old children. *Journal of Baltic Science Education, 14*(1), 109–120. http://journals.indexcopernicus.com/abstract.php?icid=1143039

Laganis, J., Prosen, K., & Torkar, G. (2017). Classroom versus outdoor biology education using a woody species identification digital dichotomous key. *Natural Sciences Education*, *46*(1), 1–9. https://doi.org/10.4195/nse2016.11.0032

Lawler, S. (2016). *Identification of animals and plants is an essential skill set.* The Conversation. https://bit.ly/2NuvMrX

Leggett, R., & Kirchoff, B. K. (2011). *Image use in field guides and identification keys: review and recommendations*. AoB Plants. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3077818

Likert, R. (1932). A technique for the measurement of attitudes. *Archives of Psychology, 22*(140), 1–55.

Millennium Ecosystem Assessment. (2005). *Ecosystems and human well-being: Synthesis*. Island Press.

Nimis, P.L., Martellos, S., & Kodele Krašna, I. (2008). *Interaktivni vodnik za določanje samoniklih in gojenih lesnatih rastlin Slovenije* [An interactive guide to indigenous and introduced woody plants of Slovenia]. Key to Nature. http://dbiodbs.units.it/carso/chiavi_pub21?sc=312

Nimis, P.L., Martellos, S., Moro, A., Kodele Krašna, I., & Torkar, G. (2013). *Spoznajmo lesnate rastline v okolici Pedagoške fakultete v Ljubljani* [An interactive guide to woody plants in surrounding of the Faculty of Education University of Ljubljana]. Key to Nature. http://www.pef.uni-lj.si/~kemija/kljuc/species/5635.html

Patrick, P., & Tunnicliffe, S. D. (2011). What plants and animals do early childhood and primary students' name? Where do they see them? *Journal of Science Education and Technology*, *20*(5), 630–642. https://doi.org/10.1007/s10956-011-9290-7

Randler, C. (2008). Teaching species identification - A prerequisite for learning biodiversity and understanding ecology. *Eurasia Journal of Mathematics, Science & Technology Education*, *4*(3), 223–231. https://doi.org/10.12973/ejmste/75344

Randler, C., & Bogner, F. X. (2006). Cognitive achievements in identification skills. *Journal of Biological Education, 40*(4), 161–165. https://doi.org/10.1080/00219266.2006.9656038

Randler, C., & Zehender, I. (2006). Effectiveness of reptile species identification - A comparison of dichotomous key with an identification book. Eurasia *Journal of Mathematics, Science and Technology Education, 2*(3), 55–65. https://doi.org/10.12973/ejmste/75464

Lindemann-Matthies, P., Remmele, M., & Yli-Panula, E. (2017). Professional competence of student teachers to implement species identification in schools - A case study from Germany. *CEPS Journal, 7*(1), 29–47. https://doi.org/10.26529/cepsj.12

Shultis, J. (2001). Consuming nature: The uneasy relationship between technology, outdoor recreation and protected areas. *The George Wright Forum 18*(1), 56–66.

Silva, H., Pinho, R., Lopes, L., Nogueira, A. J., & Silveira, P. (2011). Illustrated plant identification keys: An interactive tool to learn botany. *Computers & Education*, *56*(4), 969–973. https://doi.org/10.1016/j.compedu.2010.11.011

Skvarč, M., Glažar, S. A., Marhl, M., Skribe Dimec, D., Zupan, A., Cvahte, M., & Vičar, M. (2011). *Program osnovna šola, Naravoslovje, učni načrt*. [Basic school program, natural science, curriculum]. Ministrstvo za šolstvo in šport, Zavod RS za šolstvo [Ministry of Education, Science and Sport]. https://www.gov.si/assets/ministrstva/MIZS/Dokumenti/Osnovna-sola/Ucni-nacrti/obvezni/UN_naravoslovje.pdf

Stagg, B.C., Donkin, M.E., & Smith, A.M. (2015). Bryophytes for Beginners: The usability of a printed dichotomous key versus a multi-access computer-based key for bryophyte identification. *Journal of Biological Education*, *49*(3), 274–287. https://doi.org/10.1080/00219266.2014.934900

Šorgo, A. (2006). Dichotomous identification keys: A ladder to higher order knowledge about the human body. *Science Activities, 43*(3), 17–20. https://doi.org/10.3200/SATS.43.3.17-20

Tunnicliffe, S. D., & Reiss, M. J. (2000). Building a model of the environment: How do children see plants? *Journal of Biological Education*, *34*(4), 172–177. https://doi.org/10.1080/00219266.2000.9655714

Unger, S., Rollins, M., Tietz, A., & Dumais, H. (2020). iNaturalist as an engaging tool for identifying organisms in outdoor activities. *Journal of Biological Education*. Advance online publication. https://doi.org/10.1080/00219266.2020.1739114

Vinarski, M. V. (2020). Roots of the taxonomic impediment: Is the “integrativeness” a remedy? *Integrative Zoology*, *15*(1), 2-15. https://doi.org/10.1111/1749-4877.12393

Wandersee, J. H., & Schussler, E. E. (2001). Toward a theory of plant blindness. *Plant Science Bulletin, 47*(1), 2–9.

Wood, P. (2004). A dichotomous key for the identification of common British wild flower families. *Journal of Biological Education*, *38*(3), 125–126. https://doi.org/10.1080/00219266.2004.9655919