Classroom versus Outdoor Biology Education Using a Woody Species Identification Digital Dichotomous Key

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Abstract

The effectiveness of outdoor education in comparison to classroom (indoor) education and the acceptance of biology apps by students is still largely unknown. To bridge this gap, a quasi-experiment was performed with secondary school students within each of the schools. Students used a digital dichotomous key to identify woody species. One school performed outdoor identification and the other indoor identification. The students completed a pre-test and post-test on botanical knowledge, and they completed questionnaires about their attitudes toward the key and their attitudes toward biology and learning. The identification of plants with the app proved to be successful in promoting learning regardless of the learning scenario. The comparable results of the indoor and outdoor tasks indicate that the app itself is effective for learning about plants. There were no significant gender-related differences in knowledge results and opinions about the usefulness of biological keys. The key was very well accepted by students and it has proven to be an effective, interesting, and convenient learning tool for identifying organisms that allows experiential learning and learning about biology during the identification process.

Core Ideas

- The digital identification key proved to be successful in promoting learning, regardless of the learning scenario.
- Students who gained better results on the tests also had a better opinion about the app and its usefulness for learning about organisms.
- No major gender-related differences were found in attitudes toward the use of this app and in knowledge.

Educational technologies have greatly transformed the outcomes of the teaching and learning experience in classrooms (Chen et al., 2008; Kubiak and Halaiková, 2009). The use of mobile learning (m-learning) in education and training has proved useful in several studies (Ahmed and Parsons, 2013; Chinyamurindi and Louw, 2010; Chu et al., 2010; Farrokhnia and Esmailpour, 2010; Huang et al., 2010; Kamarainen et al., 2013; Rogers et al., 2010). It was also shown to successfully bridge the gap between school-specific digital tools and everyday digital tools, as well as between formal and informal learning (Looi et al., 2009; Rau et al., 2008; Santos et al., 2014). The advantages, disadvantages, and opportunities for using these tools were reviewed by Cheon et al. (2012), Hashemi et al. (2011), and Perbawaningsih (2013). The most important advantages are further opportunities for outdoor learning, improving collaboration among users, and the motivational effect of working with apps. Among the disadvantages that researchers mentioned were limited storage, battery capacities, and problems with signal strength. Several researchers emphasized that if one wants information and communication technology (ICT) to yield positive benefits, it is necessary to have appropriate attitudes and materials (Perbawaningsih, 2013).

The use of ICT is traditionally seen as antagonistic to experiential learning in nature, especially because it has so far kept participants from directly experiencing the natural environment (Shultis, 2001). Learning only in virtual environments is partly responsible for alienation from nature (Van Velsor, 2004) because simulations and presentations cannot replace the comprehensive experiences that can be obtained in natural environments (Evans et al., 2007; Patrick and Tunnicliffe, 2011; Prokop et al., 2007; Spicer and Stratford, 2001). Consequently, in many countries the general public has a low level of awareness about local environmental issues, a poor understanding of ecosystems, and a general lack of care and apathy toward the environment (Evans et al., 2007). On the other hand, appropriate use of computers and ICT can improve attitudes toward biology and the natural sciences (Fančovičová and Prokop, 2008; Kubiak and Halaiková,

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Abbreviations: ANCOVA, analysis of covariance; e-learning, electronic learning; ICT, information and communication technology; IE, indoor experiment; OE, outdoor experiment; m-learning, mobile learning; SiIT project, School-oriented Interactive Identification Tools project; SPSS, Statistical Package for the Social Sciences.

2009; Soyibo and Hudson, 2000) and can improve the quality of biology education (El Asli et al., 2012). Various apps already exist for courses on environmental science (e.g., Iancu, 2015; Kamarainen et al., 2013) and for botany courses. One example is a mobile location-aware learning system in which questions guide the students to observe and recognize features of plants on a school campus (Chu et al., 2008).

M-learning has an important advantage over traditional ICT methods. It offers digital data and apps that can be applied outside of the traditional learning environment (Chinyamurindi and Louw, 2010). This offers new learning opportunities for bridging the distance between virtual tools and experiences in nature (Ruchter et al., 2010). The use of mobile devices offers different learning experiences and different possibilities (Ahmed and Parsons, 2013; Ozdamli and Cavus, 2011; Rogers et al., 2010) that can help pair the benefits of computer-mediated digital learning with direct experiences in the natural environment (Ruchter et al., 2010), which are both required to understand the world (Kant, 1993). The combination of active, participatory, collaborative learning methods and outdoor experiences results in improved biodiversity knowledge and attitudes (Fančovičová and Prokop, 2011; Kamarainen et al., 2013; Prokop et al., 2007; Rogers et al., 2005; Schaal et al., 2012). Through the combination of real-world and digital-world learning resources (Chu et al., 2010; Kolb, 1984; Rogers et al., 2005; Vogel et al., 2010), learning can become active, more like continuous research than a body of facts (Kubiatko and Halaiková, 2009; Lee, 2013). It can successfully introduce students to scientific thinking (Ahmed and Parsons, 2013) and improve scientific literacy (Patrick and Tunnicliffe, 2011). Biology courses become more attractive, and they result in students significantly improving their knowledge of plants and their attitudes toward them (Fančovičová and Prokop, 2011; Huang et al., 2010; Rogers et al., 2005).

Plants are less attractive than animals and they are essentially neglected in the classroom (Tunnicliffe and Reiss, 2000), despite their decline and despite the fact that they are very important because of their numerous ecological functions (Patrick and Tunnicliffe, 2011). Studies have revealed low levels of specific plant knowledge, especially for wild plants (Bebbington, 2005; Cooper, 2008; Fančovičová and Prokop, 2011; Wagner, 2008). In Slovenia and in many other countries (e.g., Huang et al., 2010), the study of plants in schools is mostly confined to the classroom. The lack of opportunities to study organisms in their natural environment and to apply classroom knowledge outdoors further limits students' interest in botany. However, studies that compare outdoor and indoor teaching experiences are extremely rare (e.g., Chrouser, 1975).

Attractive approaches are required to motivate students and to integrate people to engage in lifelong learning. The acceptance of e-learning (electronic learning) is mostly dependent on two parameters: perceived usefulness and perceived ease of use (Chinyamurindi and Louw, 2010). Both of these aspects determine opportunities to use these apps in formal and informal education.

The majority of previous studies found that males have more positive attitudes toward the use of computers and ICT than females, and that they are more skillful at using them (Evans et al., 2002; Fančovičová and Prokop, 2008;

Johnson and Wardlow, 2004; Kubiatko and Halaiková, 2009; Ong and Lai, 2006; Plumm, 2008; Volman, 1997). Some studies have also found women to be equally interested (Fančovičová and Prokop, 2008; Johnson and Wardlow, 2004; Mizrachi and Shoham, 2004; Teo, 2006) or even more interested (Chinyamurindi and Louw, 2010) in technology-based training than males. There were important differences between cultures (Evans et al., 2002; Johnson and Wardlow, 2004), but computer self-efficacy and perceived ease of use were found to be more salient for females, whereas perceived usefulness was a salient factor for males (Ong and Lai, 2006). On the other hand, many studies showed that females generally show a higher interest in biology (Ekici, 2010; Jones et al., 2000; Uitto et al., 2006). Some studies noted that girls know more about plants and like them more compared with boys (Prokop et al., 2007), whereas others were not able to detect such differences (Fančovičová and Prokop, 2010, 2011; Lindemann-Matthies, 2005). Some studies found no gender differences in the interest in biology (Uşak et al., 2009).

The main aim was to determine the effectiveness of outdoor education in comparison to classroom (indoor) education in teaching secondary school students about woody plants by using a woody species digital identification key. Students' knowledge of woody plants was analyzed before and after the identification of plants. Gender- and attitude-related differences in knowledge were also studied.

METHODOLOGY

Participants

The research was conducted with second- and third-year students from two high schools in western Slovenia. The distance between the schools is 6.5 km. A total of 165 students participated in the study. The sample included 43% male and 57% female students. The students' average age was 16 (range: 15–18). All of the students had already been exposed to the structure and function of plants and plant taxonomy during their biology classes.

Procedure

A quasi-experiment was performed in a biology class. Students used the digital dichotomous key "Interactive Guide to Indigenous and Introduced Woody Plants of Slovenia" (Nimis et al., 2008; Fig. 1), which was developed within the project "Key to Nature" (<http://www.keytonature.eu/>). The quasi-experiment was performed with two schools that expressed their willingness to collaborate. In the first school, indoor activity was performed. In the second school, the activity was performed outdoors during field activities. The acquisition and the quality of information acquired were tested through pre- and post-tests of students' knowledge. The acquisition of key information by the students and their attitudes toward learning and biology were tested using questionnaires designed for the students. The applicability of teaching was tested through our observations.

Students first completed a 10-minute pre-test. In the test students had to answer six open-ended and multiple-choice questions that were related to the characteristics of woody species (i.e., leaves and fruits) and to their taxonomy. The identification of selected plants was performed by pairs of students (in a few cases, also

Fig. 1. Example page from the app: identification key (Slovenian version).

individually or in groups of three). Each pair had a portable or tablet computer with an uploaded app, without an internet connection.

A total of 102 students from the first school identified woody species in a classroom using portable computers. They had to identify five pre-selected woody plants. For identification purposes, they were given 30- to 50-cm branches with fruits or seeds, which were necessary for the identification. Sixty-three students from the second school had their botany lecture outdoors, during their natural science field trip on the karst Kovk Plateau. The same protocol was used. They were working on 10-inch Yarvik Gotab tablet computers.

First, the process of identification with the key was briefly introduced. It was explained to the students that they would use a digital dichotomous key, at each step of which they had to choose one of two arguments. A trial was performed, showing them the first two steps in the key to get a better idea of how the app worked. During the identification of the first sample, the author(s) helped the students, if necessary, by drawing their attention to overlooked characteristics. The students had 30 minutes to identify 5 woody species: white cedar (*Thuja occidentalis* L.), yew (*Taxus baccata* L.), black locust (*Robinia pseudoacacia* L.), European ash (*Fraxinus*

excelsior L.) or manna ash (*Fraxinus ornus* L.), and small-leaved lime (*Tilia cordata* Mill.).

Every time a pair of students identified the plant, they wrote its name on the worksheet and they were given the next plant sample. Pairs did not cooperate with each other. During the identification we observed the group dynamics, their ability to observe plants, and their ability to use the identification key. Observations were recorded on the observation list.

The identification was immediately followed by a post-test and a questionnaire. A five-point Likert-type questionnaire (Likert, 1932) was used to investigate students' approach to learning, biology, and the key. The questionnaire was composed of two parts. First, questions were related to biology and learning. The second part of the questionnaire asked about their attitude toward the key: if they felt that the key had helped them observe plants better, and find additional information about plants, their characteristics, scientific names, taxonomy, and diversity. All tests and questionnaires are in Slovenian and are available on request.

Data Analysis

Data entry and analysis were conducted using the Statistical Package for the Social Sciences (SPSS). Basic descriptive statistics were used to obtain the average values and frequencies of students' ratings and responses. The inferential statistical methods used were a one-way between-groups analysis of covariance (ANCOVA), the Spearman rank order correlation, and the Mann-Whitney *U* test. ANCOVA was used to compare post-test knowledge scores between the two experiences (indoor, outdoors). Correlations between students' pre-test and post-test scores and their opinions about the usefulness of biological keys were investigated using the Spearman rank order correlation coefficient. The Mann-Whitney *U* test was applied to compare students' pre-test and post-test scores by gender. It is a nonparametric test of the null hypothesis and does not require the assumption of normal distributions. Students' motivation to learn biology was investigated for males vs. females using the Mann-Whitney *U* test.

RESULTS AND DISCUSSION

On average, students showed 15.5% better results on the post-test than on the pre-test (15.8% in the indoor experiment [IE] and 15.0% in the outdoor experiment [OE]; Fig. 2), indicating an increase in knowledge due to the use of an identification key. The increase in knowledge on the post-test is consistent with the findings by Ruchter et al. (2010). After adjusting for pre-test scores, a one-way between-groups analysis of covariance found no significant difference between the two experiences on post-test knowledge scores ($F(1, 162) = 0.26, p = 0.61$, partial eta squared = 0.002; Fig. 2). The relationship between the pre-test and post-test scores is indicated by a partial eta squared value of 0.22. The results on post-tests show that

there was no significant difference between the indoor and outdoor learning experiences.

Results reveal that the app itself is easy to use and has powerful explanatory and illustrative power for learning new information about plants, their properties, and their names. It leads its users through guided observation in which samples of plants (branches) are also sufficient for learning. Further research will be required to reveal the effectiveness of this app in ecological learning and its ability to decrease students' alienation from nature. The results confirm the findings of Akpan and Andre (1999) and Spicer and Stratford (2001), who demonstrated that the use of a virtual environment and concrete experience can be successful in learning new information.

Analysis of responses to individual test questions (Table 1) showed that students learned the most about the characteristics of woody species (e.g., the shape of leaves, thorns, and fruits) and they learned more scientific names of woody species. Analysis also revealed that students of indoor and outdoor groups showed different levels of knowledge to some test questions in pre-tests and post-tests. However, the overall test results were comparable (Fig. 2). There was a substantial increase in the number of correctly listed tree species with serrated leaf margins. Altogether, the number of species mentioned increased from 29 to 31 and the number of incorrect answers decreased on the post-test. Number of correct answers increased in the question asking students to mark pictures with opposite leaves. However, some students were distracted by the arrangement of leaflets (e.g., black locust). They did not distinguish between leaves and leaflets, and the key was not able to clarify this concept.

Observations showed that the students preferred to work alone, without a teacher's help, even when faced with such issues. This suggests that the key should be improved with

Fig. 2. Comparison of points achieved on pre-test and post-test for both experiences.

Table 1. Students' responses to individual test questions before and after the intervention.

Test questions (correct answers are underlined) for pre-test, post-test, IE, OE		Test score			
		0 points	1 point	2 points	3 points
		%			
1. Draw an example of a compound plant leaf. (<u>many correct answers</u>)	pre-test	72.1	27.9		
	post-test	47.3	52.7		
	pre-test* IE	59.1	40.2		
	pre-test* OE	91.1	7.9		
	post-test* IE	23.5	76.5		
	post-test* OE	85.7	14.3		
2. Name an example of a plant species with compound plant leaves. (<u>many correct answers</u>)	pre-test	76.8	23.2		
	post-test	59.0	40.6		
	pre-test* IE	70.6	29.4		
	pre-test* OE	87.1	12.9		
	post-test* IE	45.1	54.9		
	post-test* OE	82.9	17.5		
3. Name three wooden species with serrated leaf margins. (<u>many correct answers</u>)	pre-test	18.8	30.9	13.9	36.4
	post-test	3.6	27.9	9.7	58.8
	pre-test* IE	10.8	30.4	12.7	46.1
	pre-test* OE	31.7	31.7	15.9	20.6
	post-test* IE	4.8	39.7	9.5	46.0
	post-test* OE	2.9	20.6	8.8	66.7
4. Which of the following five plants pictured have an opposite arrangement of leaves on the stem? (<u>a. field maple</u> , <u>b. alder buckhorn</u> , <u>c. guelder-rose</u> , <u>d. black locust</u> , <u>e. field elm</u>)	pre-test	74.5	21.8	3.6	
	post-test	37.0	49.7	13.3	
	pre-test* IE	82.4	17.6	0.0	
	pre-test* OE	61.9	28.6	9.5	
	post-test* IE	51.0	49.0	0.0	
	post-test* OE	14.3	50.8	34.9	
5. Horse-chestnut has simple/ <u>compound</u> plant leaves.	pre-test	59.8	40.2		
	post-test	51.5	48.5		
	pre-test* IE	35.3	64.7		
	pre-test* OE	100.0	0.0		
	post-test* IE	22.5	77.5		
	post-test* OE	98.4	1.6		
6. Plants with thorns or spins are... (<u>a. raspberry</u> , <u>b. blackberry</u> , <u>c. black locust</u> , <u>d. all three answers are correct</u>).	pre-test	43.3	41.5	9.8	5.5
	post-test	22.4	57.6	12.7	7.3
	pre-test* IE	64.7	35.3	0.0	0.0
	pre-test* OE	8.1	51.6	25.8	14.5
	post-test* IE	36.3	63.7	0.0	0.0
	post-test* OE	0.0	47.6	33.3	19.0
7. Whose fruit is on the picture? (<u>a. common beech</u> , <u>b. manna ash</u> , <u>c. sycamore maple</u> , <u>d. small-leaved lime</u>)	pre-test	51.8	48.2		
	post-test	31.5	68.5		
	pre-test* IE	50.0	50.0		
	pre-test* OE	54.8	45.2		
	post-test* IE	30.4	69.6		
	post-test* OE	33.3	66.7		
8. Which of the following plants are trees? (<u>a. yew</u> , <u>b. oak</u> , <u>c. hazel</u> , <u>d. ivy</u>)	pre-test	44.8	43.6	11.5	
	post-test	41.8	49.1	9.1	
	pre-test* IE	57.8	42.2	0.0	
	pre-test* OE	23.8	46.0	30.2	
	post-test* IE	49.0	51.0	0.0	
	post-test* OE	30.2	46.0	23.8	

Table 2. Correlations between the variables pre-test score and post-test score and questionnaire questions.

Questions		Pre-test score	Post-test score
By using the keys, I develop precise observation skills; I recognize similarities and differences.	r_s	0.071	0.064
	p	0.370	0.419
	n	160	160
By using the keys, I easily remember the names of animals and plants.	r_s	0.182	0.182
	p	0.022[†]	0.022
	n	159	159
By using the keys, I not only learn about the names of organisms, but also about features of groups (e.g., genus, family, species).	r_s	0.186	0.103
	p	0.019	0.195
	n	159	159
While identifying an organism, I easily track the text in the key, so I easily recognize the feature that is described by the text.	r_s	0.268	0.172
	p	0.001	0.030
	n	159	159
By using the keys, I improved my ability to perform basic natural processes (sorting, editing, arranging).	r_s	0.139	0.083
	p	0.080	0.301
	n	159	159
By using the keys, I became aware of the diversity of organisms that live in the wild.	r_s	0.171	-0.035
	p	0.031	0.661
	n	159	159
I like using the keys, because they help me become familiar with plants and animals.	r_s	0.193	0.072
	p	0.014	0.362
	n	160	160

[†] Bold represents statistically significant correlations.

explanations of all necessary characteristics important for identification. An example of possible improvement is the next generation of determination keys that were developed in the meantime within the SiIT project (School-oriented Interactive Identification Tools: exploring biodiversity in a cross-border area project; www.siit.eu). These "portals" include explanations of all characteristics (i.e., via the "i" button for information at http://dryades.units.it/rosandra_en/index.php?procedure=search).

There were small, positive correlations between the variables pre-test score ($r_s = 0.18$, $n = 159$, $p = 0.022$) and post-test score ($r_s = 0.18$, $n = 159$, $p = 0.022$), and the opinion about the usefulness of biological keys for learning names of animals and plants. The pre-test score showed a small, positive correlation with the opinion about the usefulness of biological keys for group characteristics (e.g., family, order, and genus; $r_s = 0.19$, $n = 159$, $p = 0.019$). There were small, positive correlations between the variable pre-test score ($r_s = 0.27$, $n = 159$, $p = 0.001$) and post-test score ($r_s = 0.17$, $n = 159$, $p = 0.030$) and the opinion about text simplicity and comprehension in the biological keys for determining organisms. There was a small, positive correlation between the variables pre-test score and post-test score and the usefulness of biological keys for raising awareness about species diversity ($r_s = 0.17$, $n = 159$, $p = 0.031$). Students who liked using biological keys for becoming familiar with animals and plants had a better pre-test score ($r_s = 0.19$, $n = 160$, $p = 0.014$). Other correlations between variables presented in Table 2 were not significant. Spearman's rank order correlations between students' pre-test and post-test scores and their motivation for studying biology were also investigated. There were no significant correlations between variables.

These results indicate that students who gained better results on the tests also had a better opinion about the app

and its usefulness for learning about organisms. Because the results were not related to learning motivation, it can be concluded that the key was similarly useful for all students.

Female students ($M = 4.80$, $SD = 1.81$) achieved lower scores on pre-test than male students ($M = 4.88$, $SD = 1.95$) (Fig. 3). Similarly, female students ($M = 6.87$, $SD = 2.10$) achieved lower scores on post-test than male students ($M = 6.72$, $SD = 1.75$). There were no statistically significant differences between males and females. The Mann-Whitney U test was also used to compare students' opinions about the usefulness of biological keys between males and females, and no significant differences were found. The results can be explained as equal acceptance of m-learning by both genders (Uzunboyly et al., 2009) and by a narrowing of the gap in attitude toward technology and biology between females and males (Amelink, 2009; Fančovičová and Prokop, 2008; Johnson and Wardlow, 2004; Prokop et al., 2007). The other possible explanation is that a better attitude of males toward technology (Kubiatko and Halaiková, 2009; Ong and Lai, 2006; Uzunboyly et al., 2009) was masked by a better attitude of females toward plants (Prokop et al., 2007). Females are often more familiar with plants (Ekici, 2010; Fančovičová and Prokop, 2011; Jones et al., 2000; Prokop et al., 2007) and technological tools are traditionally better accepted by males (Evans et al., 2002; Fančovičová and Prokop, 2008; Johnson and Wardlow, 2004; Kubiatko and Halaiková, 2009; Ong and Lai, 2006; Plumm, 2008; Volman, 1997).

Males ($M = 2.28$, $SD = 0.95$) were more supportive of a statement that they prefer to be left alone by others (e.g., parents and teachers) than females ($M = 1.94$, $SD = 0.86$; $Z = -2.39$, $p = 0.02$). Females ($M = 3.68$, $SD = 0.85$) were more motivated to understand the learning content than males ($M = 3.34$, $SD = 0.89$; $Z = -2.36$, $p = 0.02$). Other correlations were not significant. Female students showed

Fig. 3. Comparison of points achieved on the pre-test and post-test by gender.

a greater intrinsic motivation, which is in agreement with other recent findings (Hakan and Münire, 2014; Lee and Kim, 2014; Meece and Holt, 1993; Negovan et al., 2015). Intrinsically motivated learners achieve better results on knowledge tests and have a highly positive learning self-concept (Sarwat Mubeen and Arif, 2013).

Observations made during the identification revealed that students participated equally within pairs. Both students examined the plants and they both read statements in the key. When the statements in the identification key included more distinctive points, the students often considered only the first or the second one. They were highly motivated to make an identification, especially after the first correct identification of plants. Further research will be required to reveal if digital dichotomous keys are in any way better than traditional (paper-based) dichotomous keys. First observations reveal that using a digital platform (m-technology) eases and speeds-up the determination process. However, the quality and retention of knowledge gained in traditional vs. digital ways needs to be further studied.

CONCLUSIONS

Learning is any change in behavior, knowledge, understanding, preferences, values, skills, or abilities that cannot be attributed to natural growth or to development of inherited behavior patterns (UNESCO/ISCED, 1993). However, not all learning is equally successful. Our findings show that the use of a digital dichotomous key for identifying woody plants was successful in improving students' knowledge of woody plants in both indoor and outdoor experiences. While using the key, the user has to actively learn. Meaning, that according to (transformative) learning theory (Mezirow, 1991) we interpret our experiences in our

own way, and how we see the world (e.g., woody species) is a result of our perception of experiences. Use of digital dichotomous keys, which are already widely accessible, helps in this process of examining, questioning, and revising those perceptions. Students who gained better results on the tests also had a better opinion about the app and its usefulness for learning about organisms. No gender-related differences were found in attitudes toward the use of this app and in knowledge. However, males were more supportive of the statement that they prefer to be left alone by others, and females were more motivated to understand the learning content. There was no correlation between the level of knowledge and motivation.

In our future research we plan to focus on studying effectiveness of digital dichotomous keys vs. traditional (paper-based) dichotomous keys. We intend to include to research design two more groups of students using traditional (paper-based) dichotomous keys (i.e., outdoors group, classroom group) to make a comparison whether the app helps students learn more and better than traditional keys.

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