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DICHOTOMOUS KEYS IN THE BOTANICAL LEARNING OF NON-VISUAL (BLIND) PEOPLE

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Abstract. *Recently, the research about innovative approaches in the education of blind (non-visual- NV) students has intensified; however the use of dichotomous keys (DK) in their botanical education has not yet been examined. This research explored the contribution of two self-generated dichotomous keys (DK) for plant identification (a digital version- DDK and a printed version- DPK), to the botanical education of NV students. The research included 100 students, with an average age of 24, divided into 2 groups. Group E1 determined the plants using the DDK while in Group E2 plants were identified using the DPK. The DDK contributed more than the DPK in helping the NV participants to acquire the quality and durability knowledge they need to identify different plant groups (woody, bushy and herbaceous plants). The NV has the greatest success in the identification of woody plants, and the least success in the identification of herbaceous plants. The members of both groups (E1, E2) had possitive opinion about the contribution of the applicable dichotomous key to their knowledge, the activities in it. Due to this fact, both versions of DKs are recommended as new assistive tools in the botanical education of NV students.*
Keywords: *botanical education, plants identification, dichotomous keys, non-visual people, quasi-experimental design.*

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Introduction

The report by the World Health Organization, "Universal Eye Health", highlights the need for more intensive research in order to improve the quality of life and education of NV people (WHO, 2013). The fact is that only a small number of NV people (i.e. people born without sight and taught without visual references in school) are provided with a contemporary education, as it requires significant material resources (Hashemi et al., 2017; Livingston, McCarty, & Taylor 1997; Lamichhane, 2016, 2017). Education in the field of Natural Sciences is one of the main challenges in the education of NV people (Fraser & Maguvhe, 2008). Across a large number of studies, it has been concluded that with the help of assistive educational technology, NV students can achieve the same quality of knowledge in different natural sciences as students who have no visual impairment (Freire, Linhalis, Bianchini, Fortes, & Pimental, 2010; Rice, Aburizaiza, Jacobson, Shore, & Paez, 2012).

In the biological education of NV students, it is especially demanding to adapt the educational content in topics related to biodiversity, because so much of it is perceived visually. By contrast, the biodiversity education of NV students should be based on touch, hearing and smell (Smith, 1998; Smith, Polloway, Patton, & Dowdy, 1998). In the case of NV people, the absence of the visual sense is compensated for by the better development of other senses, primarily touch, hearing and smell (Morin-Parent, Beaumon, Théoret, & Lepag, 2017). Therefore, they acquaint themselves with their environment only partially, including in their approach to biodiversity. Research has shown that insufficient knowledge of biodiversity has the following consequences: the incomplete interaction of NV people with the environment; a negative impact on mental health and social skills, as well as limiting self-confidence (Binns et al., 2012). In order to mitigate these consequences, it is necessary to allow NV students to perceive their environment based on their available sensory experiences, insofar as it is possible.

The most common ways to educate NV people about biodiversity

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are the verbal-textual methods, the application of models and use of sensory gardens. Some researchers have pointed out that the acquisition of knowledge by the verbal-textual method causes verbalism in NV students. They interpret the content, but do not understand it because they have not adopted it through a sensory experience. They partially understand the concepts which explain the biodiversity surrounding them (Andersen, Dunlea, & Kekelis, 1993; Andersen, Dunlea, & Kekelis, 1984). By applying three-dimensional models in the teaching of NV people, the effects of verbal-textual methods are partially but not entirely removed.

Sensory gardens for NV learners are places which are specially adapted to NV visitors, through providing the maximum sensory stimulation, allowing them to encounter every part of garden by exploring them with their senses. One of the main aims of sensory gardens is the education of NV people and their preparation for task solving in everyday life. Through visits to sensory gardens, NV people are able to experience the richness of various tactile, fragrant and listening experiences, enabling them to explore, identify and understand their surroundings (Chawla & Heft, 2002; Mount & Cavet, 1995). The consequence is positive effects on the psychological and social well-being of the NV individual (Hussein, 2017). Söderback et al. (2004) pointed out that horticultural therapy and staying in nature increase the emotional, cognitive well-being, sensory functioning and the social inclusion of NV people. Due to the fact that sensory gardens are mostly concentrated in large cities and near major health rehabilitation centers, they are barely available to NV people who do not live in their immediate vicinity.

A review of the previous research indicated that the contribution of dichotomous keys (DK) for plant identification to knowledge on biodiversity has been tested only on students without any visual impairment. Recent studies (Anđić, Cvijetićanin, Maričić, & Stešević, 2018; Knight & Davies, 2014) have confirmed the positive contribution of DK to knowledge on biodiversity. Some researchers have suggested that NV students can achieve the same quality of knowledge in different natural sciences, as students who have no visual impairment (Freire et al., 2010; Rice et al., 2012), which forms the basic idea of this research. Thus, one question arises: If DKs make a positive contribution to the knowledge of people without visual impairment, will they also make a positive contribution to the environmental education of NV people when using the example of plants?

The aim of this research was to determine the relation between the contribution of the deliberately generated DKs and the quality and durability of the botanical knowledge of the NV participants, being needed for plant identification (recognizing and naming), as the basis for the sensory exploration of plants. In addition, within this aim, this research hoped to further determine the opinion of the NV participants on the impact of the applied DKs, thus it examined:

1. The similarities and differences in the quality and durability of NV knowledge in identifying plants from different groups (herbaceous, bushy and woody).
2. The opinions of NV participants on the contributions of the specific DK used to:
   - the knowledge they need to identify plants;
   - their desire to learn about plants from their surroundings and the wider environment;
   - the application of the acquired knowledge in everyday life;
   - the application of the acquired knowledge in the biodiversity education of the NV.

The basic hypothesis of this research was that both the generated DKs could be used as new assistive tools in the botanical education of NV students.

It was assumed that due to the use of educational software with speech technology in the DDK, the NV participants would acquire the better quality and longer-lasting knowledge that they need for the identification of plants, and that they would have a more positive opinion on its application, compared to those NV participants who learned using the DPK (a DK printed in Braille).

Research Methodology

General Background

The quasi-experimental design was used in the research. It was realized on the basis of an experiment with parallel groups over a period of 18 months (January 2017 to June 2018), and had two main focuses: 1) the contribution of the use of DKs to the quality and durability of the botanical knowledge of the NV participants; 2) the opinion of the NV participants about the applied DKs.

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Participants

The research included 100 NV participants whose median average age was 24, from Montenegro and Austria. The minimum sample size was determined by G* power program, following the inputs: one-tailed t test, the effect size of d = 80, desired power of .80, the error rate of .05. Results indicated that the minimum number of participants was 45 per group. The final size of the sample was determined on the basis of previous research that examined DK efficiency but which examined students and enthusiasts without visual impairment, and research in the field of the science education of NV students, as well as on the basis of the number of NV who wanted to voluntarily participate in the research and general recommendations for sample size in educational researches (Cohen, Manion, & Morrison, 2008). All the participants had a visual acuity of less than 3/60 and a narrowing of the field of view of 10° for their better visual eye (Yang et al., 2016). The demographic characteristics of the sample is presented in Table 1.

Table 1. Demographic characteristics of the sample (Total *N*=100).

Variables	Type	N	%
Gender	Male	57	57
	Female	43	43
Age (years)	Less than 7	1	1
	7-11	12	12
	11-15	14	14
	15-19	32	32
	19-25	10	10
	25-30	17	17
	30-40	5	5
	40-50	9	9

The NV were divided into two groups (E_1 and E_2), which were equal in the number of NV people (each group had 50 NV people), and which were based on the number of plant species that they could identify on the PRT.

Approval of and agreement for this research was provided by each institution from which NV participants were engaged, including schools, universities and societies. The institution managers and administrative staff, the parents of minor participants, and all the participants themselves were made familiar with the research and procedures within it. All participants were included on a voluntary basis. The anonymity of all participants and confidentiality were guaranteed. All participants were reminded of the guarantees regarding confidentiality and anonymity at every stage of the research process, and were sought permission to record questionnaires and use the questionnaire data.

Research Design

The research was divided into the following phases:

1. Questionnaire 1- semi-structured questionnaire in oral form (adapted to the NV) was used to examine the opinions of the NV participants about plant species that could be identified on the basis of the sensory perception of plants. Moreover, one aim of this questionnaire was to examine the way in which the NV participants had learnt about plants prior to their involvement in this research.
2. The level of prior botanical knowledge of each NV participant was assesed by using a non-standardised pre-test (PRT), which was based on the sensory perception and identification of fresh material of plant species listed in Questionnaire 1.
3. Descriptions of the morphological plant characteristics by NV participants – these descriptions were obtained by giving each NV student the fresh material of one plant species, to be used to examine the plant based on the senses of touch, smell and hearing. The NV participant then described all the reproductive and vegetative plant organs without being required to identify the plant species.

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The descriptions were recorded using an ICD-UX560 Dictaphone. On average, each NV participant took around 15 minutes to study the morphological characteristics of the one plant species, but the time for giving their description was not limited. Each NV participant gave a description of all one hundred plant species. This phase of the research lasted 9 months, because the species did not belong to the same aspect of flora. Some of them flower/produce reproductive structures in spring, some in summer, and some in autumn.

4. Selecting the morphological characteristic of plant for DK – in the creation of the DK, was only used the morphological characteristic of plants which were described by NV participants as the basis for sensory perception and which had a scientific relevance. To begin with, all the descriptions were transcribed and after that coded separately. The coding method used a grounded theory approach (Glaser & Strauss, 1967; Strauss & Corbin, 1990) and was similar to the coding method used in other studies in teaching biology to blind students (Fraser & Maguvhe, 2008). Codes with a frequency of greater than 85 (out of 100) were used to create the content of both DKs.
5. The creation of particular DKs (the DDK and the DPK) by using specific taxonomical markers (the morphological characteristics of plants) obtained in the previous phase of the research. The DDK was created using education software and speech technology, while the DPK was printed in Braille.
6. Formation of groups – The NV participants were divided into two groups (E_1 and E_2). The groups were equal according to NV knowledge on the PRT and in terms of the number of participants.
7. Implementation of DDK and DPK in plants determination - The determination lasted for three weeks, consisting of 8 periods of 60 minutes of teaching. Each NV participant independently determined the plants using the relevant DK and fresh plant species.
8. The opinion of the NV participant about the used DK – structured questionnaire (Questionnaire 2) in oral form (adapted to the NV) was asked with the aim of examining the opinion of the NV students on the DK which they used for plant determination. The intent was to examine the opinions of NV participants about the contribution of the applied DK to the knowledge they needed to identify plants; their motivation to learn about plants, and the opinions of the NV participants about the implementation of the DDK and the DPK in the botanical education of NV students.
9. The examination of the new knowledge of the NV participants – the new knowledge about plant identification was examined using a non-standardised post-test (POT). It was realized immediately after finishing the phases of the implementation of the DDK and the DPK in plant determination.
10. Knowledge durability of NV participants – this was examined through a non-standardised re-test (RET)- which was realized two months after finishing the phases of the implementation of the DDK and the DPK in plant determination.

Approach

In Group E_1, the NV identified plants using a DDK and in E_2 they used a DPK. Both groups performed the determination in a natural environment (parks and walking grounds). In the first round of determination, the researcher identified one species using the DK with each NV participant, in order to demonstrate to them the basic principle of the function of the DK that was used. After that, the NV received the fresh plant material of the next plant from the researcher and independently performed the determination using their specific assigned DK.

In determining, the plant species which have major morphological details and vegetative, reproductive organs were determined first, gradually shifting to smaller plant species. The accuracy of the determination was checked by the researcher. When a NV person accurately identified the plant, the researcher led them to a location where the plant grew in its natural habitat, so that the NV person could complete a mental image of the environment in which the plant species were growing.

Description of the DDK and the DPK

The DDK and the DPK were created by the researchers in three languages (English, German and Serbian) and had the exact same content (100 plant species from the environment of the NV participants). The one-hundred plant species were selected on the basis of the various plant species about which NV students learn at inclusive pre-university level in Austria and Montenegro, as well as the fact that a similar number of species was used in

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previous similar research with students and enthusiasts without visual impairments. The selected plant species grow in the environment of the NV participants in both Austria and Montenegro.

The keys hold the names of the plants which are used in everyday life, as well as their Latin names. In the DDK (Figure 1), educational software with speech technology was applied, while the DPK contents from the DDK were presented with the text in Braille. In both DKs, determination is performed on the same principle. The NV gradually turn from one claim to another. The claims describe the morphological characteristics of the given plant species, moving from the general to the specific characteristics of the plant. At the end of the determination, the NV are focused on a claim which summarizes the properties of the plant from the previous claims and designates the plant.

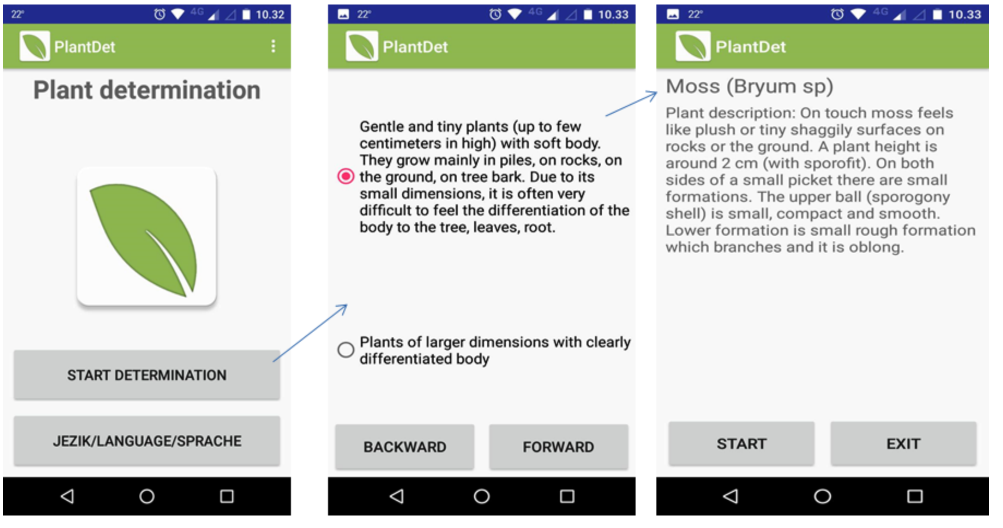

Figure 1. Example of simple determination through the DDK.

Research Instruments

A testing technique was used to analyze knowledge. Testing was carried out in the environment in which the NV were identifying the plants. On all tests, the NV were supposed to identify the plant species based on the sensory perception of fresh plant material. On the PRT, participants were supposed to identify only those plant species which most of the NV study group claimed that they were able to identify (four plants) in Questionnaire 1. Based on those responses, the PRT had four questions. The results of the PRT represented one of the criteria for equalizing the groups. The POT and the RET consisted of a total of 24 questions. Eight questions related to the identification of woody, eight dealt with shrubs and eight concerned herbaceous plants. On the POT and the RET, the participants were supposed to identify the same plant species from different groups of plants. In the selection of plants, we considered all the plants that the majority of NV participants had identified in Questionnaire 1 and those plants which are most common in the natural environment of the NV participants. The examination of the participants' knowledge was the same for all the tests, and was carried out according to the following principles:

- Every participant received one example of a fresh plant species, which was provided by the researchers. The NV participant was supposed to identify the plant species based on sensory exploring.
- On average, the NV participants took around 3 minutes to identify one plant species. The time allowed for the POT and the RET was two school classes (90 minutes) each. In this process, it was considered that all the NV participants had enough time for sensory plant identification. The PRT lasted only one school class.
- The NV participants answered in oral form. Their answers were checked by the researchers and they were written on the record sheet.
- Each answer provided by the NV participants was evaluated as either correct or incorrect because theywere only supposed to identify (name) the plants.

All the tests used in this research were non-standardized because of the lack of standardized test for testing

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the knowledge of NV people in terms of plants identification. Both questionnaires were in oral form adapted to the NV (Ratanasukon, Tongsomboon, Bhurayanontachai, & Jirarattanasopa, 2016). Questionnaire 1 had 10 items with 5 questions and it examined the way in which NV participants had learned about plants prior to the realization of this research, as well as the plant species that they could identify. Questionnaire 2 had twenty items and four blocks of questions (in total 16 question). In the first block of questions, opinions about the contribution of the applied DK to the quality of the knowledge needed to identify the plants on the part of the NV participant that was examined. In the second block of questions, their opinions about the activity in the applied DK were examined. In the third block of questions, their opinions about the impact of the applied DK on their motivation to learn about plants from their surroundings and beyond, as well as the impact of the knowledge acquired through the DK on their everyday life were examined. In the fourth block of questions, the NV were supposed to give their opinion on the possibility of using the DK in the further botanical education of other NV. The questions in Questionnaire 2 were open, ordinal (using the Likert scale of assessment) and combined in type. The Likert scale featured five points: (1 = I don't have an opinion, 2 = Disagree, 3 = Partially Disagree, 4 = Agree, 5= Agree Strongly). The questions were read to the NV participants as well as the available answers (to questions of an ordinal or combined type) and clarified if that was necessary. The NV participants answered the questions orally and the researchers wrote these on the record sheet.

Data Analysis

The contribution of the DDK and the DPK to the quality and durability of the knowledge of the NV in Groups E_1 and E_2 was measured based on the number of accurately identified plant species on the POT and the RET. The difference and similarity in knowledge between the groups on the PRT, POT, or RET, were obtained using a non-parametric Mann-Whitney *U* test and an independent t test. Also, the Mann-Whitney U test was used for analyzing differences in opinions among NV participants between Groups E_1 and E_2 on the questionnaire, the Kolmogorov-Smirnov and Shapiro-Wilk tests were used to test the normality of whether the obtained data on the three tests corresponded to a normal distribution. To determine the difference in knowledge between the POT and the RET within one group, the Wilcoxon test was used. The analysis of the questionnaire was performed by exploratory factor analysis, principal component analysis (the Barlett sphericity test and the Kaiser-Meyer-Olkin test -KMO) and Varimax rotation. The internal consistency of the factors in the questionnaire was computed using the Cronbach Alpha test (α).

Research Results

The results of Mann–Whitney *U* test, indicate (U = 2469.000; Z = -2.856; p = .936) that there was no statistically significant difference between the NV participants in Groups E_1 and E_2 in the claims about the method of learning about plants before the realization of this research. In Questionnaire 1, all the NV participants claimed that they rarely learned about plants on the basis of their personal sensory experience. The NV participants learned about plants from books (E_1: 53%, E_2 55%); from family / friends (E_1: 21%; E_2: 23%); from the media (E_1: 18%, E_2: 14%) and from personal experience (E_1: 8%; E_2: 7%).

The Knowledge of NV participants in terms of Identifying Plants before using the DDK and the DPK

Most NV (E_1: 90%; E_2: 92%) claimed that they could identify 4 plant species: the common daisy (*Bellis perennis* L.), the dandelion (*Taraxacum officinale* L.), the pine (*Pinus sp.*) and the platan (*Platanus sp.*). 17% of the NV in the whole sample correctly identified only one plant (*Pinus sp.*), while the other plants listed in Questionnaire 1 were not identified on the basis of the fresh plant material provided. The Mann-Whitney *U* nonparametric test found that there was no difference in the knowledge of the NV in Groups E_1 and E_2 in relation to the indicated plants (U = 3286.000; Z = -4.228; p = 1.717). This was confirmed by the independent t-test (t = 8.236; df =99; p = 1.336).

The Knowledge of NV participants in terms of Identifying Plants immediately after the application of the DDK and the DPK

The values of the Kolmogorov-Smirnov normality test and the Shapiro-Wilk test showed that the obtained data did not have a normal distribution (see Table 2).

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Table 2. Tests of normality of distribution in Groups E_1 and E_2 on the POT and the RET.

Test	Group	Kolmogorov-Smirnov			Shapiro-Wilk		
		D	*df*	*p*	*W*	*df*	*p*
POT	E1	.188	50	.002	.985	50	.002
	E2	.158	50	.002	.9623	50	.005
RET	E1	.189	50	.003	.915	50	.003
	E2	.123	50	.002	.948	50	.002

The difference in the knowledge of the NV participants between Groups E_1 and E_2 was used to determine the results as an independent t test. In Group E_1, the NV participants identified 21 out of 24 plant species, while in Group E_2, they identified exactly half (12 out of 24). The difference in the number of identified plants was as follows: 2 woody pants ($t = 3.971$; $df =99$; $p = .0001$); 3 shrubs ($t = 3.126$; $df =99$; $p = .0001$) and 4 herbaceous plants ($t = 4.023$; $df =99$; $p = .0001$). The NV in Group E1 were more successful in identifying the fir (*Abies alba* Mill.), the spruce (*Picea abies* (L.) Karst), the hawthorn (*Crataegus monogyna* Hawthorn), the yew (*Taxus baccata* L.), the oleander (*Nerium oleander* L.), the broadleaf plantain (*Plantago major* L.), the narrowleaf plantain (*Plantago lanceolata* L.), St John's-wort (*Hypericum perforatum* L.), and white clover (*Trifolium repens* L.).

The Knowledge of NV participants in terms of Identifying Plants two months after the application of the DDK and the DPK

Both the Kolmogorov-Smirnov normality test and the Shapiro-Wilk test, shown above in Table 2, demonstrated that the obtained data did not have a normal distribution. Group E_1 showed more durable knowledge and managed to identify 17 out of the 24 species. Group E_2 identified 8 out of 24 species. The differences in the number of identifiable plants between Groups E_1 and E_2 was as follows: 2 woody ($t = 3.759$; $df = 99$; $p = .0001$); 2 shrubs ($t = 4.823$; $df = 99$; $p = .0001$) and 5 herbaceous plants ($t = 4.129$; $df = 99$; $p = .0001$). The NV in Group E_1 were more successful in identifying the fir (*Abies alba* Mill.), the hornbeam (*Carpinus orientalis* Mill), the hawthorn (*Crataegus monogyna* Hawthorn), the yew (*Taxus baccata* L.), the broadleaf plantain (*Plantago major* L.), the narrowleaf plantain (*Plantago lanceolata* L.), St John's-wort (*Hypericum perforatum* L.), slag (*Malva sylvestris* L.), and white clover (*Trifolium repens* L.). The results of the Wilcoxon test, Table 3, show the existence of differences in the number of accurately identified plants from all groups of plants on the post-test and re-tests within Groups E_1 and E_2.

Table 3. The difference in the knowledge of the NV participants between the POT and the RET in each group, the Wilcoxon test.

	Group E1			Group E2		
	Willk λ	*F*	*p*	Willk λ	*F*	*p*
Woody	.745	.082	.017	.835	.071	.012
Shrubs	.972	.335	.014	.865	.224	.009
Herbaceous	.791	.213	.009	.887	.119	.018
Total	.795	.238	.019	.823	.158	.023

The Opinions of the NV participants about the Applied DKs

Exploratory factor analysis, principal component analysis (KMO = 740; Barlett sphericity test = 437.205; df = 66; $p = .000$) and Varimax rotation, demonstrated that there were four latent factors that explain 72.61% of total variance. For further analysis, four specific factors were taken: Factor 1: The opinion of the NV on the contribution

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of the applied DK to their knowledge, needed to identify the plants (that explain 19.62% of total variance); Factor 2: The opinion of the NV on the activity in the DK(that explain 18.15% of total variance); Factor 3: The opinion of the NV on the impact of the applied DK on their motivation to learn about plants and the importance of applying this knowledge in their daily lives (that explain 17.46% of total variance) and Factor 4: The opinion of the NV on the opportunities for using the DKs in their botanical education, (that explain 17.38% of total variance). The range, average values, dispersion of results and Cronbach Alpha coefficient by factors are presented in Table 4.

Table 4. Range, average values, dispersion of results and Cronbach Alpha coefficient by factors.

Factor	*N*	M_{min}	M_{max}	*M*	*SD*	*α*
The opinion of the NV participants on the contribution of the applied DK to their knowledge, needed to identify the plants	100	2	5	4.255	.682	.84
The opinion of the NV participants on the activity in the DK	100	1	5	3,561	.713	.81
The opinion of the NV participants on the impact of the applied DK on their motivation to learn about plants and the importance of applying this knowledge in their daily lives	100	1	5	3.228	.801	.81
The opinion of the NV participants on the opportunities for using the DKs in the botanical education of NV students	100	1	5	3.11	.905	.86

The difference in opinions among NV participants between Groups E_1 and E_2 was confirmed by the Mann-Whitney *U* test: the contribution of the applied DK to their knowledge, needed to identify the plants. ($U = 1726.000$; $Z = -4.255$; $p = .001$); activities in the DK ($U = 2044.000$; $Z = -5.111$; $p = .001$); the desire to learn about plants in the future using the DK ($U = 1768.000$; $Z = -4.052$; $p = .000$) and the implementation of the relevant DK in the botanical education of NV students ($U = 1556.000$; $Z = -3.859$; $p = .001$). The difference in the opinions of the NV participants in Group E_1 and Group E_2 was also confirmed by the percentage of NV participants who selected the option *I fully agree* in answering questions using the Likert scale, (Figure 2).

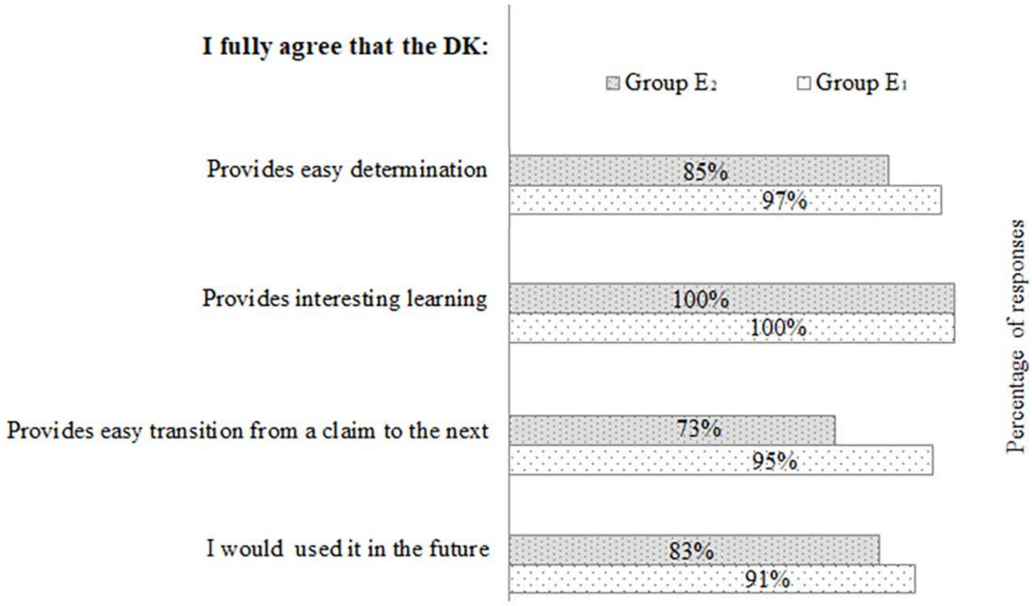

Figure 2. The difference between Groups E_1 and E_2 in the choice of the claim *I fully agree* on the impact of the DK.

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Discussion

The tactile sense of the NV individual was the primary source for the collection of information on the basis of which the plants were identified. In terms of the process among NV participants in the identification of plants, it can be concluded that identification does not begin by defining the shape and size of the plant, but rather with the sensations of touching. Using the example of the leaf, the first reported feature is the surface (bare, hairy, flaky rough or fine, very rough, and so on). Then they determined the firmness (soft, medium, hard plastic), thickness (thin, medium, thick), the nature of the edge of the leaf (unstressed, toothed, wavy) and finally its shape. The senses of smell and hearing helped them collect information to identify a small number of plants. Thus, for example, the sense of smell helps in the identification of aromatic plants rosemary and mother's thymus. Furthermore, Poison ivy (*Hedera helix* L.) was identified by the characteristic "blunt" sound of the fruits when touching.

Most NV could not identify any of the plant species they stated on the Questionnaire 1, based on fresh herbal material, before using the specifically generated DK. A small number of NV identified only one plant species (pine) from the group of woody plants. These data indicate that prior to the determination by means of the DDK and the DPK the NV (PRT) were primarily taught about the plants from the environment verbally, without sufficient sensory experience, which led to the appearance of verbalism (Greenaway & Dale, 2017). This assumption is in line with the responses received from the NV in the survey. Their main source of knowledge about plants was books, while the sensual (personal) experience had little influence.

Immediately after determining with the DDK and the DPK, the NV on average acquired the good knowledge they needed to identify the woody, or shrub plants, and significantly less knowledge for the identification of herbaceous plants. This can be explained by the grating orientation thresholds and its value of 0.96mm for NV (Alary et al., 2009). The morphological details of the woody and bushy plants are larger and beyond their threshold range, so that they heard the touch of the NV participants. The herbaceous plants are generally smaller in size, have finer morphological features comparing to woody and scaly plants. In both groups, most NV claim that the easiest to identify were plants of larger dimensions, and the most difficult plants of smaller dimensions, as well as plants that have similar structures.

A possible reason for the easier identification of the woody and shrubs plants is that the NV had heard most about these plant groups in their everyday life, but had not had the opportunity to investigate them. This probably caused internal motivation to experience them sensually and learn more about them. Most NV in both groups claim that during the determination they placed more attention and focused on the plants they had heard or read about because they wanted to find out more about them. The results obtained are in correlation with the research by Stagg and Donkin (2016) in which enthusiasts without visual impairment participated. In that research, for most enthusiasts, the woody plants were more engaging in terms of their determination by the generated DK, and relatively easy to identify. As one of the reasons for these results, these plants are more popular among enthusiasts than other plants.

Two months after the DDK and DPK determination, the NV participants, on average in both groups, achieved poorer results when identifying plants compared to the immediate POT. When comparing the quality of the knowledge of the NV related to the group of plants, it was noticed that the NV had forgotten some plant species from all the groups of plants. It is assumed that one of the reasons for forgetting is the effect of the active and passive forgetting process, as well as the non-repeating of plant content between the POT and the RET. The possible reason for the fact that some plant species were more quickly forgotten was that these plants did not leave powerful imagery ratings for the NV participants; they were not interesting, attractive during the determination process. This assumption is correlated with neuroscience studies that have examined long-term memory functions in NV. In these studies, it was concluded that there is no difference in the durability in memory between NV and those without visual impairment. NV memorize objects and environments that left them with a strong sensory rating for a longer period of time than those which left a weaker imagery rating, unless these imagery ratings are based on the visual sense (Beni & Cornoldi, 1988; Zimler & Keenan, 1983).

All the NV identified all the plant species listed in Questionnaire 1 on the POT and the RET, even though they could not identify them on the basis of fresh plant material on the PRT. On average, the NV were not successful on either the POT or the RET in the identification of similar plant species; for example, they confused the identification of the white clover (*Trifolium repens* L.) and the red clover (*Trifolium pratense* L.) as well as the

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species from the group of grasses. The small dimensions of these plants and similar structures probably caused the confusion of the NV during the identification. The sense of hearing and smell was not helpful in these cases, because both plants have neither a distinctive odor nor create a distinctive sound when touched. Similar research was undertaken by Stagg and Donkin (2016), which involved students with no visual impairments. The students who used the DK could not recognize similar plant species due to their low visibility.

In the opinion of most NV in both groups, both generated DKs contributed ("fully agree") to improving their knowledge of plants. They consider that the generated DK which they applied was an innovative way to learn about plants in the environment. The possible reason for unanimity in this answer is that the systematically explored the plants for the first time through the application of the relevant DK, which probably caused a positive opinion about DKs in general. With the generated DK the NV were enabled to replace verbal learning with research learning through the observation of plant species using their tactile, smell and hearing senses. The NV in both groups fully agreed with the claim that the generated DK which they used would be suitable for the botanical education of other NV. According to the opinion of the NV in Group E_1, the DDK could be easily be applied in the botanical education of NV students in elementary and secondary schools. The NV in Group E_2 considered that the DPK would be more successful in secondary education than in primary education.

The reason for the greater contribution of the DDK in comparison to the DPK to the knowledge of the NV needed to identify plants is probably the fact that DDK uses education software with speech technology. This made it possible for the NV in Group E_1 to actively communicate with the tablet through the right use of the touch screens, while listening to what they touched, flipping through the contents of the screen while listening, starting again from what they had heard last. This, among other things, made it possible for them to quickly determine the plants, unlike the NV participants in Group E_2, who had to read each claim in Braille. This is in correlation with the research by Cassia et al. (2009), in which it was concluded that the use of assistive technology and educational software contributed more to the quality of the knowledge of NV students and students in comparison to the traditional way of learning, in which the verbal-textual method dominates. Moving from one claim to another in the DDK was facilitated by a simple click that influenced concentration (Anđić et al., 2018) and allowed the NV in Group E_1 to focus on the tactile, auditory and smell senses while exploring the plant more than the NV in Group E_2 (Röder et al., 1999). These assumptions are in correlation with many studies in the field of neuroscience which have shown that NV encode auditory verbal material better than those without visual impairment, causing greater brain activity and better memory performance (Röder, Rösler, & Neville, 2001; Kujala, Alho, Paavialinen, Summala, & Näätänen, 1992). Given that the NV using it determined plants more quickly, the DDK indirectly causes the NV to receive faster feedback about the accuracy of their determination than the NV in Group E2, which makes it easier to correct errors in their determination process. Continuous feedback has a motivational impact, stimulating further activity in the determination process, which leads to the transformation of external to internal motivation (Csikszentmihalyi, Abuhamdeh, & Nakamura, 2005).

A possible reason for the better contribution of the DDK than the DPK is in the means of presenting the content and activities within the DK. The auditory presentation of the content made the DDK more attractive and engaging for the NV than a written presentation in the DPK. This assumption correlates with the differences in opinion of the NV in Groups E_1 and E_2. For most of the NV in Group E1, learning with the DDK was easy, interesting, and it would be relatively easy to use the DDK in learning, which is why they wanted to continue to learn about plants in the future. Most of the NV in Group E_2 claimed that their activities in the DPK were tiring after a short time and that their concentration deteriorated during the determination process. They would use the DPK to determine the plants in the future, but the determination would take a shorter time and include a longer break.

Most NV in both groups expressed the need to get to know as many plant species as possible in their immediate surroundings and further afield. Basically, for both groups, the reason for this is the desire for new knowledge, but also the curiosity of getting to know their surroundings, and also distant areas they have read or heard about. They consider ("I fully agree") that the applied generated DK helped them complete their mental picture of the landscape in their environment through the identification of plants, and that, based on listening to information on the plant species that grow in other environments; they could imagine other areas more clearly than before.

When asked "In what way does new knowledge about the plants contribute to your daily life?", most of the NV thought that based on plant identification it would be easier for them to find their way in parks and

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green areas, which made them feel safer, more independent and encouraged them to stay longer outdoors. This indicates that both generated DK can minimize the perception of environments as unfriendly from the side of NV, which is mostly caused by the lack of adaptable teaching and learning materials and negative attitudes towards them (Odame, Hwedie, Nketsia, Peprah, & Nanor, 2019). The obtained opinions of the NV participants are in correlation with the results of the research by Söderback et al. (2004) and Johnson (2012), in which they examined the influence of the sensory garden and gardening on the everyday life of their NV study group and concluded that gardening and plant exploring encourages individualistic and idiosyncratic creativity and thinking while offering diverse learning skills that enhance both land management at the domestic level and environmental interaction.

Conclusions and Implications

This research represents a pioneer study exploring the implementation of the generated DKs in the botanical education of NV students. Both the generated DKs (the DDK and the DPK) are potentially innovative assistive tools in the botanical education of NV students because they contributed to their knowledge in identifying all the plants species that they could not identify previously, before using the generated DK. The NV participants considered that both the generated DKs had helped them to acquire new knowledge that would help them to more easily orient themselves and feel safer when they are outdoors. The contribution of the DDK and the DPK to the quality and durability of NV participant knowledge needed to identify different groups of plants (woody, bushy and herbaceous) was unequal. The way the content was presented to the NV groups in the generated DK, the DK design, the activities in it, the speed of determination by using the DK, and the speed of obtaining feedback on the accuracy of the determination not only affect the quality and durability of NV knowledge, but also the desire (motivation) of NV participants to investigate the plants in their surroundings and the wider environment by using a DK. Therefore, in the botanical education of NV students, priority should be given to the DDK as compared to the DPK. The way of learning for NV participants, using both the generated DK alongside the parallel sensory research of plants on fresh plant species might be used as a new form of explicit instruction, but it could also be used in creating implicit instructions to help NV students determine and learn about plants. It is necessary to significantly increase the extent of the research in this area in order to confirm these claims. In this way, such research would contribute to the adaptation of botanical content to the needs of NV people and to innovation in biology education for NV students.

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