On Enhancing Disabled Students' Accessibility in Environmental Education Using ICT: The *MusicPaint* Case

Sofia J. Hadjileontiadou[1], Erasmia Plastra[2], Kostantinos Toumpas[3], Katerina Kyprioti[3], Dimitrios Mandiliotis[3], João Barroso[4], and Leontios J. Hadjileontiadis[3,*]

[1] Tutor at Hellenic Open University, Katakouzinou 58A 68100 Alexandroupolis, Greece
shadjileontiadou@gmail.com
[2] MEd EEEK Komotini Vrioulon 8, 69100 Komotini, Greece
isminie.p@gmail.com
[3] Department of Electrical and Computer Engineering, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece
{ktoumpas,kiaikate,leontios}@auth.gr, dimandili@gmail.com
[4] Dept. of Electrical Engineering, Universidade de Trás-os-Montes e Alto Douro (UTAD), 5001-801 Vila Real, Portugal
jbarroso@utad.pt

Abstract. This work draws upon the theoretical foundations of Special Education for People with Disability, Environmental Education and the Human Computer Interaction (HCI), from the Activity Theory perspective, to propose the *MusicPaint* software. Initially, the design considerations of *MusicPaint* are presented. Then, its pilot use by seven students with disability is described. From the qualitative and quantitative evidence of performance that was gathered, the key findings are presented and discussed. Despite the limited number of participants in the experimental validation scenarios, the findings reveal the potentiality of the *MusicPaint* to enhance the accessibility of students with disability to Environmental Education opportunities, contributing to the HCI-based enhancement of accessibility in the educational settings.

Keywords: Students with Disability, Special Education, Environmental Education, ICT, MusicPaint, Human-Computer Interaction, Didactical Instruction, Activity Theory.

1 Introduction

The evolution of society and change attitudes towards disability has led to the transition from the medical model, where the concept of disability is identical with that of the illness and interventions implemented are intended to provide the individual skills for restoration [1], to the social model created in Great Britain in the '70s with the

* Corresponding author.

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establishment of the Association of Physically Disabled against segregation (Union of the Physically Impaired against Segregation, UPIAS). In this vein, the environmental education gains its ground as it aims at the reconciliation of society with nature and between man and man for a sustainable development. A development that would destroy the balance of natural systems on the planet, covering the needs of the present, but not at the expense of future generations and ensuring ecological sustainability and social justice [2]. In recent years, developments both on the rights of persons with disabilities and in the field of environmental education is great. The marginalization of the disabled has been replaced by the principles of inclusion and inclusive education. In the context of integrating both the environmental education and education for students with disability (SwD) can be the means to achieve the cooperation of the people, the exemption from prejudice and changing attitudes that consider human master of nature and the "different" threat [3]. One of the basic problem in the environmental education is linking theory with practice. This is even worse in the cases of SwD, such as those with Moderate mental retardation. The latter have difficulty in abstract ability and symbolism; hence, they need specific examples, detailed descriptions and images to understand the symbolic meanings [4].

The conjunction of the technological evolution with the struggle of people with disabilities for autonomous and socially integrated educational experiences, set the horizon of new technological challenges and new research endeavors. Within this framework, theoretical insights to the Human-Computer Interaction (HCI) issue evolve through time, moving from the “first-wave HCI” (i.e., employing a perspective of cognitivist, information processing psychology) to the “second-wave HCI” (i.e., employing a perspective of context that includes motivation, meanings, culture, and social interactions) [5]. Among "second-wave HCI" theories, such as phenomenology [6] and distributed cognition [7], the Activity Theory (AT) was introduced to HCI [8]. It provided a theoretical insight to the analysis of the interaction with technology by considering the computer as a mediating artefact rather than an object and relating the operational aspects of the interaction with technology to meaningful goals and, ultimately, needs and motives of technology users [9].

The current paper places efforts upon the combination of the educational areas of Environmental and Special Education by employing a HCI design, influenced by AT basic principles and materialized in the form of a specially designed software, namely MusicPaint. Empirical uses of the latter provide evidence of the potentiality of the proposed design, as presented in the next sections.

2 Background

2.1 Special Education of Students with Mild and Moderate Mental Retardation and Disabilities

According to [10], disability is defined as any restriction or lack (resulting from an impairment) of ability to perform an activity in the manner, or within the range, considered to be normal for human being. The term disability reflects the consequences of impairment in terms of functional performance and activity by the individual. Disabilities thus represent disturbances at the level of the person.

The Procedure for determining the level of retardation, as proposed by the [11], includes the following steps:

1. Recognize that a problem exists (e.g., delay in developmental milestones),
2. Determine that an adaptive behavior deficit exists,
3. Determine measured general intellectual functioning,
4. 'Make decision about whether or not there is retardation of intellectual functioning,
5. Make decision about level of retardation as indicated by level of measured intellectual functioning ([11], p.13). More specifically, a classification of the levels of retardation indicated by IQ range obtained on measure of general intellectual functioning, includes
   (a) Mild mental retardation (50-55 to approx. 70),
   (b) Moderate mental retardation (35-40 to 50-55),
   (c) Severe mental retardation (20-25 to 35-40), and
   (d) Profound mental retardation (below 20 or 25) [11].

Students with mental retardation problems face difficulties to include deficiencies in academic achievement, information-processing problems, attentional deficits, hyperactivity, uneven patterns of learning performance, and difficulties in social relationships. Since the latter have been noted especially in interactions with peers and teachers, these difficulties could stem from reactions to academic frustration and failure [11]. However, students with Mild mental retardation can understand elementary school level knowledge, perform social adaptation that enables them to perform autonomously and can be trained in a profession. Students with Moderate mental retardation are able to achieve basic school skills, some level of social responsibility, adaptation to the housework, collaboration and respect to the human rights. Moreover, they may be able to work in a protected, simple workplace after receiving training, e.g., in Special Vocational Schools, where they receive specially designed intensive instruction referring to adaptations of content, methodology, or delivery to meet students' needs. It must ensure effective learning through goal-directed instruction, achieve maximum benefits with individualization and validation, and set special education apart through intensive, explicit support [12]. More specifically, the work of [13] provided highlights of research on explicit (direct) instruction, which leaves nothing to chance; all skills are taught directly. A typical direct instruction lesson includes:

(a) explicit and carefully sequenced instruction provided by the teacher (a model of what students will do),
(b) scaffolding to provide students the assistance they need before being able to complete the task on their own (guided practice),
(c) frequent opportunities for students to practice skills (independent practice), and
(d) repeated practice over time (review).

2.2 The Concept of 'the Water Cycle'

Although 'the water cycle' is a subject matter that is contained in most curricula around the world, perceptions of students about it are fragmented [14] and students do not realize its important role in life [15]. Research on perceptions of 1.000 students from 13 to 15 years old, revealed that most students find it difficult to understand the change of matter (water), to link school-knowledge concerning 'the water cycle' with their daily lives and to realize the connection of atmospheric and underground water [15]. Moreover, their finding that students consider the underground water as a static one is verified by [16]. Through empirical research with students of 8-17 years old, researchers of [17] concluded that students generally do not understand the phase changes of water, with older children being able to understand evaporation, but no liquefaction. Research with students of 10 to 15 years revealed that [18]:

(a) students 5-7 years old believe that clouds are made of tobacco or cotton and the rain falls when someone, maybe God, opens the water supply. Some students believe that clouds are bags of water and when it rains they collide or are being torn,
(b) students 8-10 years old thought clouds like sponges with water and when they swing or get cool or warm the drops fall and so it is raining, and
(c) students 11 to 15 years old believe that clouds are created when the steam cools and the rain falls when the drops become large and heavy.

Students with Mild and Moderate mental retardation, are considered students of the above age range. Environmental education from the broad perspective of the equality of students, foresees Special education as intensive, motivated, individually planned, specialized, goal-directed instruction to meet students' needs and to ensure their access in the general curriculum. Moreover, it focuses on a systemic perception of the nature's function through cycles (e.g., 'the water cycle') towards a holistic approach to nature, through multiple educational stimuli, activity-based and close to everyday life learning [2]. The effective Information and Communication Technology (ICT) integration within a didactical approach towards the realization of the 'the water cycle' as a cycle *per se* (with an empirical approach to the change of matter issues involved) by students with Mild and Moderate mental retardation, motivated the following design considerations.

2.3 The *MusicPaint* Software within the Activity Theory Context

The *MusicPaint* software, developed by the authors of the Dept. of ECE (Thessaloniki, Greece), proposes effective ICT integration to a goal-directed instruction for students with Mild and Moderate mental retardation. Figure 1 depicts the *MusicPaint* workspace, which makes explicit the simple functions that it provides. The empty workspace provides room for the user to express his/her creativity, by choosing color and simultaneously instrument, line type and drawing object.

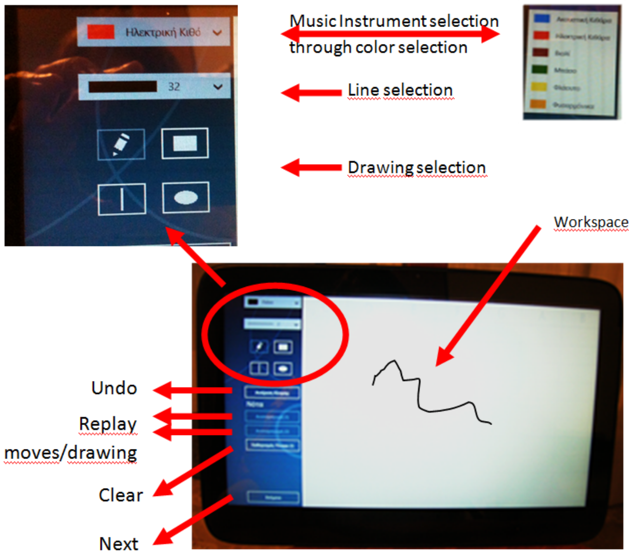


Fig. 1. Depiction of the *MusicPaint* workspace

Extra buttons of the workspace support simple undo, clear, and self-reflection actions. The next button materializes a route through three scenarios, IMAGINE, SEE and HEAR, respectively, with five experiments (#) per scenario. In every scenario, the user is asked to draw upon a stimulus that s/he receives as follows. In the IMAGINE scenario, the stimulus are five keywords, in the SEE scenario five depictions and in the HEAR scenario, five pieces of music of the domain of interest. By the end of (#5) of each scenario, the next button asks the user to fill a Likert-scaled questionnaire concerning the experience of the completed scenario. Finally, the user is asked to complete an open-ended questionnaire concerning his/her experience of the Music Paint.

MusicPaint runs at `Microsoft Windows 8` on tablets and was developed using the `C#`, `XAML` and `ASP.NET` programming languages. Automated logging of the interactions of the user allows for later raw data analysis. From the Special education perspective, the design of the *MusicPaint*, materializes a looping process (3 scenarios with #1-5 experiments per scenario), yet involving different levels of attention at each loop, according to the stimulations of the especially designed, dedicated software. Moreover, due to its simplicity in use and the open character of the design, *MusicPaint* provides the students with Mild and Moderate mental retardation a working environment that complies with basic instructional design considerations in Special education, i.e., systematic, purposeful, well-organized, hierarchical explicit direct instruction supported through feedback and iterations.

On the other hand, from the AT perspective, *MusicPaint* materializes a "second-wave HCI", as it is not designed upon a pre-conceived idea about what the users might do, but with its context-based design it focuses on what the users actually do.

Due to its flexible and adaptive characteristics, *MusicPaint* can be integrated within the instructional environment and allows for depending the investigation of the researchers into the context and motivation of user's behavior [19]. The verification of the efficiency of the *MusicPaint* was tested on an experimental setting that is described below.

3 Experimental Setting

3.1 Sampling and Pre-testing

An empirical research was carried out with seven students from a Special Vocational School in Komotini (E.E.E.E.K of Komotini), Greece. The students were aged between 17 to 23 years old, facing Mild and Moderate mental retardation according to their official classification. All students are studying gardening, so they are expected to roughly realize the 'water cycle'. However, through the individual pre-testing that took place, the aforementioned research findings were verified. More specifically, pre-testing was conducted by the second researcher who is the Principal of the E.E.E.E.K. The students were eager to participate in a semi-structured interview with open-ended questions. During the interview, the students were asked to solve a five-piece puzzle depicting the 'water cycle'. None of the students was able to realize the 'water cycle' and solve the puzzle.

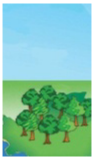
3.2 The Experimental Setup of the *MusicPaint*

Upon the pre-test findings, an experimental instructional intervention was prepared that integrated *MusicPaint*, as it is depicted in Table 1. IN the latter, the selection of the Keywords, the Pictures (pieces of the puzzle) and the Sounds/music were combined with the 'water cycle'. The repetitive nature of the design that aligns with the Special education needs, along with the direct instruction, was foreseen through repetitive circular, iterative processing of the phases of water designs, i.e., of the 'water cycle', the implementation of each scenario both in the classroom (preparation through direct instruction) and in the MusicPaint environment (autonomy in practical implementation) and the specific circular nature of the *MusicPaint*.

The aims of this design were:

1. *In terms of knowledge*: to recognize and name the water phases and describe the water cycle,
2. *In terms of skills*: to paint the phases and eventually the whole water cycle, assuming different stimuli (words, images, environmental sounds/audio) using tablets and the *MusicPaint* software, and
3. *In terms of attitudes*: to appreciate the natural environment, discover a new use of technology through tablets and boost their self-esteem through the whole process.

Table 1. The proposed instructional design

***MusicPaint* Scenario 1: IMAGINE**				
Preparation in the classroom. Experimental-realistic representations of the 'water cycle'				
Text Input (Keywords)				
Cloud	Snow	Water	Plants	Cycle
Outcome paintings using the *MusicPaint*				
(#1)	(#2)	(#3)	(#4)	(#5)
***MusicPaint* Scenario 2: SEE**				
Preparation in the classroom. Representing the 'water cycle' in the classroom schematically				
Visual Input (Images)				
				
Sea-Sun	Snow	River	Forest	The 'water cycle'
Outcome paintings using the *MusicPaint*				
(#1)	(#2)	(#3)	(#4)	(#5)
***MusicPaint* Scenario 3: HEAR**				
Scenario 3-preparation in the classroom. Listen to music pieces with lyrics concerning the sea, the sun, the cloud, the rain, the snow, the river, the 'water cycle'				
Audio Input (Sound/music files)				
Sound of boil-ing water	Song concerning the snow	Song concerning the river	Sound of irrigation	Song concerning the 'water cycle'
Outcome paintings using the *MusicPaint*				
(#1)	(#2)	(#3)	(#4)	(#5)

3.3 Implementation Steps

Before the implementation of the scenarios shown in Table 1, two tablets were used for the acquaintance of the students with the *MusicPaint* environment. Due to the flexibility and user friendliness of the latter, the SwD were, quite quickly, autonomous in its use.

The intervention initiated on the April 2, 2013, with the scenario 1-preparation of the students in the classroom. This step included experiments with the phases of the water (drink it as liquid, see it as a gas after boiling, experiencing ice cubes), PowerPoint and video presentations with realistic representations of the 'water cycle' and discussion on the role of the plants. Another teacher of the school was the external observer of all the discussion that took place. At the end of this step, the *MusicPaint* Scenario 1: IMAGINE was conducted individually by all the students. After a week, the second implementation step took place and the aforementioned PowerPoint was projected again (repetitive mode) and the picture of the puzzle was used during the discussion, moving the representation of the 'water cycle' from the realistic to a more abstract depiction. At the end of this step, the *MusicPaint* Scenario 2: SEE, was individually performed by all the students. The last step was realized on the April 23, 2013, where the scenario 3-preparation was conducted. A repetitive projection of the above PowerPoint and the picture of the puzzle were again presented to the SwD. The students listened to songs from different singers and music trends yet upon the predefined lyrics. At the end of this step, he use of the MusicPaint Scenario 3: HEAR, upon sounds and songs, was individually performed by all the students.

The duration of the preparation scenarios 1 and 2 was 45 minutes, whereas of scenario 3 was 60 minutes. All the SwD were enthusiastic with the *MusicPaint*. They enjoyed the use of a new artefact within the classroom and the freedom and ability to use it. On May 15, 2013, the researcher invited each student in a semi-structured interview. She asked each student to explain the content of each piece of the puzzle. Most of the questions were the ones addressed to them during the pre-test. Finally, she asked each student to solve the puzzle.

4 Results and Discussion

4.1 Qualitative Approach

The implementation of the above experiment provided triangulated evidence of the performance of each student, mainly of qualitative nature (i.e., the observations, the semi-structured interviews, the *MusicPaint* outcome paintings), revealing in depth information of the context and the outcome of the learning procedure.

In Figs. 2 and 3, the initial and final solution of the puzzle and the drawings of #5 from the three *MusicPaint* scenarios (see Table 1) from the third student are presented, respectively, documenting effective results.

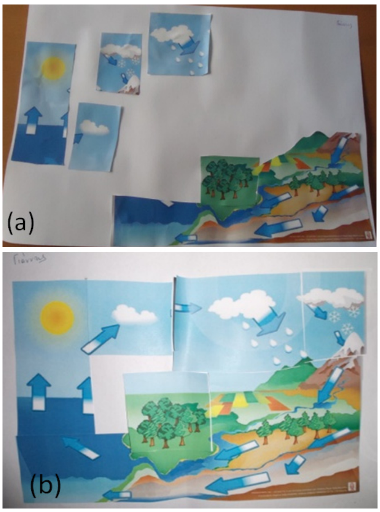
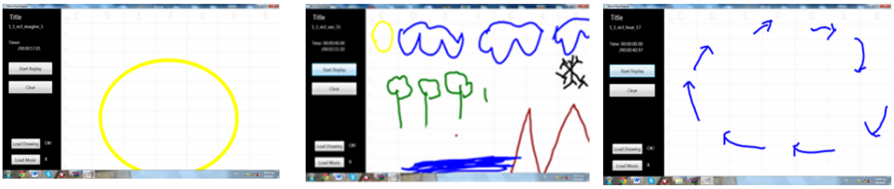


Fig. 2. (a) Initial and (b) final solution of the puzzle by the third student



(a) (b) (c)

Fig. 3. The *MusicPaint* drawings during the fifth (#5) experiment of the scenarios: (a) IMAGINE, (b) SEE and (c) HEAR, by the third student.

The qualitative analysis of the drawings like the ones shown in Fig. 3 verifies the contribution of the *MusicPaint* to the perception of the circular character of the water, through the adaption of necessary skills and knowledge to the students under consideration. This was notice in the drawing outcomes from all SwD participated in the experimental phase, and all of them managed correctly to solve the puzzle at the end, like in Fig. 2(b). This explains the liaison of the students' HCI expression and knowledge conquer, stimulating further the introduction of ICT-based activities in the corresponding educational curriculum.

4.2 Quantitative Approach

In parallel to the qualitative analysis, a quantitative analysis of the *MusicPaint* log files was conducted, contributing to its evaluation as an HCI that implements the AT perspective. In this vein, aspects that derive from the Activity Checklist [20] are discussed.

- *Means and ends*: The *MusicPaint* deals with human activity through the simple design of its interface that allowed the SwD to perform actions (use of buttons) that are part of an activity (# drawing), that holds many sub-activities (choices of instruments, line types, objects) in order to achieve the goal (realize the 'water cycle'). All the above were performed easily as derived from the relatively small duration of time that was on average 8 mins (±std 2 mins) per scenario. The distinct resources at the right hand side of the workspace provide a clear understanding of their parallel function, e.g., the distribution of the drawing within the workspace is related to the instruments frequency (higher values at the edges).
- *Social and physical aspects of the environment*: The MusicPaint was integrated with the Microsoft Windows 8 and combined with the merits of a tablet to provide touch-screen possibilities. This was proved to address effectively the social and physical aspects of the context of the specific students. Moreover, it can load the drawings from all the scenarios and replay them through a *MusicPaint Viewer*.
- *Learning, Cognition and Articulation*: The students materialized a series of repetitions along the five experiments per scenario of the *MusicPaint*, which highly contributed to realize their goal and work for it. Towards this direction, it is interesting that there were not any missing drawings from all the scenarios. The infinite

activities (drawing possibilities) that can be performed provide a flexible character of the effort towards the achievement of the goal.

- *Development*: The *MusicPaint* design allows for the possibility of the outcome (e.g., the realization and drawing of 'water cycle') to become a future activity (e.g., to work on the 'material cycle'), thus supporting the activity lifecycle.

The log files of the *MusicPaint* allow for some interesting quantitative analysis of this flexibility. In Fig. 4(a) a box plot depiction of the selection of the drawing shapes from all the students for the experimental scenario HEAR is presented. It is interesting to notice that the predominant choice is the ‘Free Line’ selection across the experiments (#1-3). This flexible tool yet is eliminated up to the experiment #5, where the Circle/ Ellipse tool is also preferred. This trend is depicted also in the previous two scenarios, underlining a move to a more formal and abstract (i.e., scientific) representation of the 'water cycle'. In Fig. 4(b) the box plot of the music instrument selection across all students and scenarios is presented. It is interesting to notice that acoustic guitar (i.e., the blue color) is the first choice of the students, followed by the piano (black) and harmonica (with more symmetrical ±std). It is noteworthy to realize that all the provided choices were tested, a trend that exists along each scenario. Finally, the sound characteristics (duration and volume) are influenced by the width of the line selection. In Fig.4(c), the box plot of the drawing line width selection across all scenarios and students, is presented. It can be noticed that the width selection has values that show distribution among low and high durations and volumes, a pattern that exists in all the scenarios.

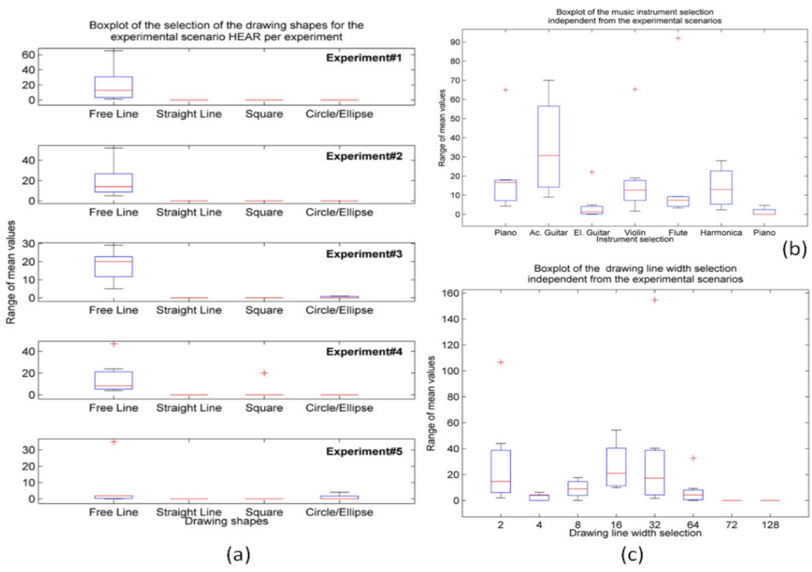


Fig. 4. Boxplots of: (a) selection of drawing shapes, (b) music instrument selection and (c) drawing line width selection

The above findings provide evidence that the students were fully engaged with the *MusicPaint*. This was also verified by their answers to the *MusicPaint* questionnaires. Moreover, they imagine its future uses, as it is seen in their responses to the general open question: "What else do you wish to do with the Music Paint", including "Music and songs", "Games", "Painting with houses", "Internet". From the latter it seems that they imagine the MusicPaint as an integrated educational framework. Furthermore, the new knowledge gained from the ICT-based teaching intervention remained in their memory, as it is shown by the confidence in the final interview and the accuracy in the students' questionnaire responses. Moreover, they developed a positive attitude to participate in the educational scenarios, mainly because a stage of familiarity with tablets initially took place. Apparently, due to the limited number of participants, the results from the above quantitative analysis cannot be generalized. The latter serves, however, as a means to the realization of the creativity of the students. Moreover, it reveals possibilities of self-monitoring feedback along with the *MusicPaint Viewer*. Following the pathway of [15], noting that it is important to stimulate students' interest first and then make the teaching of abstract concepts, *MusicPaint* was used by the students without any interference of the researcher-teacher and this filled them with joy and boosted their confidence. At the end, the students knew the 'water cycle' and what elements were set during the teaching intervention. In the approach followed here and by taking into account the methodological tools, the semi-structured interviews and the follow-up discussions, an opportunity was given to discover students' views and beliefs towards the issue of the 'water cycle'.

5 Conclusions

In this paper, the design considerations of the *MusicPaint* software were discussed within the Special Education, the Environmental Education and the Activity Theory perspectives. Synergies of instructional directions of the aforementioned perspectives, resulted in a design, which through an empirical study, was initially verified as to the potentiality to enhance students with disabilities accessibility in Environmental Education using ICT. However, due to the small number of the participants, the current study serves as a pilot one and certainly more large-scale experiments should take place to achieve generalization; it provides, however, a real-life example of an HCI-based accessibility instance in action.

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