A platform for supporting learning process of visually impaired children

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Abstract - Although ICT supported tools and e-learning material are widely available in schools to support teaching and learning, there is still a lack of specific tools and material designated for children with impairments. The costs of adapting and preparing such material is often economically not justifiable due to a small number of such children, and commonly, for the best leaning outcome the material has to be adapted for each individual child and their deficits and level of impairments. Our solution to this problem is a web platform for delivering customized exercises intended for visually impaired children. There are two sorts of exercises already prepared: a tutorial for learning and practicing Braille and ten-finger typing, and various exercises for practicing vision, memory, and motor skills. For each individual impaired learner, the teacher can select appropriate type of exercise and customize it by adjusting visual aspects of the exercise, setting the specific content (e.g., words for typing, or items to sort), or selecting the level of difficulty (e.g., set timing, complexity levels, or number of shown images). A set of such customized exercises is given to a learner for practicing and their progress is constantly monitored and saved for later inspection.

I. INTRODUCTION

Various ICT supported tools and e-learning material for assisting teaching and learning are becoming commonly available in schools and are a new standard in the teaching process. Although their availability to teachers and students is nowadays indisputable, there are still groups of potential users that cannot take a full advantage of such teaching and learning approaches.

Inclusive education and access to e-learning tools and material is also an important strategic issue. "Promoting equity, social cohesion and active citizenship" is one of the strategic objectives of the EU Strategic framework for Education & Training 2020 [1]. For more than ten years, the European Agency for Special Needs and Inclusive Education[1] has been helping member states to improve inclusive policies and practices in the field of education. Even though the EU and local governments are promoting equity and inclusion of impaired learners, there is a gap between the state legislation, strategies and policies, and the classroom practice.

Beside accessibility, the main challenge with educational tools and material is the level of their adaptability. This issue is important not only to suit the individual needs of the impaired students, but also to keep the content up to date and in line with the educational process in class. Most educational materials include fixed content, which is not modifiable by the user. Such content may soon become obsolete and consequently its usefulness in the educational setting degrades.

In this paper, we introduce a novel web platform for inclusive and accessible educational games intended mostly for visually impaired children. The platform offers a variety of games for vision and memory training, learning braille, and extending the typing skills. All games are flexible and allow for modification of the content, which permits teachers to use the game in several teaching domains, and update and adapt the game to the current needs in the class. Besides, the platform and the games provide accessibility support for the blind and visually impaired. Each game can be further customized by adjusting its visual aspects, the level of difficulty, or employing the individual user preferences.

A. Related Work

Bocconi et al. [2] discuss the issue of accessibility and usability of educational tools by visually impaired students. After examining different educational products, they claim that the issue of usability is poorly addressed and needs more attention. Not only the interface features but also the product's basic functionalities have to improve their usability. Moreover, they argue that different types of visual impairments lead to different needs and therefore ask for different solutions.

Several initiatives are actively promoting braille literacy. American Foundation for the Blind has launched the Braille Bug[2], an interactive web site for teaching braille concepts through activities and games. Milne et al. [3, 4] present some examples of learning games for blind and visually impaired children on mobile devices. However, all these approaches focus only on accessibility and usability for visually impaired, yet lack the option of altering the content of the educational games.

A key skill for digital literacy is also the ability to use a standard keyboard. Typing is an important psychomotor skill, required not only for smoother inclusion of visually impaired children, but also for all digital literates as one of the basic practical skills. Ratatype typing tutor[3] is one of the many web-based educational environments that

[1] https://www.european-agency.org/

[2] http://braillebug.afb.org/

[3] http://www.ratatype.com/

encourage users to learn touch-typing through various educational game settings. Nevertheless, they all use a predefined content not customizable by the teacher.

Another interesting initiative is All Abilities ePlayground[4], an online space offering games for children of all abilities. Although the example web-based games are all accessible, the customization and personalization opportunities are still limited.

We can see that the existing approaches focus more on the accessibility issues, but less on the usability. They do not provide sufficient support for the content customization, especially for teachers that are not IT experts.

II. PERCIEVECONCIEVE PLATFORM

In the PercieveConcieve[5] project, we cooperated with the Institute for Blind and Partially Sighted Children Ljubljana, the main institution in Slovenia in the field of education of children and young people with visual impairment. The PercieveConcieve platform was designed to meet the needs of the teachers and visually impaired children and is used directly in the Institute's adapted education programs.

The main goal of our platform is to provide a variety of modifiable educational games, which include concepts that can be applied to a number of learning domains [5]. The platform provides a special interface for teachers, which enables preparing specific instances of the game suited to a particular student and their specific needs. A teacher can take a game template and define the parameters of the game, like the learning domain, shown items, or visual look. Besides, the game instance is also personalized based on the individual student preferences, adjusting colors, text fonts, text size etc. Several predefined styles have been prepared: default, blind, inverted colors, high contrast, protanopia, tritanopia, and achromatopsia. The user can select any of them in the profile settings. Moreover, the user can also define their preferred language in the settings, as the platform supports multiple languages via the use of language files.

The platform supports three different user roles: administrator, teacher and student. The administrator's view of the platform is presented in Fig. 1. Administrators manage users (e.g., adding new users, changing roles, enrolling to classes) and classes (e.g., create new classes, assigning teachers to classes), and upload new game templates and media files (e.g., images, sounds). Each class has at least one assigned teacher, who can edit the class information and create new game instances from the available templates. Students are regular users that enroll in the class and participate in the activities the class offers (i.e., the activities the teacher prepares for them).

All games communicate with the server via application programming interface (API) [5]. The API is opened and available to any developer who wishes to create new games and offer them through the platform.

[4] http://allabilitiesplayground.net.au/
[5] http://zaznajspoznaj.si

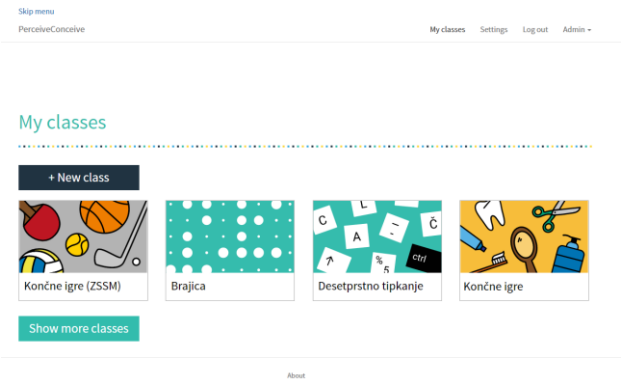

Figure 1. Administrator's view on the PerceiveConceive platform. Administrator accesses all functionalities as a regular user, but can, in addition, administer the platform, including adding new classes

This allows for further expanding the set of game templates by the contributing community.

Although the developer of the game template has full control over the adaptability of their game and how the predefined user styles are processed in the game, the use of the entire available range of customization potentials offered by the platform, through game attributes and user preferences, is highly important for inclusion of users with different impairments.

III. PREPARED GAME TEMPLATES

In the first stage, we have prepared several game templates: a tutorial for learning and practicing Braille, a tutorial for practicing ten-finger typing, and a series of repetitive games for practicing vision, memory and fine motor skills. More games templates will be developed and added according to the wishes and demands of the teachers.

A guiding light in all games is our game character in a form of a yellow personified star, which was introduced in order to encourage students throughout the playtime. The character, shown in Fig. 2, proved to provide positive stimuli on student performance and achievements.

A. *Braille Tutorial*

This tutorial is intended for children and their parents that want to learn reading and writing braille. Currently, the tutorial focuses on basic characters of the Slovenian braille, but it can be extended and adjusted to the specifics

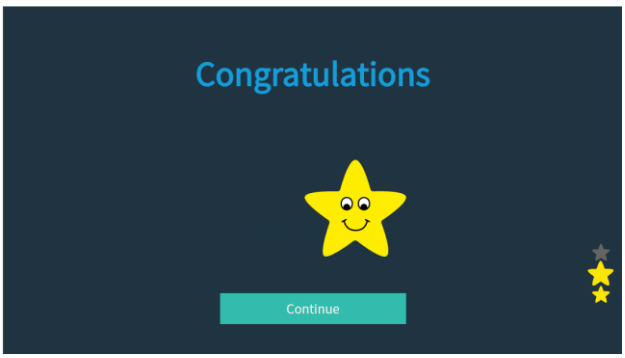

Figure 2. A star character, which encourages players throughout the game. Players also collect stars as rewards for correct answers (shown in the column on the right)

of any language. The tutorial includes a description and explanation of this tactile writing system, including a short history, and additionally offers three types of exercises: Mirror, Hidden Character (or word), and Braille Machine for letters and words.

All exercises can be performed using the keyboard (a braille writer is not required), where the keys f, d, s and j, k, l on the keyboard (or number keys 1 to 6, consequently) are used to mark the raised dots of a braille symbol.

In the Mirror activity, the user can experiment with braille symbols. This basic interactive activity introduces braille to the user via various letter conversions. The conversion form black print to braille shows a corresponding braille symbol (an image with six dots where the raised dots are emphasized) when the user enters a letter in black print. An inverse transformation is also possible: for a given combination of raised dots (entered either using keys f, d, s, j, k, l, or number keys 1 to 6) a corresponding letter mirrors in black print. Fig. 3 shows the exercise where the user presses the key numbers 1 and 5, thus raising dots 1 and 5. Consequently, the left field displays the selected braille symbol while the right field displays the corresponding letter e in black print.

Hidden Character/Word is an activity for practicing braille by recognizing the displayed braille symbols or, in case of higher difficulty level, entire words. A user has to find corresponding letter(s) for the displayed braille symbol(s) and enter the answer within the limited time. An audio pronouncing the places of the raised dots in the braille symbol helps visually impaired users, but can be turned off any time during the exercise.

The third activity for practicing braille is Braille Machine, which is the hardest of all exercises. The user practices braille by selecting the right combination of raised dots in the symbol. A letter in black print is presented to the user together with its audio recording (which can also be turned off) and the user has to enter a braille symbol via keys f, d, s, j, k, l. If the user fails to provide the correct input in the available time, the answer is displayed to provide an immediate feedback to the user. A more challenging version of Braille Machine deals with the whole words instead of individual letters.

In all braille exercises, the teacher can select the available time for answering as well as the letters and words for practicing, thus allowing the exercise modification to meet each individual user needs and difficulty level.

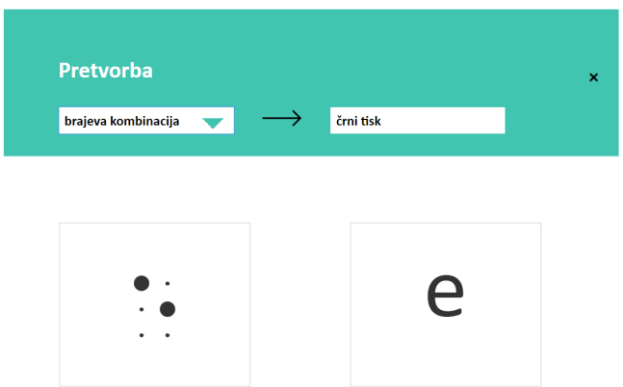

Figure 3. The Mirror exercise for practicing braille. Selecting the combination 1 to 6 for raised dots displays (mirrors) the corresponding letter in black print

B. *Ten-finger Typing Tutorial*

This tutorial explains the basic concepts of two-handed touch-typing and encourages practicing through a series of customized exercises.

Each exercise uses a predefined sequence of letters or words (either default or customized and prepared by the teacher) that is displayed on the screen and provided via audio dictation. The user has to type the sequence while the time is also being measured. Immediate visual and audio feedback is given on the user performance.

One such exercise is shown in Fig. 4, where the two basic letters f and j have to be typed interchangeably using left and right index finger. The progress of the user is visually marked in yellow and the mistyped letters in red. The help below the letter sequence shows the position of the next letter on the keyboard and the finger that has to be used for typing this letter. This help can be turned off for higher difficulty levels.

Each exercise can be customized in different ways. The most obvious is the content (i.e., the sequence of letters and words) that the user uses for practicing typing. Besides, the teacher can select different ways of displaying the content to the user (e.g., all at once, line by line, word by word, or letter by letter), adjust the maximum number of characters in one line, set the colors schemes for the content (e.g., foreground and background colors, the color for marking progress and mistakes), or shuffle the displayed content by enabling randomly generated subsets of the content.

C. *Vision, Memory, and Precise Movement Games*

An important part of the platform are various games in the form of memory games, puzzles, matching, sorting, pair identification, image understanding and description, and object navigation, controlled with fingers or keys. These exercises support practicing vision (e.g., pattern matching, standard puzzles), memory (e.g., standard memory games, finding the correct subset of the shown items, finding exact sequences, finding reverted subsets) and precise movement (e.g., object navigation, following the path through the labyrinth), and are useful directly as a

Figure 4. The Ten-finger Typing exercise for practicing touch-typing. Displayed is the sequence of letters that the user has to type, progress is visually displayed (mistyped letters are marked in red), and help (the keyboard with the marked key in question and the finger to use for pressing the marked key) is provided or hidden on demand

teaching aid for visually impaired children. Fig. 5 presents a subset of available games.

Fig. 6 shows an example of a game Sequence intended for training visual memory. The player looks at the sequence of objects on one page and, when ready, continues to the next page, where the perceived sequence has to be reconstructed from the available images. The game starts with the sequence of two images, while an additional image is added to the sequence on each next difficulty level. The player collects stars as rewards for correct answers (displayed in the bar on the right). After obtaining the third star, the player can progress to the next level.

All games are adaptable by setting various attributes, from the available topics (e.g. tools, fruit, animals, sports) and images (e.g. the selection of images can vary from color to black-and-white and line drawings) to difficulty levels (e.g. number of levels, number of images on the first level, number of additional images on the next level) and the speed of progress between levels (i.e. how many stars have to be collected before going to the next level). Therefore, the games can be adapted to each individual player, their level of difficulty, and specific deficit. This individual adaptation can be set on two levels. One level are the individual settings for the game that are prepared by the teacher, taking into account the student's impairment, performance ability, level of background knowledge, age and social background. Another level of adaptability are the student's individual settings that include pre-prepared styles according to the student deficit (e.g. changing the color scheme or contrast) and language settings, both affecting the interface presented to the user.

IV. Evaluation

The PercieveConcieve platform is still under development, thus only one preliminary evaluation on end users has been conducted so far. We evaluated user experience, while testing the platform's games for vision, memory, and precise movement. The focus was on the games for visual perception.

Three visually impaired children, two boys and one girl, participated in the evaluation. Their average age was 10 years and all had severe low vision on both eyes. One teacher, who was an expert for teaching visually impaired children, participated in the evaluation as the leader of the testing and support for participating subjects. A solution designer had a role of an independent observer in the evaluation. The tested subjects were video recorded,

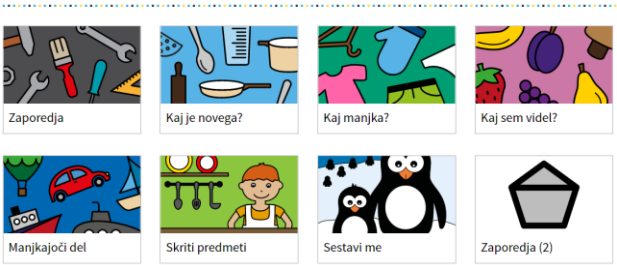

Figure 5. Various games for practicing memory, vision, and fine motor skills. Games are grouped in activities that can be customized for a particular learner and their impairment

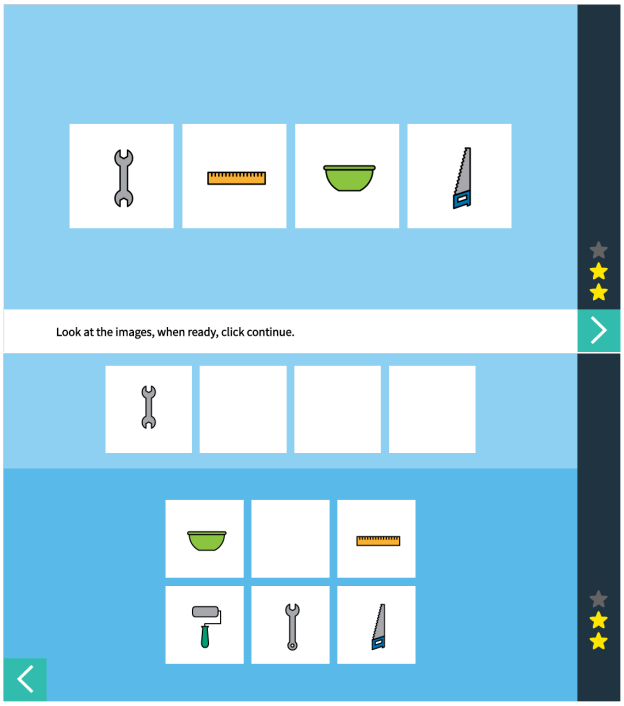

Figure 6. The Sequence Game for practicing visual memory. A sequence of images is shown to the user on the first page (top). Now the user has to reconstruct the sequence from the provided images (bottom)

observed while playing the games, and interviewed. The teacher prepared observations and notes on tested subject's performance and completed one evaluation questionnaire for each tested subject.

Evaluation tests were prepared for usability testing according to the specifics of working with and teaching the tested population. We combined three types of metrics in the tests: performance metrics (e.g. efficiency in playing the game, error frequency while playing the game, efficiency of interactions, ease of learning), issue-based metrics (e.g. why the user did not finish the task, level of satisfaction and level of frustration) and self-reported metrics (e.g. did the user like the game and wished to play again). Consequently, the evaluation questionnaire had four parts: game usability and efficiency (e.g. percentage of tasks completed, number of errors, success with performing the tasks), game effectiveness (e.g. number of help requests, number of tries before giving-up), student satisfaction (e.g. want to play more), and student dissatisfaction (e.g. student frustrations and uneasiness). The time needed to perform a task was not measured in these tests as it is not a relevant success criterion for the focus group of visually impaired children.

The main objective of the evaluation was to overcome the standard guidelines and to develop a user interface as well as to design graphic solutions that enable a visually impaired child such a user experience that is comparable to the one that children without impairments experience when interacting with didactic games.

As the tested subjects were observed while playing a specific game and performing given tasks, we could determine problematic navigational, functional, and content related elements in the application. We encountered several problems (e.g. some content elements

were not visible or not understood, some user activities did not lead to the correct solutions, problems with magnification, problematic counting of images) and identified a number of suggestions on how to improve the games. Therefore, the results of this evaluation impacted directly the development decisions and the application was improved accordingly.

The analysis of the user experience from the viewpoint of success and difficulties in interaction with the application showed that the platform and the games were adequately designed. Main disturbing factors that in some aspects restricted tested subjects from accomplishing the tasks and caused major problems were essentially related to cognitive-behavioral characteristics of our target group (e.g. age, visual impairment, social background) rather than to the game design solution.

The evaluation results [5] show that all three children were excited to play the game and the game character (shown in Fig. 2) proved a valuable visual motivation. Nevertheless, the children still needed additional verbal support during the game, especially when playing the games for the first time. Particularly, the games for visual perception are in general more difficult for the first-time players, thus an expert teacher has to be present for additional help and guidance. Later the player is more autonomous and help is needed only occasionally.

We intend to perform a more comprehensive evaluation after the winter school break. The evaluation is planned on two levels: first with the teachers that use the platform in the educational setting, and later with the impaired children that use the customized games for exercising.

The first study will focus on the teachers and will measure user acceptance and usability of the platform. We plan to gather the data for this evaluation via a questionnaire, using a set of questions from two validated questionnaires: the technology acceptance model (TAM) questionnaire [6] and USE (Usefulness, Satisfaction and Ease) questionnaire [7].

The TAM model is valuable for explaining usage behavior, as it measures the perceived usefulness and perceived ease of use, which are two fundamental determinants of user acceptance [6]. On the other hand, the USE questionnaire will help us measure usefulness, ease of use, ease of learning, and user satisfaction with the platform [7].

The second study will focus on visually impaired children and their use of the customized games for exercising. We intend to measure accessibility of the games, student engagement, and effectiveness of the games as a teaching tool.

V. Conclusion

PerceiveConcieve is an open-source platform for accessible and inclusive educational games. The platform is designed to support accessibility, adaptability, and customization of the games by the use of game templates. This way, even the less IT skilled teachers are able to freely adjust the games and modify their content, thus customizing the games according to the educational setting and the needs and preferences of their visually impaired students. The use of the PerceiveConcieve platform enables teachers to include motivating and accessible elements of game-based learning into inclusive learning scenarios, and consequently enrich and diversify the learning process.

The preliminary evaluation of the platform on target groups has shown positive acceptance by teachers and visually impaired children. The platform proved to be well designed, with appropriate graphic design as well as prepared content. We are preparing the next stage of evaluations, a more comprehensive study that will focus on user acceptance and usability of the platform.

Acknowledgment

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