Access All Areas: Designing a Hands-on Robotics Course for Visually Impaired High School Students

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Abstract. In recent years, student laboratories have been established as effective extracurricular learning areas for the promotion of educational processes in STEM fields. They provide various stimuli and potentials for enhancements and supplements in secondary school education [8]. Most courses, however, do not offer full accessibility to all students. Those who e.g. suffer from visual impairment or even sightlessness find themselves not being able to participate in all tasks of the courses. On this account, the Center for Learning and Knowledge Management and Institute of Information Management in Mechanical Engineering at RWTH Aachen University have redesigned one of their robotics laboratory courses as a first step towards accessibility. This paper presents the work in progress of developing a barrier-free course design for visually impaired students. First feedback discussions with the training staff shows that even little changes can sometimes have a huge impact.

Keywords: School laboratories · Barrier free · LEGO mindstorms · Visual impairment · Highschool students

1 Introduction

Extracurricular school laboratories have proven to be an effective way to let students playfully experience the fundamentals of robotics, computer science or other technology-related topics. In combination with a hands-on approach, e.g. by working with LEGO MindStorms, they get a chance to learn on a cognitive, emotional and haptic level. While this is a widespread approach these days, not every pupil, however, is able to participate in courses like these due to a lack of accessibility. Ludi e.g. states that "awareness of potential career paths and access to adequate preparation remain barriers to students who are visually impaired" [5]. Due to their impairment or lack of sight it is rather impossible for them to fully participate in a programming process or when building a robot using e.g. LEGO MindStorms sets.

To overcome this sort of discrimination, the Center for Learning and Knowledge Management and Institute of Information Management in Mechanical Engineering of RWTH Aachen University have teamed up with a group of experts in order to develop

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a special barrier-free course design. This group of interdisciplinary researchers and practitioners – psychologists, school and university teachers, experts in the field of accessibility as well as robotics etc. – took the original course design from an existing robotics course for high school students and transformed it into an accessible course design by applying specific changes. Applying solely technical adjustments to the course, however, cannot be fully sufficient in the development of a new and adequate course design. Therefore, all changes applied to the course went hand in hand with an adjustment of teaching and learning strategies.

When designing a programming course for pupils with handicaps in a first step these strategies as well as required tools have to be thoroughly identified. The resulting new course design allows students with a handicap such as impairment of sight to access the same courses and benefit from the same experiences as their fellow pupils. This paper will present the original course design followed by results from the expert design workshops in terms of technical and didactical adjustments to the course. Finally it will present first indications through feedback discussions on the achievements made in first courses.

2 Original Course Design: "Roborescue" and "Rattlesnake"

In the original robotics course design high school students are given the chance to get an insight in building and programming robots using LEGO Mindstorms sets in a school laboratory. The main focus of the course lies on the construction and programming of various robot models with LEGO Mindstorms construction kits. By using the graphical programming interface NXT-G, which is also suitable for non-professionals, students find an easy access into the world of programming [1].

In order to prepare and motivate students for a future career in robotics, they can try their hands at building, programming and testing robots in a highly interactive and playful environment. The course allows them to experience the fascination of robotics by letting the students create either a "rescue robot" [2] that can search for virtual victims in a simulated rescue mission or a "rattlesnake" that snaps shut when someone crosses its field of vision. The choice of the scenario is subject to the age of the students – lower grades build a rattlesnake which is easier to build and to program while junior and senior classes go on a more complex rescue mission. Within this storyline, the four main tasks of the course are embedded: an introduction giving basic theoretical information, the construction phase, the programming process as well as the reflection or evaluation phase. The underlying didactical course concept focuses on own experiences made as a basis for all implicit learning processes. These processes primarily run playfully, practically and experimentally [1].

The school laboratory where the courses take place, however, is not located at school – it has been set up at RWTH Aachen University. This allows high school students to take a peek into the daily routine at University and is meant to facilitate the decision making process when it comes to choosing further steps after graduating from high school [3].

3 Enabling Higher Accessibility for Visually Impaired Students

3.1 Expert Design Workshops

In order to facilitate the process of redesigning the robotics course and reach a higher accessibility, researchers from RWTH Aachen University invited a team of interdisciplinary experts. In a series of expert design workshops, the roadmap of the redesign was created. The main goal of these workshops was to identify the key aspects of required adjustments in order to reach a distinctively higher level of accessibility.

In the course of the workshops, the participants gradually developed a grid of these requirements. In a first step they divided the course into its individual phases based on the established approach by Vieritz et al. [10]. They used the different phases of the course and analyzed the requirements and necessary adjustments for each individual part compared to those of the original course design. These phases are the introductory part, the construction phase, the programming phase as well as the phase for reflection. Combining their different experiences and testing single elements by simulating specifying eye disfunctions, the experts came to results in terms of requirements for each phase. These results are being presented and discussed in the chapters below divided into technical as well as didactical adjustments. At the end of chapter three, the developed grid gives a summarized overview of the results from the workshops.

3.2 Technical Requirements

Due to continuous research and rapid technical advancement, today, being visually impaired does not automatically exclude one from working on and with e.g. smaller objects or computers. It does, however, bring about specific technical requirements which have to be considered when designing a robotics course. According to the results of the design workshops, the identified requirements especially include auxiliary means which can be summed up as objects, software and computer settings. There are a lot of different eye dysfunctions which call for support by different objects. In order to increase accessibility these objects are e.g. magnifiers and common magnifying glasses. Other important objects for the different phases of the course are cameras and reading devices, printed handouts for every phase, additional lighting for the building process and sorting boxes for robot components.

In terms of software, screen readers such as JAWS or Dolphin, graphic programming using e.g. NXT-G [1] as well as textual programming using e.g. JBrick [6, 7] should be provided in the programming phase. Finally, the computers provided should allow for adjustments of graphic contrast on computer screens. These adjustments should also be possible on the provided work tables. Nevertheless, there is no "universal remedy" for increasing accessibility. In preparation of the course the teaching staff should therefore always acquaint themselves with the participants in order to be prepared for any special requirements the students might have.

3.3 Didactical Adjustments

Not every measure taken is helpful for every sort of handicap and not all changes can be made at once. In the presented case a fundamental distinction between different degrees of visual impairment up to sightlessness has been essential groundwork for further research and course development. Most advancements and adjustments have to be made gradually in order to reach full accessibility. This has proven to be a very helpful approach in the process of designing the new course. Some degrees of visual impairment, for example, are even contrary to one another [5], so there is a need for different technical as well as didactical approaches in one course to reduce or extinguish existing barriers for all participating students.

As a first result and requirement, printed manuals should be provided for the first three phases, the introductory part, the construction as well as the programming phase. This allows students to reread instructions at their individual pace.

Time has also proven to be one of the main but often underestimated factor [4]. Visually impaired students need to be given more time to work on their tasks in terms of reading instructions, following presentations as well as building and programming. The more severe the impairment is, the more time will be needed to finish a task. In addition to that, additional time needs to be invested in giving detailed information regarding the content of e.g. manuals or presentations, repeating this content, reflecting processes, practicing as well as post-processing. Practitioners from the workshop have come to the subjective conclusion that the time necessary for a traditional course design should be at least multiplied by four after monitoring their own ability to work through the tasks of the class by wearing glasses that simulate an eye dysfunction. On an average it took them four times as long to finish the assigned tasks. Further research and evaluations of the course will have to prove whether that factor needs to be adjusted.

Another important adjustment relates to the teacher-student ratio. It has to be increased compared to traditional course designs which of course takes up additional time and resources on the teaching end. The required ratio can differ vastly as students have very diverse needs in terms of support. As we also know from Silva et al., even students without handicap perceive and process experiences in different preferred ways [9]. This has been confirmed also by the practitioners. Therefore, the supervisors need to provide a high level of flexibility regarding supervision and support throughout the course. Lastly the practitioners identified presorting the sorting boxes used in the construction phase as a helpful measure in the building process which does no longer exclude visually impaired students from the haptic and tangible experience of building a robot themselves.

Every course is highly influenced by diversity aspects and a thorough preparation and awareness of all possibilities and influences as well as a pre-analysis of the expected target group of each course proves to be the key to a successful course design. Table 1 sums up the results from the workshop in a grid.

Table 1. Results from the workshop: requirements for the new course design

Phase	Content	Original Course Design and equipment	Technical Requirements for a barrier free course	Didactical Requirements for a barrier free course
Introduction	Theoretical Input	Power Point Presentation	- Laptops with screen readers - Magnifying glasses	- Detailed explanations and descriptions of what the slide shows - Repetition of content - Simple slide design with high contrast - Printed Manuals
Construction	Building of the robot	Unsorted boxes	- Sorting boxes - Magnifying glasses - Reading Device - Graphic contrast on work tables	- Pre-sorting of components - Room for extra time and practice - Continuous supervision and support - Printed construction manuals
Programming	Programming of the robot	Laptops	- Contrast settings - Screenreader (JAWS/Dolphin) - Extra lighting - Printed Manual instead of beamer - On-screen magnifier - Graphic programming	- Continuous supervision and support - Room for extra time and practice - Printed programming manuals
Reflexion	Reflecting the Processes and Outcomes			Room for extra time

4 Conclusion and Outlook

The paper has described the process of redesigning of a robotics course from an educational robotics laboratory. The redesign was performed in order to increase accessibility of the course for visually impaired students. The evaluation of an expert workshop has brought about a concept for the redesign which has been implemented and is currently being tested in a second run with various groups of visually impaired students. The developed grid of the workshop suggests that smaller as well as bigger adjustments to the designated phases of the lecture can lead to a higher level of accessibility. First anecdotal but enthusiastic feedback from the students leads to the gentle assumption that the applied changes suggested by the experts were successful.

Nevertheless, a huge part of the adjustments needs to be individually taken considering the needs and requirements that the specific dysfunctions of the target group bring about. At this point of research, there is no "one-fits-all"-solution to the challenge. As a consecutive step, evaluations of the designed courses will allow for a thorough analysis and serve the pursuit of continuous improvement. Additionally, it will be the key to future research. In order to broaden the range of accessibility, further research will have to focus on full accessibility also for blind students as well as other impairments such as hearing and e.g. physical disabilities.

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