Pre-Vocational Skills Laboratory: Development and investigation of a Web-based environment for students with autism

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Abstract

The use of Information and Communication Technologies (ICT) in educating children with Autism Spectrum Disorder (ASD) is a dynamic field linking both special education and learning technologies research areas. This paper reports on the design and development of Pre-Vocational Skills Laboratory, a Web-based learning environment aiming to support students with ASD towards developing pre-vocational skills. The first section addresses theoretical foundations regarding ICT applications in educating and supporting individuals with ASD. The key design features, the structure and the functionality of the system are analytically presented. Following, preliminary findings regarding an instructional intervention implemented in a special education school in Greece are also presented. The paper concludes that the environment can help students with autism to acquire pre-vocational skills, while the combination of multiple source data (observation notes, system log files and biofeedback data) can offer valuable information regarding the design of effective individualized interventions.

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1. Introduction

Autism is related to social skills impairments regarding three fundamental expressions of human life: social interaction, communication and constructive thinking/imagination. Emotional limitations are typical in autism, e.g. individual inability to manage social relationships, to understand the feelings expressed by others, to communicate one’s own feelings, and to develop symbolic or imaginative activities [1]. Alternative learning environments and individualised interventions are promising towards supporting individuals with Autism Spectrum Disorder (ASD) to overcome their barriers of adaptive functioning and social interactions. Computer-assisted instruction is considered an effective educational method for all students with developmental disabilities; when it comes to students with autism the results are even more encouraging. ICT and Web-based environments have been suggested to design alternative learning interventions and effective treatment strategies aiming to enhance the quality of life for people with ASD and their families [2].

Literature review indicates promising results regarding the potential of ICT to motivate engagement of children with ASD, to attain skills for increased adaptive functioning and improve their communication and social skills. The majority of computer-assisted environments for students with special needs include training in vocabulary, arithmetic calculations, conceptual correlations, and communication and social skills. Existing literature [3, 4, 5, 6, 7, 8, 9] suggests that research regarding ICT application in children and adults with ASD has been directed to three main areas: a) language reading and expression skills; b) face processing and emotion recognition comprehension; and c) social skills development.

However, the research on using ICT to support the development of pre-vocational skills of students with autism is rather limited. In addition, to understand why autistic students are so inclined to computer assisted environments we need to examine the characteristics of the disorder and how individuals interact with ICT. The study presented in this paper aims at contributing towards this direction. The pedagogical design framework of Pre-Vocational Skills Laboratory (PVS-Lab), an interactive Web-based environment aiming to enhance the instruction of students with autism attending a Special Vocational School (SVS) in Greece, is outlined in detail. Preliminary results, regarding a two month instructional intervention in a public SVS are also presented. Finally, conclusions are drawn for future development and research regarding Web-based environments and pre-vocational skills development by students with ASD.

2. Literature review

Children with autism are characterized by a limited, monotone and repetitive repertoire of activities and interests, while their cognitive development does not follow a homogeneous path [1, 10]. In addition, they constitute a very heterogeneous group. It is very difficult to list defining symptoms while they may manifest different intelligence levels, e.g. ranging from a very limited intelligence to a series of intermediate stages or even to exceptionally high levels. While traditional educational models are mainly based on verbal communication and social interaction, autistic individuals have serious difficulties to take advantage of such approaches. Negative emotions, such as stress and disappointment can hamper or completely disrupt their learning and development processes [11]. Individuals with autism may be especially vulnerable to stress in domains such as: communication; socialization; sensory factors; physical factors; executive function; and maladaptive behaviors. Furthermore, sudden or rapid changes tend to distract attention of autistic learners leading thus to escape behaviors [10]. This is also linked to the difficulties they have in maintaining visual contact with persons and in interacting with them, since they are too sensitive and unpredictable. Therefore, in order to focus attention, learning activities to be proposed should be simple and repetitive, embedded in familiar environments, introducing minimum changes and eventually using verbal stimulation if necessary.

People with autism have monotropic interest systems [12]. This means that their attention is tunneled, their interest is trapped and they perceive objects as isolated entities, out of their context. Computers are suitable tools for ASD persons because they are by nature monotropic, they are rule-governed and predictable, and they offer very clear boundary conditions. Moreover, they offer restricted stimuli in all sensory modalities, a safe error-making environment and possibilities of verbal or non-verbal expressions.
Since the decade of 70’s, when Colby [13] first argued that computer-based instruction can promote learning for children with autism, many research studies on this field have been published. The majority of these studies confirmed that computer-assisted instruction (CAI) can reduce behavioral problems (e.g., avoidance of eye contact, echolalia), increase responsivity and use of speech, help the improvement of social, communication and language skills, and facilitate progress of autistic persons [3, 14, 15]. A very decisive moment of CAI for people with special needs was the evolution of affective computing research [16], which combined engineering and computer science with psychology, cognitive science, neuroscience, sociology, education, psychophysiology, value-centered design, ethics, and more.

The primary advantage of computer-based environments is related to ADS children’s preference for visual stimuli [6]. Multimedia [17] and Web technologies [18] provide participatory and interactive environments, multimodal information, and structured spaces that support children’s independence and individualized learning trajectories. In addition, they can be used to create predictable, rule based systems with repetitive patterns to which children with autism tend to be naturally drawn. Multimedia interventions became very popular and were enriched with animated tutors [19], embedded video [20] or even emotionally expressive avatars [21]. Other studies investigated the role of virtual reality (VR) environments in emotion recognition, rehabilitation through social skills training, and social cognition and functioning [22]. Lately, there is a growing interest about using of mobile devices [8, 23], like tablets and smartphones, to educate children with ASD. As browsers are becoming the universal interface to a range of tools and applications, Web-based learning environments have a growing impact on education and learning. The evolution of mobile technologies has led to applications that transfer images to speech in order to facilitate communication of non-speaking autistic children [8].

In conclusion, research on applying ICT to support students with autism tends to become intensive; the investigations could be classified into three main categories: a) expressive and receptive language (including reading skills and vocal expression); b) face processing, emotion recognition, and comprehension; c) social skills development (non-verbal communication, play skills, daily life skills). The present study aims at contributing to an under-researched area, that of supporting ADS students’ development of pre-vocational skills by using Web-based tools.

3. Design framework

3.1. The context

Students with disabilities can develop special skills as long as they are in a learning environment which can help them identify, reveal and exploit these skills. This is the best way to support individuals with ASD to overcome their barriers of adaptive functioning and social interaction and, consequently, to achieve an equitable personal development and social participation. Given the high risk of marginalization and social exclusion associated with ASD, early adulthood is a particularly critical period for individuals. This is the key idea behind the establishment of special vocational schools around the globe.

In Greece, students who attend Special Vocational Schools (SVS) are not required to accumulate knowledge but to develop technical, vocational, social, communicative and intellectual skills that will enable them to respond to everyday life and job requirements. Therefore, the main goal of SVS is education/training of people with special needs in a professional field of their choice and to prepare them for an inclusive workplace. Students have the opportunity to acquire knowledge and technical skills of a specific profession; they have contact with technical, laboratory equipment; and they are trained to use tools and materials. At the same time, they are becoming familiar with working habits, such as timekeeping, good behavior towards colleagues and supervisors, decorous appearance, personal hygiene, care for working space, materials and tools etc.

To achieve these objectives, new teaching methods have been established in SVS. Each student has a different, individualized educational program (IEP) that meets his/her needs and inclinations. IEPs refer to everyday experience and avoid theoretical or abstract terms, in order to facilitate students with difficulties to communicate, understand and express their ideas and feelings by speech. ICTs, educational software and the Web play a crucial role in SVS curriculum, since they offer tools that facilitate communication, personalization and interdisciplinarity.
3.2. Needs identification and goals

PSV-Lab is a web-based environment simulating a school laboratory which includes a series of tasks, related to pre-vocational skills that the curriculum of SVS is aimed to achieve. The main goals of this environment and the consequent intervention were to support pre-vocational skills’ development; to discover students’ inclinations and make suggestions for efficient working tasks; to monitor students’ stress levels; to create a more detailed learning profile for each student; and to adapt students’ individualized educational program accordingly.

To achieve these objectives, the system keeps records of students’ performance, in terms of time needed to complete a task and the accuracy of students’ actions. In addition, a multitude of vital biofeedback signals offer valuable information about students’ stress situation levels; therefore, tutors’ interventions can be adequately directed towards adapting the learning processes accordingly. The Web-tool includes specific activities simulating common tasks that are of value in real life and working environments. The activities can be divided into five main categories: a) sorting objects (by letter or number); b) grouping objects (by size, colour, and shape); c) creating patterns; d) placing objects in relative positions; and e) assembling objects.

Each activity has two or more levels of difficulty. The activities aim at enhancing skills like attention to details, visual-motor coordination, insistence, preparedness, self-evaluation, familiarization with objects and working routines. They are more effective in a context that facilitates the acquisition of functional skills and their generalization from school to society. Therefore, the environment offers opportunities to the students to practice at both, school and home; however, it must be combined with practice in a realistic context. A long term goal is to help students applying their knowledge and skills in problems and situations that might be faced at home or at work. Therefore, PSV-Lab aims to help them develop the skills and self-confidence needed for a successful transition to the working place.

3.3. Key design features

PVS-Lab is a Web-based application, programmed in HTML5, which is accessible by any device (PC, notebook, tablet or smartphone) using just a browser. It is hosted in a server at the University of Peloponnese (http://eprl.korinthos.uop.gr/pvslab). A database system keeps log files regarding student username, activity and difficulty level, student working time, and student errors per activity. The fundamental rule driving the design of PVS-Lab was the demand of a minimalistic user interface. We used a minimum set of buttons, with almost no text, in order to encourage engagement of students with serious reading or other learning difficulties: Home button, Clock (counting task implementation time in seconds), Errors (counting false drop trials), Music (on/off), and Help (Text/image instructions for each task). The buttons are placed at the same position, at the top bar of the screen, along with student’s name and the ‘time’ and ‘errors’ counters (Fig.1).

The navigation/performance area is clearly distinguishable since it is bound on an extra, semi-transparent background layer of solid colour. In addition, icons are made of fabric in contrast with the wooden background. The representation of objects is limited to one realistic 3D image and does not include text or sounds, in order to avoid confusion of ASD students who, generally, face difficulties when simultaneously handling information of different types. The 3D images have been designed in Google Sketchup and rendered with Maxwell Fire plugin. The objects were mainly come from the Sketchup Open Library (3D Warehouse) and the sounds are under creative commons license.

3.4. Structure of the environment and learning tasks

After registration, the student has access to the first room (Fig 1a) which simulates a laboratory with four workbenches. There are two main rooms in the current version of the software; the number of the room is written on the door. Each bench supports a different task with various levels of difficulty. The objects placed on are directly related to this task. By clicking on the bench, students can be transferred to the level-selection screen of a particular task (Fig 1b). After completing a task, students are able to either repeat it, in order to improve their performance, or to return to the level selection screen and, afterwards, to the laboratory room. By clicking on the
painting on the wall of the room, they can have a creative break by solving a jigsaw puzzle. More analytically, there are ten basic tasks included in the Lab:

- **Grouping by number**: Group postal envelopes according to the postal code (ignoring name and address). From the one level to the other the number of different postal codes on the envelopes increases (starting from 2).
- **Grouping by colour**: Group peppers of three different colours into three crates. One pepper is already put in each crate to help grouping.
- **Grouping by shape**: Group red peppers of three different types into three containers. One pepper is already put in each container to help grouping.
- **Grouping by quality**: Separate the fruits according to quality (toss away the rotten and put into the container the good ones). In Level 1, separate fruits of one kind (i.e. only apples). In Level 2 separate two kinds of fruit (apples and oranges) by quality and regardless of colour or shape.
- **Pattern creation**: Create a necklace by inserting (dragging and dropping) beads on a thread, according to a given pattern. In Level 1, two colours are placed alternately (e.g. red-blue-red-blue), in Level 2, three colours alternately, and in next levels more complex patterns are created (e.g. 2 red - 3 blue).
- **Placing objects in relative positions**: Set the table by putting cutlery into the right position. In Level 1 use three objects (plate, fork, knife) and in Level 2 six. In the first two levels, there are semi-transparent indicator areas helping students to put objects into the right place. In the advanced levels, there is no indicator at all.
- **Sorting by size/length**: Put the eggs into the cartons according to their size (small, medium, large). Both eggs and cartons have three different sizes. A ruler can be used to help students’ choices.
- **Sorting by length**: Put the carrots into the containers according to their length (short, medium, long). Carrots have three different lengths while all containers are similar.

![Fig. 1](image-url) (a) Lab room (task selection); (b) Level selection (task ‘Patterns’); (c) task ‘Patterns’ (Level 3); (d) task ‘Table Settings’ (Level 4).
• Sorting alphabetically: Put the folders on the shelf according to the name written on each folder. The letters of the alphabet are written on the selves to help matching. In the next level, the number of folders is increased.

• Assembling objects: Put the batteries in the charger so that the green light is on. Students should take into account the polarity of the batteries. In Level 1, all batteries have the same orientation; in Level 2 students need to discriminate between the two orientations of the batteries.

In the various tasks, the screen was divided into two areas: the source area (upper half) and the target area (bottom half). The student had to select an object from the source area, to drag it to the target area and drop it on the right spot, until there were no objects left on the source area. If the student drops an object on the wrong spot of the target area, this action is identified as a mistake and it is recorded in the log file. If the student drops an object in the source area this is recorded because it is considered as an incidental and not a false action.

3.5. Formative evaluation and improvement

To achieve evaluation goals and the improvement of PVS-Lab, we developed an online scale included 36 Likert type questions. The evaluation criteria related to system’s usability, usefulness/quality of the content and the tasks included, technological design issues (navigation, interface and graphical design, performance), pedagogical design (in relation to the curriculum, the objectives, students’ pre-vocational skills etc.). In addition, 7 open-ended questions were also included. 16 experts in both fields (academicians/educational technologists, special education teachers, and CS teachers) responded to the scale after using PVS-Lab. They proposed changes, modifications or extensions regarding navigation, user interface, graphics and colours of the objects, the sounds, the level of difficulty, and additional tasks that could be included in the final version of the software. The environment was modified according to many of their suggestions and, afterwards, it was tested in SVS classrooms.

4. Research method

To investigate the many aspects of students’ interaction with PVS-Lab environment, students’ specific barriers or difficulties, and their development on pre-vocational skills, we designed and implemented a long-term study in a public special vocational education high school in Athens, Greece. 6 students (5 boys and 1 girl) diagnosed with autism were enrolled. They were between 15 and 20 years old and attended different training laboratories (2 of them carpentry, 1 ceramics, 1 tailoring, and 2 gardening). The severity of the disorder varied from low-functioning autism with severe communication difficulties to high-functioning autism. The preliminary results presented in this paper concern one student, which is referred as S1.

The study was implemented in a period of 2 months. Every student in the sample attended 4 or 5 personalized sessions regularly scheduled for 45-min. During sessions students were engaged in activities using the PVS-Lab. For each student, all sessions took place at the same time of the day. This is justified because the level of arousal depends on day time (i.e. hunger, sleepiness or fatigue affect the levels of SR and HR). In the first preparative session, the students were guided by the teacher throughout the procedure. In the next sessions, they worked independently and the teacher intervened only to offer support, approval, encouragement or help.

After a break of 2 weeks, the students participated in a last session which aimed at studying the transferability of pre-vocational skills to real life situations. The students had the opportunity to repeat some of the main tasks by using real objects, in order to investigate the degree they can generalize knowledge achieved through the computer environment.

4.1. Data collection

There were four data sources used in this investigation:

• System log files from PVS-Lab database; it automatically stored information for every participant (username) like, task difficulty level, tasks implemented, task duration, false choices/mistakes per task etc.
• **Biofeedback signals** (skin response and heart rate) recorded by clip sensors attached to the student’s fingertips
• **Video records** of students’ actions and comments during the sessions, by screen capture
• **Observation protocols** of students’ activities on PVS-Lab, which were kept in detail by the teacher during every session; in addition, details regarding student’s actions, reactions and comments, and any external event that occurred during the sessions (e.g. unexpected sounds, schedule changes or other factors that might affect students’ attention or mood) were also recorded.

4.2. *Analysis levels*

Individual log files, biofeedback signals, video transcripts and field notes were inspected in combination, for every student. The researchers analyzed the log files stored in the database which revealed a progress overview for each student, in terms of speed and accuracy. Then they analyzed the biofeedback data, by calculating the mean value and the mean variance of the skin response and the heart rate for each session. These four metrics revealed the changes in the students’ performance and their level of stress, during the whole training period. Finally, students’ performance, while working with real objects, was compared to their performance in the last computer-assisted session. At a second level of analysis, we analyzed in detail the variance of the biofeedback signals throughout each session. Valuable information regarding stress level of each student, under various circumstances, was extracted.

5. *Case study preliminary results*

5.1. *Learning performance*

Student S1 has been diagnosed with autism. He has difficulties in communicating and entering social groups. He can follow complex orders and express his needs verbally but, very often, he is soliloquized and echolalic. He has very intense attention deficit disorder and he is distracted by external stimuli and his own obsessions.

The student achieved proficiency in almost all tasks after six sessions and he improved his performance in terms of speed and accuracy, as it is illustrated in Fig. 2. Considering that a task is successfully completed when the student makes one or no mistake at all, we conclude that the student was successful in 18 out of 21 tasks. Comparing the duration of each task in the first and the last session, we found that his speed performance was improved in 18 tasks. In fact, the speed improved even for the tasks that the student was able to complete successfully since the first session. At a second level, we are going to assess the student’s performance for each category of tasks, in order to explore his inclinations and weaknesses and modify his IEP accordingly.

![Fig. 2](image-url) (a) Comparison of task duration between first and last trial of student S1. (b) Comparison of student S1 mistakes per task between first and last session. The task number represents category and the letter the level of difficulty.
5.2. Diagnosis of arousal

Having in mind student’s additional diagnosis of echolalia and attention disorders, we aimed not only at improving his scores but also at increasing his concentration, which is directly connected with the levels of arousal. Analyzing the biofeedback data from all sessions we found a reduction is the mean Skin Response (SR) value and a clear, intense reduction of variance (Fig. 3). This suggests a better emotional stability of this student. On the other hand, the variance of SR illustrates the changes of the arousal level caused by stress, excitement or other external stimuli. Stability of the SR variation reflects balanced emotional state, which is strongly desirable during any learning process. Combining these results with our field notes, we found that the student showed actually less disruption and echolalia, as the sessions proceeded on. PVS-Lab assisted instruction has clearly helped this student to improve his performance in a short period of time and, in parallel, to reduce his problematic behavior. Further analysis of student’s involvement into the tasks with real objects can help to identify the degree of knowledge and skills transfer from the Web environment to real life situations.

The graphical representation of the mean SR is not so easy to interpret, because the ideal level of SR is different for each individual (with great differences among people of different gender or age); it is not yet defined what the ‘normal’ level of SR should be. The only information available is that according to the Yerkes-Dodson law, SR should be neither too high nor too low [24]. Yerkes-Dodson empirical relationship between arousal and performance dictates that performance increases with physiological or mental arousal but only up to a point; performance decreases when the level of arousal is very high. In order to export more information from the SR data, we have recorded the signal throughout each session and compared how it changes during the session and from one session to the other.

Examining the field notes for S1, along with the video captured by the screen, we noticed that his mistakes were always made when he was very close to successfully completing the task. For example, if S1 had to thread 12 beads, he would thread correctly 10 of them and then stop. After being asked by the teacher, he would thread the 2 left, but with a high probability of making a mistake. In order to investigate further this behavior, we studied analytically the SR signal for the specific session. As it is illustrated in Fig. 4(a), there is a peak in arousal a few seconds before the end of the task, exactly when the student seems to give up the task. Combining repetitive data from all sources, we concluded that the peak was due to excitement; the student, when was about to finish, considered the task completed. Consequently, he was not concentrated enough to complete the task without mistakes.

After the analysis above, we decided to modify student’s IEP accordingly. During the next sessions the teacher had to remind the student how many objects are left, by reverse counting the last 3 objects. Teacher’s intervention resulted in eliminating this problematic behavior. As it is illustrated in Fig. 4(b) the peak at the end of the task was shifted a few seconds later, at the exact moment when the student was actually completed the task. In conclusion, by combing data from different sources we gained information about student’s learning behavior that we couldn’t have had otherwise. Following, we were able to intervene and support the student to improve his performance.

5.3. Students’ adoption and usage of PVS-Lab

The intervention presented here had a positive impact not only on ASD students’ practicing and developing particular skills but also on improving the behavioral and communication skills of the participants. Overall, students perceived positively the PVS-Lab environment, they showed excitement while using it and were rarely reluctant to enter the class. They easily familiarized with the system and they soon developed a fixed routine and were able to start the process on their own.

The students in the sample were encouraged to express their feelings and ask for a pause if necessary. As a result, a general reduction and smoothing of their arousal levels was observed. The SR measurements gave us valuable information about their level of stress, fatigue or excitement and we adjusted the lesson accordingly. We made a break or even ended a session whenever we had indications of excessive stress. Therefore, we gradually avoided negative or violent behaviors to which students were prone in the first sessions.
The results of this research indicate that properly designed interventions with assistive Web technologies are effective and useful for students with ASD in order to support skills’ development and facilitate learning. In addition, they can offer critical information about the emotional situation of the students, especially of those who are unable to express their feelings. This information is of major educational value, since it offers to the educator enhanced abilities to individualize learning sessions and maximize their effectiveness.

6. Conclusion and future work

In this paper we reported on the design framework and the development of PVS-Lab, a Web-based environment aiming to support students with autism towards developing pre-vocational skills. A two month instructional intervention in a special vocational school, in Greece, showed that students seem to be positive about PVS-Lab.
environment; they easily used it and they enjoyed interacting with the environment and the tasks included. The preliminary research data revealed that most students, like S1 in this case, got familiar with the learning procedure and improved their performance, in terms of speed and accuracy in all cases actually. Appropriately designed assistive technologies can play a crucial role in supporting people with special needs to acquire pre-vocational skills. Our study confirms existing research findings [3–5, 7] that students with autism can benefit from Web-assisted instructional interventions, because of their inclination to visual-interactive systems that are predictable, customizable and with limited boundaries.

However, the main contribution of this study is that harnessing multiple source data (e.g., system log files, biofeedback data, video of students actions, and observation notes) is promising to extract valuable information about individuals’ inclinations, preferences, barriers, feelings, as well as arousal diagnosis related to stress, excitement or external stimuli. By combining data from these sources we are able, not simply to assess students’ performance by using their scores, but to construct a holistic view of every student’s learning profile and identify various emotional or environmental factors affecting their performance and behavior. Therefore, we are able to adapt instructional interventions accordingly and modify students’ long-term IEP in order to minimize distractions and negative behaviors, and maximize their performance.

In conclusion, this study suggested a new research framework aiming to improve performance and pre-vocational skills development of students with ASD which gives emphasis on the interrelation between performance, behavior and stress-emotional situations. Undoubtedly, constructive critiques and debates are welcome and extremely beneficial to identify potential problems and weaknesses of PVS-Lab and the framework proposed about students’ evaluation. Our current research is directed towards investigating students’ performance in similar tasks with real objects and to identify possible transfer of knowledge and pre-vocational skills to real life situations.

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