First Experiences with eBlocks as an Assistive Technology for Individuals with Autistic Spectrum Condition

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Abstract - **The integration of technology into autistic classrooms has shown promising results, including an increase in attention span, creativity, and social skills. We have introduced a low-cost learning technology composed by electronic modules called eBlocks to an autistic middle-school classroom. The participants of this study had the opportunity to learn concepts in the design and implementation of electronic systems by using the eBlocks. Our initial findings show that the integration of hands-on real world based projects, centered on the design of systems for a Smart House estimulated peer-to-peer interaction and teamwork, while promoting spontaneous creative thinking. We present our experiences with six students, including summaries of our overall experiences, teacher's pre- and post-surveys, and the examination of students' work.**

Index Terms - Learning technologies, autism, disabilities studies, human-computer interaction in education.

INTRODUCTION

Autism Spectrum Condition (ASC) is a neurodevelopment impairment that affects individuals in different ways for example, subjects may show deficits in social competence, and lack of interest to work collaboratively with other subjects. Impairment in social competence is regarded as one of the core features of ASC, characterized by a lack or deficient play skills including turn taking and imaginative play, as well as trouble interacting collaboratively with other subjects. In a traditional classroom, a large emphasis is placed on working in groups, as students are able to learn from one another while teachers are more readily able to manage a larger number of students. Many times, working collaboratively is not an alternative learning approach for autistic students as they show a strong preference for solitude and are not inclined to socially interact with their peers. Moreover, other common characteristics of individuals with ASC such as a tendency to perform repetitive activities accompanied by narrow interests, and challenges to communicate and develop reciprocal social interactions contribute to the challenge to develop specialized teaching methods [1].

While originally developed as an interactive platform to enable non-expert users to build a variety of sensor-based systems, we have introduced the eBlocks platform into a local ASC classroom. As part of this exploratory study, the eBlock platform was evaluated to determine if learning experiences that encourage students to work in a naturalistic manner could be developed. We had found that middle-school students are able to quickly design and build interactive systems using the eBlock platform [2]. The eBlock platform is accessible to educators and students who may be reluctant to work with a programming language or with low-level electronic components. Thus, we hypothesized that the eBlocks can provide an appropriate technology for ASC students while supporting the learning of meaningful concepts in the design of systems.

I. Methods for Teaching Students with ASC

As traditional teaching methods typically fall short for autistic learners, a great deal of research has gone into learning how to effectively teach students with ASC. Visual approaches to lessons have been found to yield higher success rates than purely verbal approaches [3]. Visual cues become important aids to help students not only become more familiar with their surroundings but also allow for extra time to process the new information being taught as these visual aids are static. Additionally, the way in which material is presented is important. Students' failure to respond correctly, whether verbally or physically often stems from not understanding what is expected of them because the amount of information presented is overwhelming or perceived as unnecessary. To alleviate some of these difficulties, examples need to be provided to help students jump from abstract to concrete. Using concrete examples along with hands-on activities help to engage students and clarify the tasks to be performed.

Social stories are another common method of teaching social skills to students with ASC [4]. A social story describes, in first person, a commonly encountered social situation, the appropriate reaction to that situation, and the positive outcomes that will result. By succinctly presenting the relevant information in a story form, research has shown that children with ASC are able to better understand the reasoning behind a particular behavior toward others, and results on a positive impact on social behavior. Social

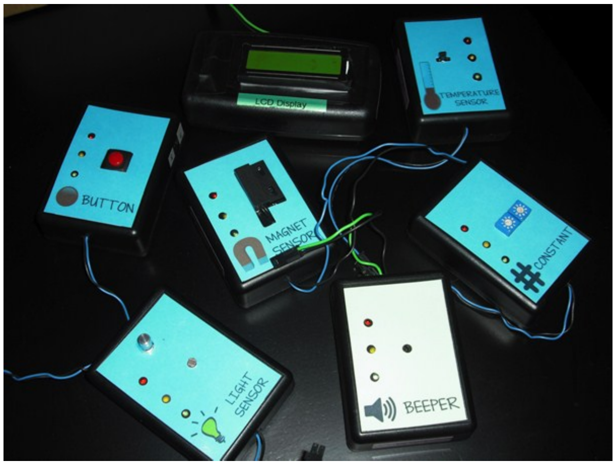

FIGURE 1
SUBSET OF BUILDING BLOCKS FROM THE EBLOCK EDUCATIONAL PLATFORM.

stories are also a viable mechanism to assist in teaching new academic skills, or to introduce changes and new routines.

II. Assistive Technologies for Students with ASC

Initial research into the integration of learning technologies within an autistic classroom has yielded positive findings, and has been shown to act as a learning stimulant. The use of learning technologies for ASC education and therapy are abundant and include video and computer games [5], animated series and movies [6], robotic platforms [7] and interactive websites [8]. Technologies for ASC can be designed and grounded on several theoretical models such as the *Medical Model* or *Functionalist Theory*, *Social Constructionism*, *Postmodernism*, or *Critical Theory*. These models generally differ in their perspectives on concepts such as the origin of a disability (physical origin or social origin), the purpose of assistive technologies (to fix and impairment or to empower a disabled subject) and the way impairments are socially perceived (from a negative outlook or from a neutral outlook) [9][10].

The critical theory approach to ASC education integrates and reconciles some of the tensions between the aforementioned theories for the development of assistive technologies. Critical theory's main tenet is that disabilities are a consequence not only of impairments, but also of a society that has been built unequally favoring the typical subject. Technology should strive to integrate disabled subjects to an ordinary world by decreasing the challenges confronted by these subjects [10].

With this tenet in mind, our approach integrates three proven methods of success: social stories, visual symbols, and computer-based instruction. Students with ASC have a tendency to interact very naturally with computers [11], generally relieving any social anxiety faced by these students by eliminating interaction with other subjects while providing a well-structured environment that minimizes interference from outside variables. Furthermore modern cognitive theories such as the *Empathizing and Systemizing* theory suggest a natural tendency of ASC subjects is to think in a systemizing way, with an intrinsic motivation to analyze and construct systems [12]. Grounded on these theories we utilize the eBlock educational platform to teach meaningful content to ASC students such as the design of systems, while observing social interactions, critical thinking and levels of engagement.

MATERIALS AND METHODS

I. The eBlock Educational Platform

The key to the eBlock approach is to add compute intelligence to components that previously did not have any, like sensors and switches, to abstract interfacing to the underlying hardware, handle any processing of data, as well as communication between blocks. These building blocks are classified into three categories:

- *Input blocks (Blue blocks)* contain sensor that detect environmental events of interest, such as motion, light, sound, or contact
- *Intermediate blocks (Green blocks)* assist with communication as well as perform basic logic transformations (e.g. AND, OR, NOT), basic state functions (e.g. prolong, toggle, trip, pulse), or integer operations (e.g. comparison, addition)
- *Output blocks (White blocks)* provide stimuli, and include light-emitting diodes (LEDs), beepers, electric relays

eBlocks communicate using "YES", "NO", or integer packets. Users can observe the transferred packets in real-time with the aid of embedded light indicators. Each block is color-coded, labeled with text and can also be identified with a graphical icon (Figure 1). A wide variety of systems can be constructed utilizing the same set of building blocks.

II. Smart House Project

To accompany the physical eBlock platform, the "Smart House Project" was developed as a guide book to introduce students and teachers to the platform usage while teaching engineering systems' design in a meaningful context where learners can make real life connections [13]. The module is composed of a storyline that describes a family moving to a new home and has students play the role of engineers hired to collaborate in groups to build a variety of systems using the eBlock platform.

Anticipating the diversity of learning styles and skill levels in the ASC classroom, the original version of the "Smart House Project" was modified to keep a balance between deductive instruction, active learning, and reflective experiences. The adapted version of the educational module (Figure 2) contains lessons featuring basic information of systems design, cookbook type guided activities, and open-ended activities. Lessons begin with direct instruction, providing an overview of systems design along with examples to illustrate the eBlock platform usage. Lessons were designed such that students' participation and

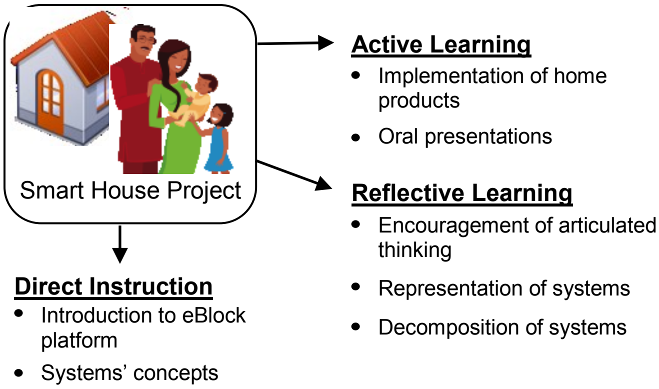

FIGURE 2
TEACHING METHODS USED IN THE SMART HOME PROJECT.

FIGURE 3
STUDENTS WORKING WITH THE EBLOCK PLATFORM TO BUILD A VARIETY OF MONITOR/CONTROL SYSTEMS FOR A SMART HOUSE APPLICATION.

interaction with each other gradually increased over the span of our intervention. In the final lesson students are provided with the opportunity to define and implement their own products by identifying needs and requirements.

III. Methodology

As part of this exploratory study, we describe our experiences during a three-week period working with six middle-school students (ages 11 to 15) diagnosed with ASC. All participants show medium to high-functioning skills in different metrics relevant to the autistic spectrum. All participants were able to speak, read and write. Students worked in groups of 3 to 4 during the intervention. There were two researchers, two auxiliary teachers and one teacher present in each session.

A series of six lessons, centered around the Smart House project, were taught over a three week period emphasizing two main research goals; (1) evaluate the use of the eBlock platform to stimulate social interaction among teammates and serve as a mechanism to enhance social skills, and (2) evaluate the ability for the hands-on projects to encourage abstract and creative thinking on the design of systems.

The lesson plans were organized to build progressively upon each other, starting with an introduction to the eBlock platform and the Smart House story line, coupled with close-ended learning activities and moving towards open-ended projects. The first day of testing students were introduced to the eBlock platform, how eBlocks can be used to design different systems, along with the opportunity to work with the platform. On day two, the Smart House storyline was introduced, written in the style of children's literature, the motivations and habits of a family who wish to have a smart house. As a group, the entire class brainstormed to define what types of systems could make up a Smart House and how they might use the eBlocks to implement these systems. In lessons three to five students built systems from well-defined requirements. Students also reflect and demonstrate how such systems can be utilized within the smart house. On the sixth and final day of our intervention, the students worked together to either create a new system for the Smart House or build their favorite system from previous lessons.

Reflective activities were fostered by asking students to articulate their thinking while they build a system, drawing representations of their designs, and prompted about the various components within their designs. Social interaction was encouraged by having students share their designs with others when they believe that they have built a "cool" system.

Throughout the classroom activities, data was collected in the form of teachers' pre- and post-surveys, qualitative observations, student worksheets, and quantitative observer evaluations. The questionnaire used in the teacher's pre- and post-survey is composed of 16 items: 6 items measure *Social Skills*, 5 items measure *Critical Thinking* and 5 items for *Excitement Levels.* The items were taken from the Gilliam Autism Rating Scale (GARS) and the Gilliam Asperger Disorder Scale (GADS) [14][15]. The teachers' pre- and post-surveys were used to evaluate teachers perceptions regarding social skills and creative thinking exhibited by the students during the intervention period. In addition to the rating scale, several fill-in questions were posed such as a description of the student's normal day-to-day interaction among peers and if the student's is able to think creatively. Statistical analysis was performed using SPSS statistical software, as the data was nonparametric the Wilcoxon analysis is appropriate to determine significance between pre- and post-survey answers.

Moreover, students were also asked to fill out a reflections worksheet to learn if they enjoy working in teams using the eBlocks, and creating systems for a Smart House. We speculate that if the students enjoyed teamwork during the intervention, it would be more likely for these students to want to work in teams again in the future.

OBSERVATIONS AND RESULTS

Through observations and student worksheets, we found that students demonstrated high excitement levels, active engagement, a basic understanding of the eBlock platform and how it relates to real life, as well as increased social interaction working collaboratively. Each student was able to complete the required project planned for each day, however the provided assistance varied. Table 1 shows the success rates for four of the guided projects, constructed by students, and categorized by the assistance level received. We define minor assistance as having to break repetitive actions that did not lead to a feasible solution, or providing a general hint to the participant. Major assistance is considered as having to provide specific hints or telling the participant exactly how to do the next step.

The Doorbell Application required students to construct a system that would alert a homeowner if someone were at the door, and typically consisted of a button and beeper block. A majority of the students (75%) were successfully able to build the Doorbell Application with no assistance, while only a quarter of the students required help. Students were asked to develop an alarm system with the requirement that an alarm must sound if the input code provided was not equal to 55. Only 20% of the students completed this task with no assistance, while the remaining students were evenly split between needing minor and major assistance to complete the task. We believe that because the Alarm System required a mathematical understanding of number comparisons, a larger number of students required help to complete the application. Conversely, in the Lighting System scenario, students were asked to build a system that turns on a light if it was dark or if a button was pressed. More students were able to complete this system on their own (25% compared to 20%) as no mathematical comparisons were needed, and fewer students needed major assistance (25% compared to 40%) when compared to the previous task. The most challenging issue for the students encountered in the Lighting System application stemmed from the use of an intermediate inverter to change the “no” light detected output, to a “yes” turn on the light. Lastly, a Temperature System was developed to turn on a fan if the ambient temperature reading was ever greater than 65 degrees Fahrenheit. Similar to the Alarm System, the Temperature System also required the use of number comparisons. However, we find that when students encountered a similar system later in the eBlock activities, the number of students who required major assistance dropped from 40% to 33% illustrating student growth.

While students’ ability to build a variety of systems using the eBlock platform is important, we believe that an ability to relate these projects to real life applications are equally, if not more, important as it illustrates that students are not just repeating memorized knowledge, but rather taking what they learned and creatively applying that knowledge outside of the classroom. Students were asked to explain in their own words the real world context of each project and how it could be applied to a Smart House. If the students were able to describe how the system could be used, and not just what the current implementation did, these students were considered to have a full understanding. If the student understood the functionality of the system and with further prompting questions could identify a practical

TABLE 1
SUCCESS RATES FOR VARIOUS SMART HOUSE PROJECTS.

Project	Unable to Complete	Completed with Major Assistance	Completed with Minor Assistance	Completed with No Assistance
Doorbell	0 %	25%	0 %	75 %
Alarm	0 %	40 %	40%	20 %
Lighting System	0 %	25 %	50 %	25 %
Temp. System	0 %	33%	50%	17 %

TABLE 2
UNDERSTANDING REAL WORLD APPLICATIONS.

Project	No Understanding	Some Understanding	Full Understanding
Doorbell	0 %	25%	75%
Alarm	20%	40 %	40%
Lighting System	0 %	50%	50 %
Temp. System	0 %	67%	33%

use for the system, then they were considered to have some understanding. As illustrated in Table 2, 75% of the students had a full understanding of how the Doorbell System would apply in a real-world scenario. However, as the complexity of the systems increased, it was not surprising to see students’ understanding similarly decreased. These findings suggest that the students understood basic systems concepts such as input, outputs and signal processing and were able to apply those theoretical concepts to a practical application using the eBlock platform.

When students were asked to create their own systems with no guidance other than the system had to have a purpose in a Smart House, all students were successful in creating a wide variety of systems. A total of five different systems were built in teams. Each team not only built a system, but also described the functionality of the system in a Smart House. For example, one team expanded on the simple doorbell system by adding a second doorbell, creating a two-doorbell system. The students explained that this system could be used in a home with multiple points of entry, for example, a front and back door. Students were able to build a variety of systems with planned purposes in the Smart Home, which indicates that they understood both the functionality and practicality of the eBlocks. We observed a shifting from students’ independent and parallel working mode to a more cooperative style, this behavioral change has also been observed in other research works with ASC subjects [7]. We speculate that this shift in working modes originated by three main factors 1) students acquired enough knowledge using the eBlock platform to actively purpose and describe to others their ideas; 2) students were motivated by building real systems and 3) there was a limited number of eBlocks per group therefore in order to

TABLE 3
COMPARISON OF TEACHER PRE- AND POST-SURVEYS LOWER SCORES SHOW AN IMPROVEMENT.

Student	Social Skills and Teamwork		Imaginative and Creative Thinking		Excitement Levels	
	Pre	Post	Pre	Post	Pre	Post
1	2.3	**2.2**	2.4	**2.2**	3.4	4.0
2	3.7	**3.0**	4.4	**3.4**	2.0	3.2
3	3.3	**3.0**	4.4	**3.4**	2.0	2.8
4	3.2	**2.3**	2.8	**2.6**	4.2	**3.6**
5	4.5	**3.8**	3.8	**3.2**	4.4	**4.0**
6	3.3	**2.3**	2.8	2.8	3.0	**2.6**

build more interesting systems students will have to cooperate and share the blocks.

In a reflections worksheet and post interview, students were asked whether or not they liked working in a team and why they had a particular preference. Only one of the six participants stated that they did not like working in a team. The other five participants indicated that working in teams was preferred because they were able to get help from their partners when they were confused. Additionally, all of the students stated that they enjoyed working with the eBlocks and wanted to learn more, as well as play with the platform again to create new systems.

In comparing the teacher pre- and post-surveys, we found there was a perceived overall improvement in both social skills/teamwork, as well as imagination/creative thinking. Table 3 lists the results of the teacher's pre- and post-survey assessment of each student. The questionnaire items were averaged across each construct. Perceived improvements are indicated in bold (Table 3). In the pre- and post-survey, a lower score is related to a more desirable outcome. A Wilcoxon test was conducted to evaluate the significance of the teacher's perceived improvement. The results indicated a significant difference in the constructs of *Social Skills and Teamwork*, z=-2.207, p<.05 and of *Imaginative and Creative Thinking*, z=-2.041, p<.05. Significant results were not obtained for *Excitement Levels* according to the teacher's response; the lack of change in excitement levels can be attributed to the extreme anxiety condition observed in multiple students. While a majority of the students were openly excited to be involved in the eBlock activities, a few students remained very anxious due to the disruption in their normal routine. However, we observed that once these students got involved, their anxieties tended to fade, but their initial anxiety was enough to impact the evaluation of the excitement levels construct in this study.

Overall, the results of the eBlock use in an ASC classroom are positive. We found that students and teachers perceived an increased in creativity accompanied by significant social engagement, thereby meeting both of our initial goals. Although the improvements may seem minor to an outside observer, for autistic students and educators

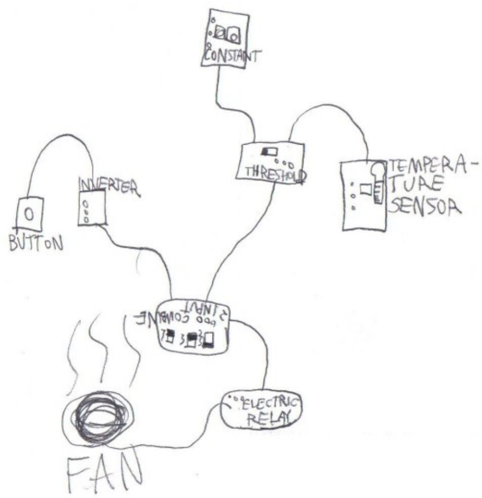

FIGURE 4
STUDENT WORK ILLUSTRATING A TEMPERATURE SYSTEM BUILT WITH EBLOCKS.

they are meaningful. According to the teacher, for these students to show any big leaps in growth it typically takes up to a year of continual teaching depending on the student. Considering this study was only six lessons over a three week period, the teacher was surprisingly pleased with how quickly the students were able to learn the eBlock platform and the concepts taught in this study.

INDIVIDUAL STUDENT OBSERVATIONS

We briefly highlight three student cases that are representative of our findings while working with eBlocks in an ASC classroom. To ensure the anonymity and privacy of participants, the names have been changed.

I. Chris

From the teacher pre-survey, Chris displayed a tendency to migrate to the staff or higher-level students for attention, not socializing with peers and often experiencing extreme anxiety that interfered with interaction and participation. However, from the pre-survey we found that Chris was able to hold conversations with peers, and when a concept is understood, exhibits an ability to generate unique ideas.

Throughout the eBlock lessons, this student was very enthusiastic, quickly understanding the core concepts and able to build each of the proposed applications easily. However, when Chris encountered anything confusing, he asked just enough questions until the concept was grasped, preferring to gather the knowledge needed to complete the task independently. In the first few lessons, Chris simply built what he was asked to build. Chris demonstrated an understanding of the taught systems concepts, built the required systems, and was done for the day. As the lessons progressed, Chris became more creative and eager to explore new ideas expanding the basic systems to create more elaborate designs (Figure 4). In the first few lessons, Chris provided teammates with the necessary help only when prompted. Toward the end of the eBlock activities however, when Chris observed their partners struggling, he would step in and start explaining how a particular block worked, or how a system might be constructed without needing to be prompted to do so. Chris demonstrated great teamwork, cooperation, and high socialization skills during the intervention.

II. Alex

Alex similarly showed improved social skills after working with the eBlock activities. Initially, the teacher described Alex as isolated, never showing any interest in interacting with peers. Alex was extremely focused on the eBlocks and enjoyed experimenting with the blocks to build a variety of system but had no interest in interacting with teammates. As activities progressed, Alex's desire to work with the eBlock platform overcame the apprehension of working with others. Initially, a great deal of prompting was required to work with others and share; however as the activities continued fewer interventions were needed. Alex willingly shared blocks when asked by teammates, showing a positive outcome in social interaction.

III. Jamie

In contrast, Jamie was described in the pre-survey questionnaire as always aiming to please everyone they interacted with. While Jamie is able to think creatively at times, specific step-by-step instructions are preferred. In the beginning, this student demonstrated a basic understanding of how the eBlock platform worked and was capable of creating a simple system; however, Jamie did not appear to be overly interested in working with the team to explore the platform unless provided with a specific task that was required for the lesson. As the eBlock activities progressed, Jamie began to ask teammates for help and in return shared a few ideas when prompted. Jamie began to ask questions and gather a greater knowledge about the eBlocks, which appeared to spark more interest in working with the platform and the team. Prompting was no longer needed to engage Jamie in activities with other participants, showing positive strides in teamwork as well as cooperation and social interaction.

These three cases demonstrate progressive improvements in social interactions and creative thinking skills, which were the main aims of this study. While no two students had identical experiences, the majority of students who participated in the eBlock activities showed promising behaviors in social skills and creative thinking in the design of systems.

CONCLUSION AND FUTURE WORK

Initial results suggest that hands-on experiences with the eBlock platform in combination with the Smart House project can positively impact social interaction and creative thinking skills in middle-school autistic students. All students involved in this intervention understood the concept of eBlocks platform, while in 95% of the cases students also had an understanding of how the various systems constructed translate into real world applications. While many learning technologies exist for autistic education, eBlocks offer a low-cost, non-expert platform to encourage teamwork, as well as enable students to develop a diverse realm of applications. Our goal is not only to develop technology that ASC students find attractive, but also to also accommodate the everyday challenges experienced by ASC students. We also recognize the importance of developing technology that allows ASC students to learn meaningful concepts. Our initial findings are encouraging and show the possibility of using the eBlock platform in autistic classrooms. In the future, we plan to expand our experiments to include a larger sample size and increase the eBlocks domain.

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