# Exploring the use of Virtual Learning Environments to support science learning in autistic students

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***Abstract*— Autism and Autism Spectrum Disorders (ASD) are general terms for a group of complex disorders of brain development. Autistic children exhibit certain characteristics in varying degrees including difficulties in verbal/ non-verbal communication, social interaction and repetitive behaviors. This paper discusses the role of Virtual Learning Environments (VLEs) in helping autistic children learn science and engineering concepts. VLEs are a type cyber learning environments created using Virtual Reality technology; as part of a learning activities, a set of VLEs to teach autistic students concepts in related to the solar system, robotics and density has been developed; assessment results underscore the potential of such VLEs to support science and engineering learning.**

***Keywords—Autism, Virtual Learning Environments, Cyber Learning***

## I. INTRODUCTION AND OBJECTIVES

This paper deals with exploring the use of Virtual Learning for teaching science and engineering to school students (elementary level, grades 1 – 5) with autism.

Autism and Autism Spectrum Disorders (ASD) are general terms for a group of complex disorders of brain development (in this document, the term 'autism' is used to encompass individuals across the length and breadth of the Autism Spectrum). Autistic children and teens exhibit certain characteristics in varying degrees including difficulties in verbal/ non-verbal communication, social interaction and repetitive behaviors. The disorder occurs more often in boys than girls (4:1). [59]. The Center for Disease Control (CDC) estimates that one in 68 children in our nation have autism [2]; this is a substantial increase since 2012 (when 1 in 88 children were reported to be diagnosed with autism). The causes of autism remain largely unknown; some research has indicated that genetic, neurodevelopmental and environmental factors are involved, alone or in combination, as possible causal or predisposing effects in the development of autism [5]. Virtual Reality (VR) is considered one of the technologies that holds potential to help individuals with autism be better prepared to lead productive lives [29-31].

**Objectives:** The primary objective of the research conducted was to explore the potential of advanced Virtual Reality (VR) based learning environments to help autistic school students in learn engineering / science concepts.

## II. BACKGROUND : VIRTUAL LEARNING ENVIRONMENTS (VLE) AND VIRTUAL REALITY TECHNOLOGY

A brief note on Virtual Reality and Virtual Environments is necessary to highlight certain key nuances of the technologies involved. Virtual Learning Environments (VLE) are Virtual Environments [61, 62] which are computer graphics intensive and use Virtual Reality (VR) technology.


Fig. 1-3 Non Immersive, Semi Immersive and Fully Immersive Virtual Environments

*Virtual Environments* involve the use of Virtual Reality technologies in creating a 3 dimensional artificial or synthetic environment which enables users to perform 'what if' analyses, understand target problems as well as compare solution alternatives for a wide range of domains. *Virtual Learning Environments (VLEs)* are virtual environments created and used for educational and learning contexts. Such VLEs provide information rich learning contexts where students can virtually interact with target environments to understand various engineering, scientific and other principles. *Virtual Reality* (VR) can be described as a 3 dimensional (3D) computer graphics intensive technology that allows users to interact at 3 levels of immersion: non-immersion, semi-immersion and full-

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immersion. Immersion refers to the ability of a user to 'go inside a virtual environment' and touch, navigate and explore more interactively. Typically, users will employ a variety of such devices (such as a controller or keypad). Non-immersive environments (NIM) are the most basic of such environments and do not provide 3D views (Fig. 1 shows a student interacting with such an environment). Semi-immersive environments (SIM) provide 3D stereo views of target environments using 3D eyewear and trackers (Fig. 2). The screen of interaction can be a computer screen (Fig. 1 or 6 b) or a much larger wall sized screen (Fig. 6 a). In fully-immersive environments, users can wear Helmet Mounted Displays (HMDs) (Fig. 3) on which the target environments are projected. Recently, immersive systems such as the Vive™ are low cost technology alternatives to more expensive traditional CAVE based technologies.

In general, it has been recognized that physical demonstrations appeal to the visual learners and lab exercises to the active and global learners [4, 60]. VLEs have the potential to enable visual learning as well as provide 'virtual' lab contexts that appeal to both active and global learners. In a recent NRC study [4], it was noted that computer simulations hold great potential for teachers to engage students while improving understanding of scientific principles in domains ranging from environmental science to physics [67-70] including treating phobias [6-19].

**Exploring technology mediums and avatars**

For the general student (or non-autistic) population, there has been limited research comparing the impact of using various cyber technology mediums and interfaces on learning (non-immersive, immersive, haptic etc.) [67-88]. Studies indicate that haptic augmented simulations [20 – 22] and use of avatars [27, 28] were more effective in helping school students learn while making the instruction more engaging. While these earlier studies involved general student populations, we hypothesize that haptic based learning experiences will also benefit autistic children; we will investigate whether the elements of choice, control and feedback provided through haptic interfaces can influence engagement and learning.

Many autistic students exhibit behavior deterioration and sensory dysfunction when interacting with multiple sources of sensory input [48, 59]. Virtual environments can help control how much sensory input children can experience while making generalization easier due to the degree of realism that it brings to specific learning contexts. Researchers have demonstrated that autistic children are not only more willing to engage in computer-based activities, but also found that the content of the programming can be transferred into classroom settings [56].

Most Autism Spectrum studies have focused on epidemiology, genetics and neurobiology; it is recognized that more intervention research is needed in order to help individuals with autism, their caregivers and educators [57]. Past studies have demonstrated using VR environments to teach autistic children how to cross a street [32-33] and for social skills training [43, 44]. Other researchers [46] agree that the potential of virtual reality technologies needs to be explored with great interest as it provides the technology capabilities of creating safe environments as they are (a) better suited to reduce and remove competing and confusing stimuli from a target environmental context, (2) are computer driven which enables modifications as well as allowing for 'learning breaks' depending on the participants and (3) most importantly allow explore positive stimuli to encourage interaction from students if necessary.

Some researchers have noted that thinking in individuals with autism is primarily visual [48]. VR based environments (as they emphasize 3D visual skills), seems a natural and appropriate modality for children with autism; this was our primary motivation in exploring the use of VLEs for children with autism as it provides a great avenue for learning new concepts and ideas. As virtual environments are computer driven applications, they can be modified if need be for individual students. While it is acknowledged there are general characteristics that people with autism share, effective approaches must be capable of being customized to meet the needs of individual students [35]. Further, specific imagery associated with a target VLE can be modified ('readjusted') to accommodate individual styles and patterns.

**Research Contribution**

The primary contribution of this research is to throw more light on the effectiveness of using Virtual Learning Environment (VLE) based learning approaches to teach science to autistic students.

## III. Design and Content of the Virtual Learning Environments

Cyber Tools have been shown to improve communication and social problem solving in autistic children [36 -41, 71], who have also demonstrated greater enthusiasm, motivation, attention, and response when a computer is used rather than toys or traditional teaching methods [55]. Some researchers [46] also agree that VR technologies needs to be explored as they (a) are better suited to reduce and remove competing, confusing stimuli from a target environment (2) can enable modifications and (3) most importantly allow exploring positive stimuli to encourage student interaction. Other researchers have noted that thinking in autistic individuals is primarily visual [48]. Graphics rich virtual environments can serve as a natural and appropriate modality that can be safe and exciting for an autistic child to explore and learn new concepts. While it is acknowledged there are general characteristics that autistic individuals share, effective approaches must be capable of being customized to meet the needs of individual students [35] to accommodate individual styles and patterns.

Virtual Environment and Virtual Reality (VR) technology hold the potential to help children with autism for several reasons [39, 40]. Large numbers of children with autism experience problems and encounter difficulty including behavior deterioration when interacting with multiple sources of sensory input [49]. Virtual environments can allow children to control how much sensory input they can experience (this in turn can be used to simplify complex stimulus arrays). Virtual environments and tools make generalization easier due to the degree of realism that it brings to specific learning contexts and situations.

As part of our research, several VLEs were created to teach school students science and engineering concepts. A total of 9 students participated in this research activity from elementary school level (grade 1 – 6).
A summary of the learning focus (topic addressed) along with the level of immersion used in the various modules is shown in Table I.

TABLE I. LEARNING AND TECHNOLOGY MATRIX USED IN RESEARCH STUDY

| Learning Focus | Immersion Technology | Haptic | Participants |
|---|---|---|---|
| Solar System | Semi-immersive | No | 2 second graders and 2 fifth graders |
| Robotics | Non- and Fully Immersive | No | 1 third grader, 2 fourth graders |
| Density (basic) | Non- immersive | Yes | 1 third grader and 1 fourth grader |
| Density (advanced) | Non- immersive | Yes | 2 sixth graders |

A description of these learning modules follows. Each module had a different immersive capability as shown in table 1.

### A. Solar System Module

The solar system module is a semi immersive environment where the user can see and interact with a 3D VR environment using stereo eye wear; however, the user if they want to can turn and look at the real world as the projection screen is only in front of them. Fig. 4 (a) shows a view of the semi immersive system used at the lab at Oklahoma State University (the blurriness disappears when you are wearing stereo eyewear). The learning environment introduces students to the various planets in the systems, their relationship to the sun as well as basic concepts in rotation and revolution.

The autism students who participated in this study were from grades 2 to 6 (a total of 9 students). The general approach used to evaluate their learning included first conducting a pre-test and then allowing them to learn interactively; the approach emphasized incremental learning where a student could go back and interact with the learning environment several times if they wanted to during the learning interactions.
Sample questions include:

(1) Which planets are neighbors of Earth?
(2) Can you identify the planet which has rings?
(3) Which is the planet closest to the Sun?
(4) Can you write or sketch what is meant by the term 'rotation'?

Fig. 4 a. View of the Semi Immersive VLE to learn Solar System Concepts

### B. Robotics Learning Modules

The robotics learning modules introduced the students to basic concepts involved in basic pick and place tasks while also introducing students to vocabulary relating to a robot. Three learning environments were used to support this learning. The first interactive learning environment was a fully immersive environment using a low cost technology called the Vive (from HTC); an image of a student interacting with this environment is shown. In this interactive session, visual cues were provided along with a mentor explaining how to virtually perform an assembly using controllers (similar to game controllers) and 3D eyewear. This was primarily conducted to introduce the autistic students to the process of "assembling something". After they were exposed to this 'virtual hands-on' assembly activity, they interacted with 2 other robotic learning environments. One of them introduced them to axial robots and assembly shown in Fig. 4b. Another module introduced to a different type of a robot called a Cartesian robot and assembly tasks (a view of this VLE is shown in Fig. 4 c). These modules focused on 2 different types of robots which had some similarities as well as differences with each other. Using a menu driven software, the students were guided to perform pick and place tasks of parts from target locations to target destinations. An avatar provided a voice over about the functioning of a robot as well as described the various parts of each robot (the base, the gripper, the arms, etc.). Subsequently, each student's learning was assessed through a set of questions. Some of these questions included:

(a) Which part of the human body does this part of the robot resemble?
(b) Of what use is the gripper?
(c) Can you point to the robot base?
(d) Can you assemble / move part X to destination P1?

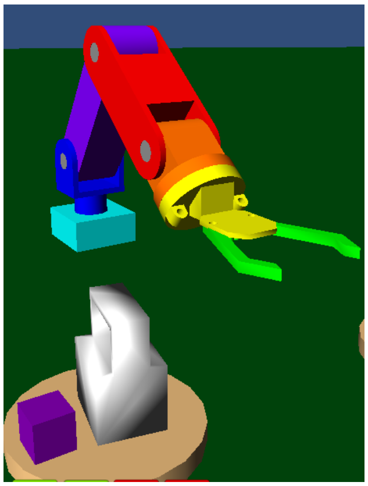

Fig. 4 b. View of a Robotics learning environment for axial robotss

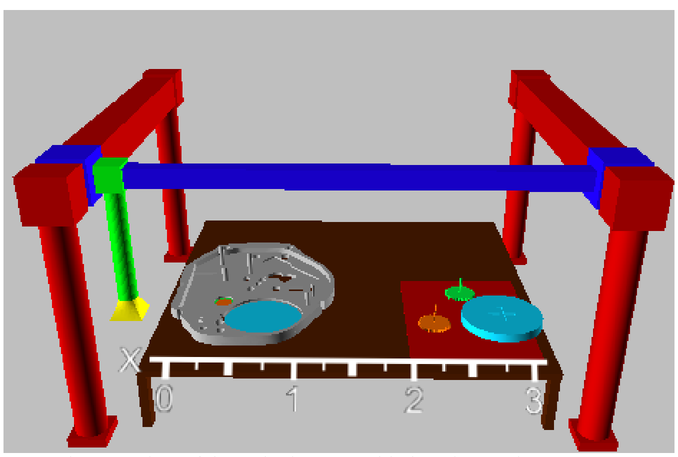


Fig. 4 c. View of the Robotics Assembly learning environment

Another advanced VLE was also developed to help introduce students to micro robotics assembly; in this environment (figure 4 d), the learning activities focused on the use of micro positioners and stages which allow more complex assembly to be completed; the robot gripper is capable of moving along the z axis while the assembly area plate can rotate to support more complex activities. The capability to move in different axis (or directions) was first introduced; the students were also introduced to the notion of a robotic work cell as comprising of a robotic gripper, other robot components such as micro stages (which help move the assembly plate as well as rotate it, etc.), an assembly plate on which parts can be assembled, and cameras for monitoring, among others. The students were assessed on the understanding of concepts addressed in this module; some of these questions include:

(a) What is a micro positioner?
(b) Can you show how the micro gripper can pick up a part?
(c) In what directions can each of the micro positioners move in?
(d) What are the components of the robotic micro assembly cell?

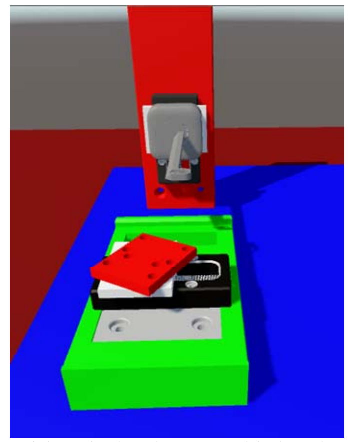

Fig 4 d. View of the robotic micro assembly learning environment

### C. *Density Learning Modules*

The density learning module was the most advanced of the learning modules. There were 2 learning levels: the basic module introduced the students to mass and size of bodies and their relationships to density; the students interacted with this module using a haptic interface which allowed them to 'feel' weight and resistance. The more advanced module introduced students to the equation relating density to mass and volume using virtual immersion experiments within a Virtual Reality environment; this learning environment was developed as a non-immersive desktop environment where a student could interact with a mouse and keyboard.

For the basic density module (figure 5), visual and text cues were provided as part of the interactive activities; as the students could 'feel' the weight of a part they picked up, they were first asked to answer basic questions comparing parts with different materials (metal and foam); subsequently, they were asked to reason about the space occupied by a given part along with what was meant by 'less dense' or 'more dense'. Some of the learning assessment questions for the basic density module included:

(a) When you picked up part A and then part B, which part felt heavier?
(b) In the scene above, which occupies more space or volume?

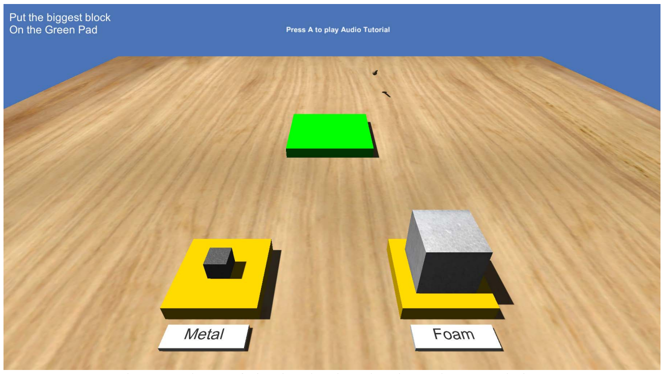

Fig. 5. View of the basic density learning module

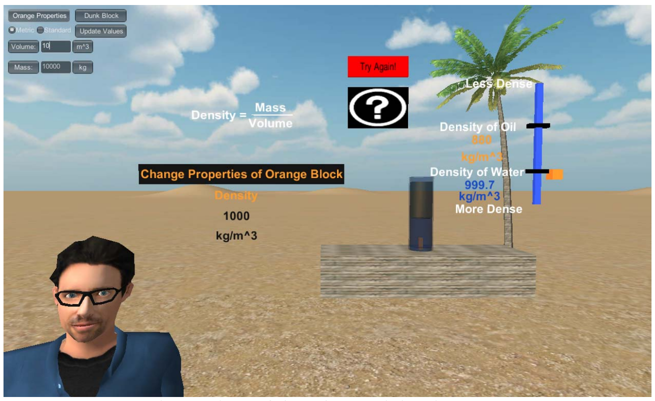

Fig.6. View of the advanced density VLE

The second density module (figure 6) was more advanced and introduced students to basic relationships between density, mass and volume. This module was aimed at middle school students (both were in grade 6). Using containers filled with different liquids (oil and water) and with parts of different sizes and densities, the students conducted virtual experiments observing and comparing various behaviors of objects and materials.

## IV. Assessment Methods and Outcomes

All the students were pre-tested and then post-tested; the number of attempts in obtaining the right answer was also recorded. The outcomes based on these tests is discussed in the context of each module. During the post-test based evaluation, students who did not get all the answers correct in their first attempt were encouraged to go back and interact with the VLEs as needed before they were assessed again.

Solar System concepts:

The two second graders were able to correctly answer only 2 of the 10 questions on pre-tests; in post-tests, both the students were able to answer 8 out of the 10 questions correct after one cycle of learning through VLE interactions. Both were allowed to go back and interact with the VLE to answer the two questions related to rotation of planets; after two more interactive learning cycles, they were able to answer all questions correct.

Robotics concepts:

For the learning interactions involving the robot VLE modules, during post-tests, the third grader was able to answer 80% of the questions correct after one cycle of learning interactions with the VLE and 100 % of the questions after two cycles. The other 2 students (fourth graders) were able to answer all of the questions correctly after one cycle of learning interactions with the VLEs.

Density concepts:

For the basic density learning, the third grader was able to answer 60 % of the questions after one cycle of learning interactions with the VLE and 100 % of the questions after two cycles; the fourth grader was able to answer all of the questions correctly after one cycle of learning interactions with the VLEs.

For the advanced density learning activities, one of the sixth graders was able to answer all of the questions correctly after one cycle of learning interactions; the second student obtained a score of 60 % after the first learning cycle; after 3 cycles of learning, this student gradually improved to scoring 100 %.

The research contribution in this ground breaking study is our conclusion underscoring the potential of adopting VLE based learning approaches to teach science and engineering to children with autism; based on our research studies discussed in this paper, we conclude that Virtual Learning Environments can help autistic students learn science and engineering concepts (from topics such as density to robotics); to the best of our knowledge, this is the first reported research paper focusing on exploring the impact of such Virtual Reality VLEs and haptic based environments to support science learning for students with autism. Another interesting observations is all the autistic student participants were enthusiastic about the learning interactions; the majority of the student participants also indicated a preference for the semi-immersive and fully immersive learning environments. While this study is ground breaking in its focus on science and adoption of innovative VLE based approaches, it is equally important to underscore the need for additional studies to throw more light on the learning patterns of autistic students. Another initial conclusion is that each autistic student may have different rates of learning (which is reflected on the number of learning interactive cycles); additional studies are needed to compare the effectiveness of haptic based learning environments to non-immersive and semi-immersive learning environments.

## V. Conclusion

This research focused on studying the impact of Virtual Learning Environments (VLEs) on helping autistic students learn science and engineering concepts. The VLEs were developed using non, semi and fully immersive technologies as well as with haptic technologies which allowed to touch and feel objects inside a learning environment. The learning modules dealt with exposing the students to concepts dealing with the solar system, basic robotics and density. Nine students participated in this study. The assessment outcomes indicated that a majority of the students were able to understand the concepts that was the focus of the learning activities of each of the learning modules.

The potential of adopting such VLE based approaches to support university level students also needs to be explored. With the increased level of occurrences of autism among children, it behooves us as a nation and as a community to explore innovative ways which will enable autistic students to learn science and engineering.

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