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Visual Disabilities, Information Technology, and the Learning of Mathematics

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INTRODUCTION

Students are any nation's future work-force; they shape the future and influence the economic wellness of countries. Students with disabilities are often limited in their ability to function in daily life. Policy makers have emphasized the importance of inclusion of individuals with disabilities. For example, the Assistive Technology Act emphasizes that disability is a natural part of someone's life and it should not deprive anyone of their rights, such as education, employment, and all kinds of society participation and integration: social, political, economic, cultural, and educational. However, in practice, there are several instances where people with disabilities are not given the same opportunities as their peers; as a consequence, they are missing opportunities to improve their quality of life.

Vision impairment is one of the most challenging disabilities for students. Visual impairment is a disability that affects individuals in all aspects of daily life – e.g. inability to read prints, limitations in performing tasks that need a level of detail, challenges in mobility, and difficulties in recognizing people and objects (American Optometric Association, 2010).

Among the efforts made to address this situation, *assistive technologies* play a critical role to aid individuals who are visually impaired. Assistive technology products take many shapes. The goal behind these technologies is to enhance the functional capabilities of individuals with disabilities. These solutions help with simple to sophisticated tasks that might be impossible to fulfill otherwise. In particular, assistive technology has a significant role in education; many countries enforce laws to provide equal access to technologies for students who are disabled. In the past 20 years, students with disabilities (including those with impaired vision) have been increasingly integrated into mainstream classrooms. Such inclusion entails the facilitation and availability of a solid assistive technology infrastructure and tools in these schools. Assistive technologies in education are aimed to ensure that students with visual disabilities have equal access to instructional material, class collaboration, assignment work, and testing as their sighted peers.

Mathematics is among the most challenging subjects for all learners. Students who are visually impaired encounter additional challenges in learning mathematics compared to sighted students. However, there is evidence that, if given a proper experience to develop mathematical skills, students with visual impairments can gain levels of proficiency in mathematics at par with their sighted counterparts. This has prompted researchers to focus their efforts on developing effective solutions that target students with visual disabilities to open wider education opportunities for them in order to succeed in the mainstream world.

BACKGROUND

According to the latest estimates, 314 million people worldwide live with visual impairment due to either eye diseases or uncorrected refractive errors. Of these, 45 million are blind. (World Health Organization, 2010)

Vision loss varies from one person to another, and consequently the ability to interpret the visual input differs according to factors such as: type of visual

DOI: 10.4018/978-1-4666-5888-2.ch033

impairment, severity of the case, cognitive ability, and previous knowledge of the context (Alberta Education, 2006). Limited vision affects information reception, which in turn limits individuals' capabilities in many tasks (e.g., learning). In particular, learning disabilities occur when there is a deficit in one or more of learning skills: absorbing, remembering, processing, organizing, analyzing, synthesizing, and applying information as well.

Mathematics, viewed as the abstract tool to investigate quantitative measures and dimensions (e.g., space, numbers, change), is a core instrument underlying our understanding and practices in a variety of different disciplines, such as engineering, economics, social sciences, medicine, and natural sciences. Mathematics is highly dependent on visualization, and hence, the visual processing is essential in learning mathematics. While in early years of school mathematics is related to daily practiced activities and concepts, the nature of the subject gradually becomes more complex, abstract, advanced, and more representational (Tanti, 2006). Mathematics is basically taught in visual written notations rather than verbal communication (Edwards & Stevens, 1994; Schleppenbach, 1997). These mathematical representations are very complicated, rich, bi-dimensional, and have a spatial nature.

Students who are visually impaired have challenges in the conceptual understanding and procedural fluency in mathematics due to the lack of visual perception of information, limitations in visual memory, and ability to build visual-spatial relationship images based on prior knowledge of concepts. These limitations create difficulties in areas like accessing, formulating, representing, and solving mathematical problems. However, vision loss does not affect cognitive structures (Agrawal, 2004). In fact, visually impaired students need multisensory experiences in order to learn and apply mathematics. The presence of perceptual inputs, that rely on touch instead of vision, and allowing more time for students to understand given complex concepts, make it easier for students who are visually impaired to learn the subject. The use of tactile manipulatives, Braille codes, assistive technologies, and suitable teaching methods, enables visually impaired students to learn like other students (Tanti, 2006).

In the early years of school, mathematical concepts are communicated to students through the use of concrete functional manipulatives (The Little Rock Foundation, 2011). At the elementary level, the need for other tools starts to match the increased complexity of mathematics. These tools include Braille textbooks, if large font material or magnifying lenses do not work, Braille writers to record data on Braille special paper, abacus to carry out calculations, pocket slate, and talking calculators for more complicated calculations.

ADVANCED MATHEMATICS AND THE NEED FOR EXTRA HELP

Although the previously mentioned approaches are effective to help visually impaired students in handling mathematics at the elementary level, they are less suitable to handle mathematical content that is more advanced (Gugerty, 2008).

Mathematics at the secondary and college levels is not easy for many reasons. At the college level, instructors are not familiar with using Braille (e.g., Nemeth code) in advanced mathematics topics (Gardner et al., 2002; Pontelli et al., 2009). In addition, instructors are neither prepared to accommodate disabled students in classes, nor used to dealing with the special equipment and approaches that meet the special needs of students with visual impairments (Durre, 2010). Besides, the volume of terms and vocabulary in the visual context of representing mathematics in advanced topics is larger than what has been made accessible through Nemeth code notations, and unfortunately is not always straightforward to render non-visually.

At the college level, where the use of special education instructors is not the norm, students who are visually impaired face significant challenges in following the non-verbal instructions for which there is no adequate verbal counterparts (Durre, 2010). Instructors tend to the use of the blackboard and electronic media to express ideas rather than orally conveying concepts. Adding to that, advanced topics in algebra are based on complex structures that are not redundant; any omission of one symbol can dramatically change the semantics of the whole algebraic expression. The complexity of representing sophisticated mathematical notations using Braille requires the student to invest an excessive amount of effort in writing and a hierarchy of steps to be performed (Tanti, 2006). Advanced mathematics tend to rely on visually challenging activities (e.g., drawing, graphing, sketching, hierarchies of inter-related steps), making it harder for students to reach a satisfactory operational comfort level, especially when

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