Better Education Opportunities for Students with Autism and Intellectual Disabilities Through Digital Technology

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Abstract: The provision of new opportunities to maximize learning is a fundamental right for all students. This paper explores the role of digital technology in the provision of educational opportunities for secondary age students who have been diagnosed with an intellectual disability and/or autism spectrum disorder. We describe a learning environment in which a range of technologies have been introduced to enable students' access to the national curriculum, and acquire skills that improve their ability to navigate the world outside the classroom. Through a qualitative study, we describe promising experiences of emerging technologies used to assist learning at the Inclusive Education Centre of a public secondary school located in regional South Australia. Our results suggest that emerging technologies can provide guidance to groups of students, encourage them to express their ideas, motivate physical activity, and improve general social interaction skills. In particular, we explore the impact, limitations and future opportunities of immersive virtual reality and social robots.

Keywords: Equal education, autism, intellectual disability, technology, social robotics, virtual reality

Parents, families and the global community expect formal education to provide a myriad of opportunities for all individuals, regardless of ethnicity, gender, geographical location, socioeconomic disadvantage, and disability to engage in a rigorous, challenging, authentic, real-world curricula (Saggers et al., 2016). This requires an instructional pedagogy that provides students with the motivational framework to engage successfully in new learning, and activities outside their comfort zone and personal experience.

There is little doubt that decisions made by teachers about the way in which they structure tasks, set expectations, stimulate or impoverish the educational environment, create the balance or imbalance in learners. It is universally acknowledged that digital technology has become an integral element of daily life for many young people (Lever-Duffy et al., 2004; Palfrey & Gasser, 2008; Sharma, 2016; Shelley et al., 2010). In fact, mainstream education has heralded students as digital learners, who integrate technology and multimedia as part of their core learning strategies to innovatively solve and deal with real-life issues both at school and home (Beetham, 2013; Prensky, 2001; Thompson, 2013; Trilling & Fadel, 2012).

Twenty first century learners are visually oriented, ‘entertainment’ focused, goal oriented, able to efficiently engage in multi-tasking, and communicate across a range of digitally complex and integrated levels (Beetham, 2013; Shelley et al., 2010). Digital technologies including video conferencing, virtual environments, and online classrooms are already becoming the standard learning tools that stimulate student ownership, lifelong learning and the development of international community partnerships (Koper, 2014; Lane, 2012; Ward, 2015). This allows teachers and students to exercise their imagination and integrate possibilities into realities, facilitating more self-directed learning (Beetham, 2013; Candy, 2004). Through the creation of global community networks, digital technology facilitates collaborative mentoring and the development of curricula that reflects constructivist pedagogies that embrace emerging technologies (Amarin, 2013; Clarke et al., 2008; Kozma et al., 2003).

In this paper, we argue that digital technology is central to the integrated learning experiences of young people with a diagnosis of intellectual disability (ID) and/or Autism Spectrum Disorder (ASD). Digital technology is already used to support traditional education, and underpins teaching pedagogy that enables students to acquire the skills necessary to navigate the world outside the classroom (Newbutt et al., 2017; Bauminger-Zviely et al., 2013). Technology can provide environments that allow for self-paced learning and immediate feedback, while minimizing the need for ‘real world’ social interactions during the learning process, a common source of anxiety for these student populations (Golan et al., 2006).
This paper reports on a qualitative study, implemented using focus groups and semi-structured interviews, at the Inclusive Education Centre (IEC) of a public secondary school located in regional South Australia. Our results describe promising experiences of different technologies used to assist learning. In particular, we explore the impact, limitations and future opportunities of immersive virtual reality and social robots from the perspective of parents and staff members.

The Impact of ASD and ID

ASD (hereafter referred as autism) is an ongoing neurodevelopmental condition that results in deficits in communication, social interaction and behavior (American Psychiatric Association

2013; Carrington et al., 2015; Kent et al., 2013). The degree of the impairments related to autism varies significantly across a spectrum, ranging from severe to near-typical social functioning. Characteristics such as narrow interest focus, social and emotional isolation, limited communication, increased frequency of repetitive behaviors, and low capacity to form and maintain relationships can reduce the learning opportunities in students on the autism spectrum (Baird et al., 2003; Bieniarz, 2011; Dahlgren, 2002; Jones et al., 2001; Kenny et al., 2015; Saggers et al., 2016).

Speech and language deficits are evident in early childhood, and form one of the key diagnostic criteria for autism (Prelock & Nelson, 2011). Almost 50% of children on the autism spectrum present with insufficient spoken language for effective communication (Koegel, 2000), with many never developing functional speech. Some will use non-verbal means to express their needs, while others will speak in phrases or sentences that have little-to-no meaning to others (Wainer et al., 2014). When present, verbal communication might be characterized by repetitive or idiosyncratic speech. Additionally, many autistic individuals possess high levels of social anxiety, lack of spontaneity, or have difficulty initiating verbal and non-verbal communication with others, making interpersonal communication challenging.

O'Brien and Pearson (2004) observed that 30% of young people with a severe learning disability are likely to be autistic, and 75% of individuals on the autism spectrum will have a severe learning disability. The impact for some can be significant and reduce the quality of life (Farley et al., 2009). On completing school, young people with ID and autism are far less likely to move into the labor force than their mainstream age peers (Sardo, 2013; Siperstein, Parker & Drascher 2013).

Digital Technology in Special Education

It is well known that young people enjoy playing with computers and mechanical devices. Mainstream technologies—including Mobile Apps, computer games and virtual reality devices––are commonly used to facilitate interpersonal communication for students with intellectual disability and autism (Grynszpan et al., 2014; Bauminger-Zviely et al., 2013; DiGennaro et al., 2011;). It is often believed that by using first-person, realistic-looking, computer-generated environments, students can develop a functional range of daily living skills (e.g. social and communication skills) that would increase their opportunities for a more independent life (Newbutt et al., 2017; Bozgeyikli et al., 2016; Newbutt et al., 2016; Rajendran, 2013). Although these technologies appear to be effective, a significant concern is that the large gap between the safe and structured environment of computer-based interventions and real-world social behavior may result in poor transfer of skills to real world interactions (Bauminger-Zviely et al., 2013). In recent years, consumer grade socially-assistive robots (SARs) and head mounted displays providing 3D immersive virtual reality (IVR) have become affordable and available to the consumer market. These technologies allow people to undertake realistic experiences with high levels of engagement and potential for ecological validity.

Socially-assistive robots. The field of socially-assistive robotics entails the design and implementation of machines (robots) that aid humans through social interaction, rather than physical intervention. The use of robots as attractors, mediators, or assistive tools during therapy for children with autism is one of the first applications of SARs (Feil-Seifer & Mataric, 2009).

To date, existing research in this field has been focused in three main categories: the use of robots to (a) increase engagement and motivation; (b) elicit behaviors and (c) model, teach, and/or practice skills with young children (Diehl et al., 2014; Silvera-Tawil et al., 2018). The outcomes vary according to the intervention method, the robot being used and the severity of the child's symptoms.

Immersive virtual reality. Virtual reality (VR) is a technique that uses computers to simulate life-like, interactive environments and avatars with realistic appearances that emulate the experience of being in an alternate physical space – a 'virtual environment' (VE). Educational virtual environments (EVEs) can be customized to the student's needs, with the potential to increase or reduce stimulus and distractions. Environments and social situations can be easily changed to provide hierarchical learning, reduce social anxiety and promote the transfer of skills across different contexts. Importantly, EVEs provide safe, non-threatening environments where mistakes have no real-life consequences, by providing new opportunities, raising awareness, improving confidence, as well as enhancing social skills and motor skills (Mikropoulos et al., 2011; Mitchell, 2007; Smedley, et al., 2005; Roussou et al., 2006; Munger, 2014; Yogeswara et al., 2013). It has been argued that the realism of computer simulated environments, as well as an increased sense of presence provided by IVR, can help promote learning and increase the probability that a person would generalize newly learned skills into everyday living (Miller & Bugnariu, 2016; Newbutt et al., 2016).

Context of the IEC

An IEC located in regional South Australia has created a technology-rich learning environment that aims to enhance the opportunities of students with moderate to severe intellectual disabilities, language communication disabilities, autism, Down Syndrome and significant severe and multiple disabilities. Eligibility for enrolment is determined by an educational psychologist and accommodates the learning needs of students aged between 13 and 19 years. Between 21 and 30 students are enrolled every year; all of whom have a One Plan (Education Health Care Plan) that outlines the student's educational programs, learning goals, health care support, accommodations, and transition pathways from school to work and the community. Students have the opportunity to undertake work experience, and engage in School-based apprenticeships, work readiness training or attend Day Options on completion of schooling.

During the last decade, a range of digital technologies have been introduced at the IEC to enable students to access the national curriculum and further develop life and work skills. Some of the available technologies include: digital manipulatives in mathematics, Raspberry Pi, Lego Mindstorm, laptops, tablets (e.g. iPads and Kindles), 3D printers, audience response systems (i.e. ActivExpression and Activote), Skoogmusic, Vernier Labquest, an ActivTable and a sound wall. Interactive whiteboards or a Promethean V4 ActivPanel are located in each of the learning spaces, and are used every day.

Learning and technology are interconnected across the IEC. Different technologies are used depending on the subject content. For example, the mixed Augmented and Virtual Reality laboratory encourages students' awareness, within a flexible exploratory framework, to demonstrate the illusion of depth by bringing the content 'alive' in the classroom. In Science, students can pull apart various elements of cells, plants, insects and skeletons and view them in 3D. They can view a virtual heart, look inside it, turn it around, follow the direction of blood flow and speed up the heart rate. The assembly and disassembly of Lego Mindstorm or a robotic arm, enables them to experience how a basic engineering concept is applied to make a simple robotic structure. Teachers and School Services Officers are gradually introduced to the complexities of new technologies, which they may have otherwise found challenging and intimidating. Consequently, students are exposed to progressions of experiential learning with multiple levels of engagement.

In June 2015, the IEC introduced two types of SARs: NAO and Paro (Figure 1). NAO is a small (58 cm height, 4.3 kg weight), programmable, humanoid robot developed by SoftBank Robotics. It is controlled using a Linux-based operating system, and includes a user interface that allows users to script robot behaviors. The hardware platform includes tactile sensors, speakers, microphones and video cameras, as well as prehensile hands with three fingers. It can reproduce sound, synthesize speech, and understand verbal utterances. NAO allows for a range of applications that stimulate the development of social and communication skills.

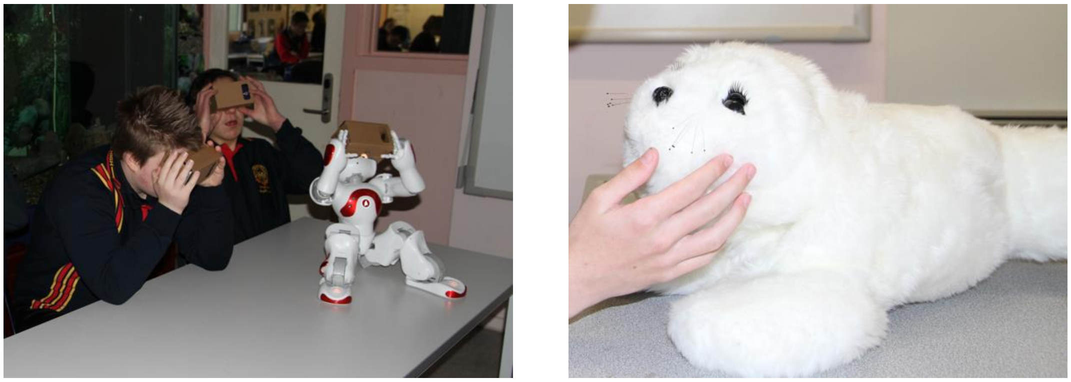

Figure 1. NAO (left) and Paro (right) robots with students from the IEC

Delivery of robot-assisted lessons (with NAO) at the IEC is generally done with groups of five to ten students, where the robots act as an instructor or a social mediator, and provide students with the opportunity to take individual turns. The NAO robots are individually scripted and programmed by staff members to be positive role models and provide specific guidance and instructions during lessons, encourage students to express their ideas and provide positive feedback and reinforcement. Lessons are often reviewed, modified and repeated according to the students' needs and interests, teaching requirements and other demands across the learning areas. Lessons are structured following different formats including: performance, role-playing, step-by-step instructions, questions and answers, and social stories. Under the programmed instruction from NAO, for example, students practice number and letter recognition using the coordinates in basic chess games, design pictures using shapes, cook meals in an industrial training kitchen, practice coding using Raspberry Pi and Lego Mindstorms, and construct Leonardo da Vinci's self-supporting bridge. Additionally, role-play is used to share information and model behaviors related to physical activities, personal safety (e.g. the safe use of a kitchen knife and a 3D doodler pen) and social interaction.

The NAO robots are normally scripted to respond to the students' speech or touch according to the requirements of the lesson. The LEDs in their eyes are programmed to change color depending on the context of the script, or when the robots are ready to listen. Together, these behaviors encourage turn taking, eye contact, active listening, joint attention, problem solving, social interaction and social communication. The NAO robots are used multiple times per week, depending on the curriculum focus and external activities across the IEC. Each individual session would run for approximately 30-45 min.

In contrast, Paro is a zoomorphic robot that has the appearance of a harpy seal cub. It was designed by Takanori Shibata of the National Institute of Advanced Industrial Science and Technology of Japan. Paro responds to touch and sound by moving its tail, head and opening and closing its eyes, while it simulates sounds similar to those of a seal cub. Paro's physical appearance, soft fur covering, and the movements of its flippers, eyes and tail often result in positive responses from the people who interact with it (Banks, 2013; Gelderblom et al., 2010; Kidd et al., 2006; Stanton et al., 2008; Robinson et al., 2013). Likewise, its simulated cries when touched or stroked provide a catalyst for relaxation and social interaction (Chang et al., 2013; McGlynn et al., 2014; Shibata et al., 2012). Paro was introduced as part of the animal-assisted therapy program with the IEC—together with a giant Flemish rabbit, chickens, a fighting fish and Australian green tree frogs—where it is used as a companion to encourage self-expression, relaxation and emotion regulation.

Since February 2017, additionally, all the students from the IEC experience an introductory programme to VR that consists of several short cameos of different VR contexts, including encounters with a dinosaur, origami animals, an alien, and a high-rise streetscape. After this initial familiarization with the technology, the students are given the opportunity to 'immerse' themselves in different scenarios that relate to their curricula, for example, IVR allows them to explore the African wildlife they observed during their work training at the Zoo. Immersion in a virtual ocean, furthermore, enables them to appreciate a pristine ocean when collecting data about ocean pollution, while a physics puzzle in IVR stimulates decision making, problem solving and risk taking, whilst learning about the effects of gravity and chain reaction. Likewise, a refugee crisis in IVR transports students to a beach with an escaping refugee family, encourages them to appreciate the sadness of war, and stimulates self-expression in Art when designing their refugee posters. Similarly, immersion into the human body allows them to explore the complexities of human physiology, while watching a story about a lonely hedgehog on his birthday encourages the students to feel empathy. During and after all VR sessions, the students are asked questions such as: What can you see? What do you feel? What is happening? What have you learned from this experience? What are the graphics like? They are also given the opportunity to share their experiences with their peers. The interaction with the IVR device is limited to once per week given that only one device is available for all students.

The VR device installed at the IEC is the Oculus Rift. Oculus Rift is an IVR headset developed and manufactured by Oculus VR. The headset includes an OLED display with 960×1080 pixels of resolution per eye, a 90 Hz refresh rate, and 110° field of view. It has integrated headphones, rotational and positional tracking. The headset's positional tracking system is supported by external infrared tracking sensors, which track the position of the headset device. The system includes Oculus Touch, a pair of handheld units (one for each hand) that can be used to detect hand movement and finger gestures within the virtual space.

Methodology

The aim of this study was to collect insights from parents/carers and staff members about the impact of the SARs and IVR at the IEC. Observations of the potential benefits, challenges, limitations and opportunities of these technologies were explored.

Procedure

This study was implemented 24 months after the introduction of the SARs at the IEC. Over the 24-month period (June 2015-2017), 28 children were enrolled and had multiple opportunities to interact with both technologies. Only three students were averse to wearing the head mounted device. Focus groups and semi-structured interviews were conducted between July and November, 2017. Each focus group was audio recorded and a thematic analysis was undertaken by the researchers. Ethics approval was sought and obtained in July 2017.

Participants

All parents/carers and staff members who were involved with the students from their IEC during the 24-month period were invited to participate. Nine focus groups and semi-structured interviews were conducted with a total of 18 participants; six parents/carers, six teachers, and six additional staff members including the school Principal and school services officers (SSOs).

Results

The Use of Technology at the IEC

Overall, participants responded positively toward the use of technology within the IEC. They noted that while different devices are widely used to support education, the more variety there is the greater the opportunities for students to explore their individual learning styles. However, parents emphasized the possibility of the students becoming obsessed with technology. While this hasn't happened with the robots and IVR devices, participants believe it is because they only have access to them at school, as learning tools, and during limited periods of time. Some parents acknowledged that their kids identify most technologies used at the IEC as learning tools, and prefer to do different things when they return home.

> *I have to say because it's so IT advanced in here [at the IEC], when [the student] gets home he has no interest in his iPad or computer… occasionally, he'll grab his iPad and play a game [Parent 3]*

Socially-Assistive Robots at the IEC

According to participants, the appearance and social aspect of the robots is a fundamental component of their success, and provide opportunities that are impossible with other technologies. NAO's small size, simplified human-like form, and monotone voice were referred as key elements in reducing sensory overload in the students. Paro's appearance, on the other hand, was described as cute, soft and cuddly, while its behavior was perceived as friendly and calming. Both robots were referred to as safe, patient, respectful, non-confronting and non-judgmental. Participants also highlighted the capacity of the robots to provide unlimited repetition together with the students' ability to manage the robots' pace (via touch or speech) as key elements in reducing the students' stress and anxiety, creating exceptional opportunities to achieve learning outcomes. Finally, participants mentioned that robots don't convey unexpected changes in behavior as a result of their 'own' emotions providing the level of predictability that was needed by the students.

Main benefits of the humanoid robot NAO. According to participants, NAO has proved to be an engaging social companion for students. It provides positive feedback, encourages active listening and reinforces positive social behavior. It was noted that with the introduction of NAO, students became more interested in schoolwork, demonstrating a willingness to listen and interact. It also provided a safe environment to develop learning in areas that would originally have been a cause of stress and anxiety, increasing the student's confidence and resilience. While NAO appears intelligent, participants believe that through its technical limitations it has created a safe environment where students feel comfortable to engage in new activities even if they were not proficient. Even after 24 months, it was noted, the students' enthusiasm to interact with NAO remained undiminished as the programs changed with the focus of the curricula and the developing needs of the students. Participants also mentioned that NAO's benefits extended to teachers and parents, by triggering creative thinking and innovation.

Benefits of NAO in learning. Staff participants noted that NAO's capabilities enriched instructional programs by stimulating the learning process, prompting self-initiated interactions, supporting participation, and providing positive reinforcement, encouragement and motivation. Students become involved in observational learning by imitating the posture, gestures and movement of the robots, as well as participating, albeit peripherally at times, in the learning activities, thus having an overall positive influence on their learning development. As a result, the NAO robots enabled students' development in a number of areas including academic skills, speech, life skills, social skills, physical activity, gross and fine motor skills.

Main benefits of Paro the robot seal. At the IEC, Paro was used as a calming strategy to help students reduce anxiety, and as an additional stimulus for communication, particularly for students with low functioning autism and limited verbalization. Participants highlighted that students with indistinct articulation, who did not initiate conversation with their peers, found time relaxing with Paro to be beneficial. For example. Paro's cries and movements resulted in smiles from the non-verbal students, who then progressed to stroking its fur, whilst students with severe and multiple disabilities responded with varying degrees of eye contact, hand clapping and smiles when Paro was placed in front of them. Although initially some students showed little inclination to touch Paro, they responded favorably to its presence and were content to spend extended time with it.

> *Sort of offers security to them... I think if [a student] had a bad day with mum she can sort of express... she can tell that to… Paro but not to anyone else. [SSO 1]*

Generalization and transfer of skills. Some of the skills learned using the robots seemed to transfer to different contexts. Staff and parents mentioned that they have seen improvements in the students' patience, confidence, self-expression, physical activity and emotion regulation. They also mentioned improvements in social communication, interaction and emotion recognition. According to participants, the simple step-by-step instructions provided by NAO were particularly beneficial in reducing anxiety outside the classroom, with many students now being able to separate complex tasks into small steps by themselves.

Limitations. Participants mentioned the robots' cost and fragility as the two main limitations. For this reason, the robots are only used during monitored situations. Participants also mentioned that a minimum level of cognition and verbal ability is required to maintain motivation when interacting with NAO. Participants also mentioned that effective use of the NAO robot requires commitment, imagination and technical skill. If the teachers are not creative, the robot would be a distraction for students and not provide any benefits. The difference in planning a lesson can go from less than an hour without the robot, to a day depending on the complexity of the lesson, and technical skills of the programmer.

Opportunities. While the robots were used only with students from the IEC, teachers noted they could be used with students from mainstream education classes who have mild learning disabilities. While teachers provide as much attention as they can, larger groups with varying levels of skills make it difficult, and students with cognitive disabilities fall behind, lose interest and concentration:

> *Some of these students fall between the cracks because mainstream education is too difficult for them, but the disability unit is too basic. [Teacher 1]*

Immersive Virtual Reality at the IEC

All participants responded positively toward the use of IVR devices and mentioned that VR is a risk-free environment where students can learn, make mistakes and learn from their mistakes, knowing that if they do the wrong thing, they are not going to get hurt. They also supported both single-user and collaborative VEs but emphasized that, to reduce potential anxiety due to the new interactions introduced into the virtual world, the transition from single-user to collaborative VEs should be slow.

Main benefits. According to participants, the student's engagement with IVR stimulates their imagination, encourages free expression and communication, extended attention spans and increases social communication as they relate their experiences to peers, friends, and family:

> *The other day when several of them had trialed it… they were all excited and talking… because it's on your own… they were then interested to hear about what the other person saw and having quite a discussion about it. [SSO 1]*

Participants also mentioned that the students enjoy the experience provided by the IVR devices, evident from student's comments[1] such as: "*the graphics were awesome*" or "*the scene was cool or fun*". It was noted that students observe the different environments, listen to the narrator (when available) and are often able to comment about the facts they watched or heard, including: "*elephants don't like meat but are fascinated by its smell... they eat plants*." Participants also mentioned that the VEs have triggered the student's feelings and empathy towards the virtual characters, and would make comments such as: "*you're never too prickly to make friends… anyone should be able to have a friend… it's good to get friends*"; "*I feel tingly, a bit happy, it feels real and a bit weird*"; "*I feel a bit weird watching a turtle because I've never seen a turtle in the sea before*"; and "*I feel frightened because great whites are scary*".

Limitations. According to staff participants, while most students have expressed their enjoyment using the technology and their want to use it again, others (approximately 9 out of 28) either disliked the headset or found the immersive experience confronting. The main challenge is that many people in the target population suffer from sensory sensitivities; their senses—sight,

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Student's comments were provided by staff members during the focus groups. The identity of the students who made the comment was not shared with the researchers.

hearing, touch, smell and taste—take in either too much or too little information from the environment around them. As a result, the audio-visual stimulus provided by the IVR device may also be overwhelming. Participants also mentioned motion sickness, also known as virtual reality sickness, as a potential limitation causing symptoms such as headaches, nausea, fatigue, drowsiness and disorientation:

> *Even before they [students] get to see anything, they've learnt to put this thing on their head… that might be confronting [SSO 3].*

Opportunities. When asked about the areas where participants believed IVR can beneficial, all participants highlighted that IVEs would be particularly helpful in areas that are either risky, or difficult to teach at school or at home, such as traveling or crossing the street. Staff participants also highlighted key elements for an independent life that could be taught using this technology, including phobia management, choice making, hazard identification, motor skills, and reinforce academic learning in all kinds of subjects matter from mathematics and science, to history and geography, allowing for better and deeper understanding. The importance of social norms and interaction associated with anxiety management was also highlighted by staff and parents. As noted, people with IDs and autism can find it difficult to understand social rules and unpredictable behaviors with small changes or deviation from their expectations, can cause significant distress:

> *He [the student] will see somebody swear or yell at things… if you could get someone like that in the virtual reality where it's controlled to teach him that you can still survive with [people] doing that… then he'll be able to join the rest of the world. [Parent 1]*

Another area of opportunity mentioned by participants was experiential learning. More specifically, experiencing activities that prompt imagination, creative thinking, emotion activation, reflection and a change of mindset or practices:

> *… when you ask them something, they are very limited in what their sort of experiences are… expanding their experiences will then create… perhaps they'll have a bit of a thought process and think and think, "Oh, I remember seeing this" [SSO 3]*

Conclusions

The provision of new opportunities to maximize learning is a fundamental right for all students. Unfortunately, many students with ID and autism, struggle to achieve parity with their mainstream peers. Emerging technologies, however, are demonstrating their influence for sealing this chasm. Through a qualitative research method, outcomes from this study suggest that technology can be used to engage students in multisensory, active, experiential learning that encourages active listening, increases motivation, reinforces positive social behavior and reduces anxiety, further improving learning across the curricula. The integration of SARs has been particularly effective, providing specific guidance to groups of students and encouraging them to express their ideas, involve themselves in physical activity and improve general social interaction skills. The SARs can be programmed to stimulate participation, provide real-time feedback, offer positive reinforcement, and demonstrate a patient, pleasing communication style across a variety of educational contexts. IVEs, on the other hand, had provided opportunities for students to stimulate their imagination, encourage free expression, empathy and communication.

Looking into the future, we may require changes at many levels of education. The broader educational systems need to be dynamic and spontaneous in the provision of digital technologies. Risk needs to be managed without diminishing the creativity of educational practitioners. While digital devices can be used to shape the learning process to meet the needs of individual students, research partnerships could provide new opportunities for students with ID and autism to acquire a range of daily living and social communication skills, enabling them to become more independent and productive members of the community.

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