Using Simulated Learners and Simulated Learning Environments within a Special Education Context

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Abstract. The needs of special education populations require specific support to scaffold learning. The design and use of intelligent tutoring systems (ITS) has the potential to meet these needs. Difficulty in the development of these systems lies in their validation due to the ethics associated in studying learners from this population as well as the difficulty associated with accessing members of this learner group. This paper explores the use of simulated learners as a potential avenue for validating ITS designed for a special education population. The needs of special education learners are discussed. Potential avenues for employing simulated learners and simulated learning environments to test ITS, instructional materials, and instructional methods are presented. Lastly, the expansion of an educational game designed to develop emotion recognition skills in children with autism spectrum disorder is used to illustrate how simulated learning environments can be used to support the learning of these students.

Keywords: Special Education, Ethics, Simulated Learners, Simulated Learning Environments

1 Introduction

Many intelligent learning environments have been shown to help learners who belong to the general population, but few existing systems have been shown to meet the needs of those who fall under the umbrella of special education [1]. Learners in this category have highly differentiated needs that are specified in an individual education plan (IEP) [2]. Their increased need for personalization and continuous reinforcement makes the argument for augmenting their education with intelligent tutoring systems (ITS) even stronger. However, this has not been done widely.

Several factors may contribute to the lack of ITS use within special education. The lack of validation that has been performed on the systems for special education populations [1], the difficulty of integrating ITS into special education settings [3], and the difficulty of designing activities that ensure deep understanding may contribute to the lack of ITS that support this population. The variability of learner needs presents additional challenges for system designers with respect to content development [3]. Furthermore, challenges that relate to the motivation, attitude, and social vulnerability of members of this population make it more difficult to design and validate systems. Developing systems for the special education population as a whole is difficult [4].

In addition to the above challenges, it may be difficult for designers to obtain access to a sufficiently large sample of the population to ensure that their ITS is beneficial in special education contexts. This is where the use of simulated learners and simulated learning environments can be advantageous since their use can mitigate the challenges presented by limited access to this vulnerable population and reduce the negative ethical implications of testing these systems on members of this population.

It is important to look at the research on situated learning in order to understand the achievements in best practices and lessons from research on simulated learning. Critical to this research is the combination of immersion and well-designed guidance that supports the situated understanding of learners whereby they not only have a deep understanding of the particular concepts that are being targeted, but the learners are able to then generalize and apply these learned concepts to other contexts [5]. Research shows that game-like learning through digital technologies is a viable tool across disciplines [6] and suggests that elements of game-like learning scaffold and guide learners towards a deep understanding of concepts. The on demand instruction of information that is vital to progress in the game is also important [5] and can be exploited to encourage learning. Simulations can include these elements and use stimuli to which special education populations react positively. Some stimuli that have been shown to increase student engagement include music, visual cues, and social stories [7]. Not only do these "strategies…help teachers increase engagement [but they] are vital for promoting positive outcomes for students" [7].

To support the argument for the use of simulated learners in this educational context, we first describe the characteristics and needs of this population as well as the learning environments in which they can be found. Following this, we discuss the use of ITS by special education students, which includes student interactions with agents. After laying this groundwork, we discuss the ethical implications and potential benefits to using simulated learners for validating ITS for use by special education populations. We then describe the potential uses of simulated learners and learning environments. This includes the description of an educational game, called EYEdentify, which was designed to develop emotion recognition skills in children with autism spectrum disorder (ASD). A discussion of how gaming principles and simulated environments can be further employed to expand EYEdentify for the purposes of helping scaffold learners' social interactions is provided.

2 Special Education

An introduction to the learning environments that exist in schools and the needs of learners who are classified as special education is presented. The use of agents and other forms of intelligent tutoring, within special education contexts, is then provided.

2.1 Learners and Learning Environments

These learners are either segregated into dedicated special education classrooms or integrated into classrooms whose majority population consists of learners from the general student body. Research has explored the design and integration of ubiquitous technology into special education classrooms [8], but few e-learning environments have been created to specifically support these students.

The needs and abilities of this population are highly variable, which can make generalizability hard [9]. This variability can be used to argue for the importance of personalizing students' learning materials, environments, and experiences, which is evidenced by the existence of IEP that detail the learner's specific needs and the accommodations that can be used to help the learner succeed [2]. Some of these accommodations include providing learners with additional time in order to complete tasks [1] or allowing learners to perform tasks using different modalities (e.g., oral responses rather than written ones) [2]. While these accommodations are necessary to ensuring the learner's success, it can be difficult to provide the necessary support, especially in integrated classrooms. The use of ITS that better support the individual needs of these learners could help alleviate the teacher's need to provide these supports.

2.2 Simulated Learner and Agent Use

While the use of agents within ITS used by special education populations has been studied, it appears that researchers and system developers are not simulating learners who have special needs. Nilsson and Pareto have instead used teachable agents within a special education context to help learners improve their math skills [3]. However, they experienced difficulty integrating the ITS into the classroom. Whereas, Woolf et al. were able to integrate their ITS into a classroom that had a mixed demographic: the class consisted of both low and high performing students, and of those who were low-performing, one third had a learning disability [10]. In this case, students interacted with an agent who played the role of a learning companion in order to support the learner's affective needs. It was found that this approach was especially beneficial to the low-performing students in the study, which may indicate the potential that this system holds for helping many of the learners who fall under the special education umbrella. Other work has also shown that interactions with agents within an ITS can improve or maintain learner interest and motivation [1].

3 Ethics

Given the vulnerable nature of this population, it is important that we not increase the risk that they are exposed to by introducing them to ITS or other learning techniques that have not been properly vetted since these could threaten the emotional well-being of learners or their learning success [11]. The use of simulated learners can help ensure that these systems are properly tested before we expose special education learners to them. Simulated learners can help teachers, instructional designers, and system developers meet the ethical guidelines of professional bodies by providing evidence of the limitations and appropriateness of the instructional methods used by systems or of the system itself [12].

4 Potential for Simulated Learner Use

We foresee two potential uses for simulated learners within a special education context both of which have been explored within other contexts. The first is during the development and testing of ITS [13, 14], and the second is for teacher training [13]. Using simulated learners in these ways provides developers and instructors with access to learners in this population and prevents any potential harm that could result from experimenting with members of this population. However, it may create a false sense of the validity and usefulness of different systems and instructional techniques, especially when we lack a full understanding of the abilities and symptomology of some members of this population (e.g., those with Phelan-McDermid Syndrome).

Generalizability is difficult to perform with this population [9], but some level of generalizability is required if a system is to be used by many people. Unfortunately, current design methods, such as participatory design, fail to address how the system's use and design should change over time. Furthermore, most users are unable to predict how they will use a system until they have integrated that system into their environment [15]. Carrying these challenges into the special education domain increases their severity because of the additional communication barriers that may exist between system designers and learners with special needs [4]. While observation is a component of many design methods, the lack of access to this population when combined with the communication challenges that exist reduces the feasibility of employing many of the more traditional user-centered design techniques.

Using simulated learners could benefit system designers and developers by allowing them to evaluate a system with various members of the special education population. This could reduce demands on a vulnerable population while allowing for some level of system validation to be performed. Furthermore, the use of simulated learners would allow systems to be tested with a far greater variety of learner types in order to identify where the system may or may not be beneficial. If the system were web-based, the simulated learners could be implemented using a Selenium test suite based on behavioural models of the system's target learners.

To effectively use simulated learners in this context, it is important to create these learners using different and competing theoretical models of their behaviours and abilities. This also alleviates some of the concerns that have been expressed over the use of simulated users when testing adaptive systems [16]. The source of these models can be teachers or special education experts since their mental models might inform good stereotype-based models of learners that capture general behaviours which are grounded in the expert's classroom experience. For example, haptic feedback can be used to reinforce certain behaviours (e.g., pressing a button) in children with ASD.

However, we would argue for also including models from other sources since the above experts are in short supply and cannot provide sufficient diversity in the models to ensure that systems are adequately tested for a general special education population. Simulated learners can be created from the cognitive models that are currently described in the educational psychology literature or through the application of educational data mining and learning analytics techniques to the logs of ITS usage where low performing and special education students were included in the classroom intervention. An example from the educational psychology literature could consider models of attention deficit hyperactivity disorder (ADHD), which include the amount of hyperactivity and inattention that a learner has, to create simulated students that behave in a way that is consistent with both the inattention that is known to affect individual outcomes and the hyperactivity that can affect the classroom environment for all students. Thus, allowing teachers to explore strategies that minimize the impact of both of the behaviours that characterize students with ADHD [17].

The diversity of models on which the simulated learners are based may help compensate for the inaccuracies that are inherent to modeling techniques, therefore, reducing the need for simulated learners to have high-fidelity cognitive models. Especially, since there is an incomplete understanding of the cognitive processes of all those who fall under the umbrella of special education, as is demonstrated by research in mathematics and learning disabilities [18].

That said, simulated learners that are based on these models could be used to validate the design of learning materials and to ensure their effectiveness or comprehension [13, 14]. Teachers could use simulated learners to test learning materials for their ability to increase learner engagement across a variety of contexts [7] before trying the materials on learners in their class. This would give teachers the opportunity to refine their teaching materials and confirm their suitability for students in the class.

Simulated learners can also be used to help prepare teachers either during pre-service training or before a new school year begins when the teacher is preparing for his/her incoming students [13]. The use of agents who play different types of special education learners reduces the need to worry about the possible negative consequences that mistakes would have on learners [19]. This use of simulated learners also holds the potential to reduce teacher errors since teachers can try new techniques with the simulated learners and learn from those experiences, which may reduce the risk of their committing errors with live learners.

5 Potential for Simulated Learning Environment Use

While simulated learning environments can pose a threat to learning because of the complexity of the learning experience [20], they still hold the potential to benefit learners with special needs. Simulated environments allow learners to take risks in order to develop a deeper understanding of the situations they encounter [5]. This can increase learner awareness of potential situations that could be encountered when interacting with others. Ideally, simulated learning environments would be used to help the learner develop and transfer skills into the real world by gradually increasing the external validity of the tasks being performed.

Simulations allow system designers to ensure that the problems or activities being studied resemble those that learners experience outside of the simulation [1] and they allow for the gradual increase in the complexity and ecological validity of tasks [21]. This means that learners can begin their learning activities in a simpler environment that is safe and progress towards more realistic situations, enabling the use of van Dam's spiral approach, where learners encounter a topic multiple times at increasing levels of sophistication [22]. This can help learners transfer their developing skills into the real world. Additionally, the use of simulations accessible on different technologies can shift learner dependence on experts to technology whereby learner use of the technology can help learners gain a sense of independence and begin to develop the skills required to expand and extend their interactions to the real world [23]. We illustrate this trajectory through a discussion of a mobile game that was designed to help children with autism spectrum disorder learn to recognize emotions.

5.1 EYEdentify: An Educational Game for Emotion Recognition

EYEdentify is a mobile application for the Android platform that is designed to develop the emotion recognition skills of children with ASD since these are lacking. Previous technologies that have tried to teach this skill to children with ASD have primarily focused on the use of videos to model emotions for the learner [24]. Current research focuses on social skill development through the use of interventions that use a video series to develop social skills by exploiting the relationship between facial expressions and emotion [4, 25]. Emotion recognition research suggests the most important features of the face necessary to correctly identify emotions are the eyes and the mouth [26]. Considering research on social skill development and advancements in portable technology, a mobile application that can support anytime-anywhere support to children with this deficit is timely.

EYEdentify is a game that uses a basic learner model to provide a flexible intervention in the form of an engaging game. It has an open learner model that can show the child's progress to parents, caregivers, teachers, and specialists. The first version of this application incorporates four emotions (i.e., happy, sad, frustrated, and confused) into a matching game that progresses through different levels (Fig. 1). There are three types of images that are used in this game to help scaffold the child's learning: cartoon robot faces, real faces that are superimposed on robot faces, and photographs of actual faces. The cartoon robot faces are designed to emphasize the eyes and mouth. The superimposed faces are designed to activate the child's knowledge of focusing on the eyes and mouth to correctly identify the displayed emotions while maintaining the scaffold of the robot head. The photograph of an individual making a particular expression is used to activate the knowledge from the previously superimposed images to correctly identify the emotions. Difficulty increases with respect to the type of emotion that is incorporated into game play and the types of images that are used. Positive feedback is provided to the child throughout the game to encourage continuous play. The game also has a calming event that is triggered by the accelerometer when the mobile device is shaken aggressively. The calming event increases the volume of the music that is being played and prompts the child to count to ten. The child is then asked whether or not s/he wants to continue playing the game.

Fig. 1. The gameplay screen with the correct responses identified (surrounded in green).

The mobile application provides the ability to customize game play by incorporating personalized feedback and images. Users can customize feedback by typing a comment and recording an audio message before adding this feedback to the schedule. Image customization uses the front camera of the device to capture individuals parroting the facial expression represented on the robot prompt. As children progress through the levels, they are rewarded with parts to assemble their own robot.

The current version focuses on developing emotion recognition skills for four of the fifteen basic emotions identified by Golan et al. [25]. The addition of the remaining eleven emotions could be used to extend game play. Currently, the mobile application is functional; however, more emotions are being incorporated and iOS versions are being developed before releasing EYEdentify on Google Play and the App Store.

5.2 Expanding EYEdentify to Include a Simulated Learning Environment

The expansion of EYEdentify to include a simulated learning environment draws on Csikszentmihalyi's definition of flow and research on gaming. Flow is described as the experience of being fully engaged in an activity where an individual is "so involved…that nothing else seems to matter" [27]. This is derived from activities where a person's skills are matched to the challenges encountered [27]. For learners, this means that they will be in a mental state that keeps them motivated to stay involved in a particular activity. Research in gaming and game design incorporates these psychological underpinnings whereby elements of a game seek to cultivate and support the player's active engagement and enhanced motivation [28]. In educational games, these elements are employed to scaffold learning just-in-time and provide instructors with the ability to adapt the system to the specific needs of the learner [29].

EYEdentify currently provides a matching game with rewards that are self-contained within the mobile application. Preliminary trials indicate that it keeps learners involved in the activity of identifying emotions for long periods of time. These trials parallel the findings of research that used a video intervention program known as "The Transporters" to develop the social skills of children with ASD [30].

EYEdentify's game play can be expanded into simulated learning environments to move players beyond the acquisition of emotion recognition skills toward the development of social skills. In creating game-based simulations for learners to use, the capacity to scaffold their learning within game play and support the development of transferable skills to the real-world increases.

There are several ways to expand game play into a simulated learning environment. All possibilities would require the mastery of basic emotion recognition and could involve levels of progressive difficulty that incorporates these emotions into depictions of social situations. The front camera of the mobile device could be used to scaffold the recognition of emotions by way of augmented reality, as could the recent introduction of Google glass. Avatars that represent individuals from the learner's day-to-day life could be used by learners to practice particular social situations. Additionally, game play could incorporate depictions of situations that model different social interactions. This could then be incorporated with a Sims-like environment where learners would have to identify the emotion of the character that they are interacting with and demonstrate the appropriate behaviour or emotional response. Specific to keeping learners engaged, the addition of an emotion recognition system that can detect the learner's emotion from the front camera and keep track of their emotion when playing the game to determine that learner's level of engagement would be useful. Through the development of these possibilities, EYEdentify has the potential to enhance learners' emotion recognition and social skill development in a way that enables the learner to transfer these skills to their day-to-day encounters.

6 Conclusion

The use of simulated learners and learning environments within special education contexts holds great potential for improving the quality and applicability of ITS use by members of this population. Simulated learners can be used to test learning materials, learning methods, and ITS to ensure their appropriateness for the members of this population, who have highly variable needs. The use of simulated learners and learning environments can be further exploited for teacher training. In addition to this use, simulated learning environments can be used to help learners who have been classified as having special needs to transfer their knowledge and skills to their everyday lives. The potential for members of this population to use simulated learning environments was illustrated through an example of an educational game, EYEdentify, that is used to help children with autism spectrum disorder improve their ability to recognize emotions. The described potential expansions of this game show how different approaches to simulated learning environments and the use of augmented reality can be used to help learners transition between the simulated world and the one they encounter every day.

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