Bridging Simulation Technology with Evidence-Based Behavior Management Practices to Support Early Career Teachers: An Interdisciplinary Approach

Abstract

Early career teachers working in high poverty schools face of overwhelming challenges navigating disruptive behaviors with studies highlighting behavior problems as one of the strongest predictors of attrition (Ingersoll & Smith, 2003). Simulation-based technology leverages important pedagogical strengths (e.g., realistic training context, opportunities for practice and feedback, low-stakes training) that may confer advantage over traditional training for teachers in behavior management. This manuscript describes interdisciplinary collaborations to develop Interactive Virtual Training (IVT), a simulation training model in which early career teachers practice responding to disruptive virtual students in a 3D classroom. Advisory board members (*N*=5) with significant teaching experience in high poverty schools provided iterative feedback on the authenticity, realism, and representativeness of three IVT components: vignettes, 3D virtual students, and 3D classrooms. Findings highlighted that the advisory board members rated the vignettes, students, and classrooms as logical and realistic with prototypes introduced earlier undergoing more revisions than prototypes introduced later. Descriptive feedback identified inconsistencies in vignette content and pedagogical issues. Implications for teacher training in behavior management, interdisciplinary collaborations, and using advisory board feedback early in the design of IVT are discussed.

Bridging Technology with Evidence-Based Behavior Management Practices to Support Early Career Teachers: An Interdisciplinary Approach

Early career teachers working in high poverty schools face profound and predictable stressors related to preventing and managing challenging behaviors. Studies document that early career teachers (with four or fewer years of experience) are “shocked” by persistent non-compliance and report a troubling discrepancy between their expectations regarding teaching and the stark reality of a complex classroom (Shernoff et al., 2015; 2016; Veenman, 1984). Teacher effectiveness in behavior management mitigates student behavior problems by improving instruction and increasing opportunities for learning (Creemers, 1994; Crone & Teddlie, 1995; Oliver & Reschly, 2007). Thus, training and support for early career teachers working in high poverty schools around managing disruptive behaviors represents a critical step toward facilitating successful school trajectories for students.

Limitations to Traditional Professional Development in Behavior Management

Behavior management encompasses a complex set of skills related to preventing and responding to challenging behaviors. Prevention includes proactive monitoring, establishing clear rules and expectations, and delivering engaging instruction. Responding to challenging behaviors involves non-punitive, non-reactive approaches and helping teachers develop skills in differential attention -- knowing when to attend and when to ignore specific behaviors using principles of operant conditioning (Kazdin, 2005). Developing early career teachers’ knowledge and skills in evidence-based behavior management strategies is a critical professional development goal given the empirical link between effective behavior management and student academic outcomes (Korpershoek et al., 2016).

Despite the critical role that effective behavior management plays in student engagement and learning, traditional professional development (e.g., workshops, whole group inservice training) has failed to produce substantial improvements in teachers' work related knowledge and skills (Penuel; Fishman, Yamaguchi & Gallagher, 2007). This situation is exacerbated for early career teachers who receive limited mentoring in behavior management (Grossman et al., 2008) and must acquire these skills on-the-job, with real students while delivering instruction. Fast-paced, high-stakes, live instruction leaves little time for practice with feedback, which can be costly to teachers and learners (Henry et al., 2011; Schussler, Frank, Lee & Mahfouz, 2017).

It comes as no surprise that early career teachers rank disruptive behavior as a significant stressor and their top ranked reason for initiating transfer requests or leaving the field of teaching (Gonzalez, Brown & Slate, 2008; Ingersoll & Smith, 2003). The inadequate impact of behavior management training on teacher knowledge and skill has been linked to the time-limited nature of training that leaves few opportunities for reflection and feedback to enhance future performance (Penuel et al., 2007). The focus of this manuscript includes describing the interdisciplinary collaboration to develop and refine Interactive Virtual Training (IVT; citation omitted for blind review). IVT is a virtual training computer system which simulates the real-life interactions between students and teachers, with 3-dimensional (3D) animated graphics. IVT is designed to support early career teachers to enhance their knowledge and skills in using evidence-based behavior management practices when confronted with aggressive, non-compliant, inattentive, and hyperactive virtual students.

Leveraging Technology to Support Early Career Teachers

Technology has been leveraged for years to train a range of professionals (e.g., surgeons, pilots, first responders) who make high-stakes decisions for which errors are costly. Simulation training models such as IVT include instruction delivered via personal computers or mobile devices. Simulation training is designed to immerse trainees in decision-making exercises in a 3D environment to explore and learn about the consequences of their decisions (Regalla, Hutchinson, Nutta & Ashtari, 2016; Sitzman, 2011). These training models leverage the interactive nature of video games to improve work-related skills and knowledge (Schrader, Archambault & Oh-Young, 2011; Sitzman, 2011; Vogel, 2006). Simulation training models, including intelligent tutoring systems (designed to provide guidance and support to learn new skills where thinking is made visible) and serious games (designed to immerse learners in a playful environment that also fosters learning and targeted skills) have been described interchangeably in the literature. This creates challenges for developers and researchers interested in designing, programming, and evaluating simulation training models (Girard, Ecalle & Magnant, 2012; McCarthy et al., 2012; Sitzman, 2011). It is also widely noted that there is a need for more scientific research on the effectiveness of the specific elements of simulation training (Girard et al., 2012; Hartson & Pyla, 2012; Sitzman, 2011; Vogel, 2006). Four elements of simulation training described below may confer advantages over traditional training models, in particular for supporting early career teachers working in high poverty schools.

Promotes realistic work scenarios. Simulation training builds on studies documenting that learning and transfer are maximized when users confront realistic work scenarios and make decisions that are relevant to their job performance (Bellotti, Berta & De Gloria, 2010; Sitzman, 2011; Tawadrous, Kevan, Kapralos & Hogue, 2012). A recent meta-analysis comparing the instructional effectiveness of simulation games to alternative training methods (Sitzmann, 2011) revealed that user confidence in performing training-related tasks was 20% higher, knowledge regarding how to perform specific actions was 14% higher, immediate memory for facts and principles was 11% higher, and recall was 9% higher in the simulation training condition versus comparison (alternative instructional method or no-training control). For early career teachers, access to an authentic, realistic virtual training experience may enhance their knowledge of how to respond to disruptive behaviors by observing the consequences of their decisions (Amory, 2007; Belloti et al., 2010; Gee, 2005).

Maximizes practice and feedback. Simulation training can also provide extensive opportunities for practice with feedback to develop users' knowledge and skills. Technology for learning can differentiate correct and incorrect selections for the user along with providing feedback on misconceptions and the best course of future actions (Heeren & Jeuring, 2014). For early career teachers, learning how to effectively prevent and respond to disruptive behaviors is a complex skill that improves over time (Denton & Hasbrouck, 2009; Sabers, Cushing & Berliner, 1991). Traditional professional development for new teachers may underestimate the time required to develop and hone these skills; for instance, a recent study documented that 50% of early career teachers required nearly two years to cultivate these skills (citation omitted).

Provides low-stakes training. When the stakes associated with making errors are low, deliberate decision-making may require less time, practice, and cognitive effort (Dunbar et al., 2014). However, when the cost associated with making errors is high, simulations may be uniquely advantageous due to the practical and ethical advantage of encouraging freedom to explore and fail in a low-stakes setting. Examples include training pilots to navigate challenging flying conditions (Fletcher, 2009), training novice clinicians to conduct assessments for clients at risk for suicide (Beutler & Harwood, 2004; Horswill & Lisetti, 2011), helping teacher candidates identify and respond to student bullying (Schussler et al., 2017), helping children to respond to bullies (Vannini, et al., 2011), and helping first responders make decisions during emergencies (Mantovani et al., 2003). As the achievement gap widens, there is a pressing need for early career teachers working in high poverty schools - where students are at greatest risk for academic failure - to develop their behavior management skills in a compelling but safe, low-consequence-for-failure virtual (but realistic) environment. This is in contrast to developing these skills on-the-job, with real students, for whom cumulative errors may have long-term consequences.

Enhances access. Improving teachers' behavior management skills is among the most important predictors of student learning (Atkins et al., 2015). Simulation, unlike individual consultation or coaching with early career teachers, provides an unprecedented opportunity to reach large numbers of teachers in need of support (Kazdin & Blasé, 2011; Kazdin, 2015; Schussler et al., 2017). Recently, avatars have been used to develop preservice teachers' classroom management skills (Dieker et al., 2008; 2014) in a mixed-reality environment called TeachLivE. Dieker and colleagues' work is groundbreaking and innovative by exposing teachers to disruptive avatars via a projection screen, with urban teachers in particular reporting a realistic and compelling training experience (Dieker et al., 2007). However, in the TeachLivE model, the avatars are controlled by actors using high-end laboratory equipment which may limit its reach.

IVT, in contrast, will be programmed such that the finite state machine will be integrated with the avatar to endow it with behaviors that can be activated, as opposed to actor-controlled avatars. IVT will also be web-based, allowing training to be accessed from a range of locations using a wide variety of computing systems available to early career teachers (e.g., Tablets, laptops, smartphones). Leveraging existing computing systems available to teachers may also circumvent the significant time barriers associated with teachers participating in live coaching during the instructional day (Shernoff et al., 2015; 2017).

Bridging Simulation Technology with Research on Evidence-Based Behavior Management

Interactive Virtual Training (IVT) for Early Career Teachers in High Poverty Schools is a

4-year Development and Innovation Grant funded by the Institute of Education Sciences (citation omitted). IVT will leverage innovations in 3D computer graphics, 3D animations of avatars and objects, auditory stimuli, visual user interface design, computational behavior modeling, and web programming to develop an interactive virtual classroom environment populated by virtual disruptive characters, or virtual humans (Magnenat-Thalmann & Thalmann, 2005). IVT is based on experiential learning theory (Kolb, 1984), which emphasizes that practice is critical for mastering complex skills such as delivering instruction and managing disruptive behaviors. Experiential learning theory further posits that mastery develops through concrete, physical learning opportunities in authentic learning contexts. These learning experiences form the basis of reflection and problem solving regarding what is working and not working, and how to improve during future performance (Kolb, 1984; McCarthy, Maor, & McConney, 2017; Schrader, Archambaut & Oh-Young, 2011; Schussler, Frank, Lee & Mahfouz, 2017).

Despite the instructional potential of merging simulation technology with evidence-based behavior management strategies, gaps in the literature remain regarding methodologies and tools to develop and refine 3D training programs (Alvarez & Michaud, 2008; Arnab et al., 2015; Jeremic, Jovanovic & Gaševic, 2009; Schrader et al., 2011). Thus, the aims of this manuscript included illustrating Year 1 development and refinement activities comprised of conceptual design, prototype development, advisory board feedback, and adaptations to three IVT components: (1) **Vignettes** (illustrating the sequence of interactions between teachers and virtual students) (2) **3D Virtual Students** (disruptive and non-disruptive), and (3) **3D Virtual Classrooms** (one first grade and one sixth grade classroom). Given affordances that 3D simulation training environments provide related to representational fidelity, the aim of the manuscript also included examining the authenticity, realism, and representativeness of the three

IVT components. With these goals in mind, research questions focused on examining the quality of IVT content, including the authenticity, realism, and representativeness of the vignettes, virtual students, and virtual classrooms.

Method

IVT Development Team

Bridging research on simulation-based learning technologies with research on evidence-based behavior management practices requires collaboration among experts from multiple disciplines. Experts, for example, in education, urban schooling, and teacher professional development are responsible for ensuring that IVT reflects current research on effective instruction and evidence-based approaches to preventing and managing challenging behaviors. The computer science team has expertise in 3D computer graphics, 3D character animations, responsive web technology, and learning technologies and has assumed responsibility for creating the virtual students and classrooms during Year 1. The computer science team will translate the vignettes into programmatic form during subsequent funding years. Usability engineers will also contribute expertise to the design and evaluation of 3D interactive systems to maximize user experience and engagement.

Although IVT end users are early career teachers, their limited experience in high poverty schools restricted the type of feedback they could provide regarding authenticity, realism, and representativeness. Therefore, five retired educators with significant teaching experience in high poverty schools (Mean = 31.8 years, SD = 13, Range = 11 to 35) served on an advisory board (four female, four European American, one African American, all with Master's Degrees in Education).

IVT Simulation Technology

Through simulation technology, early career teachers will view a 3D rendering of a first or sixth grade classroom with animated virtual students via first-person perspective. Using a mouse and keyboard, teachers can freely move about the classroom and will access IVT via Unity3D (www.unity3d.com), a powerful widely used cross-platform 3D game engine that will produce a web-based application of IVT. Through interactive storylines or vignettes, early career teachers will interact with virtual students who exhibit disruptive behaviors prevalent in K-8 schools (Junod et al., 2006). Disruptions include *off-task* (e.g., difficulty staying focused and following instructions; disorganization, wandering around the classroom) or *non-compliant* behaviors (e.g., arguing, refusing to follow instructions, verbal and physical aggression).

IVT will provide opportunities for early career teachers to *practice* responding to disruptive behaviors and master simple tasks (e.g., taking as much time as needed to respond to disruptive behavior) before practicing at more challenging levels (e.g., selecting an optimal response with time constraints; Buche & Querrec, 2011; Gee, 2003; Mayo, 2009). After early career teachers practice, they will *reflect* on the disruptive behavior, why it occurred, the relative effectiveness of their response, and plans for selecting different responses during subsequent training sessions. Because practice alone is unlikely to result in strategy retention or transfer without explicit feedback (Richey, Klein & Tracey, 2011; Tracey et al., 2014), teachers will also receive *feedback* regarding the type of strategy used (e.g., ignore, praise, redirection, empathy) and its relative effectiveness. The long-term goal is to develop a simulation training experience that has high representational fidelity and is highly interactive, both of which are theorized to enhance immersion and presence (Dalgarno & Lee, 2010).

An eight-week online course will complement the simulation training and is focused on building teacher knowledge regarding when and how to implement evidence-based behavior management practices. The online course will also focus on preventing behavior problems through clear rules and expectations, cultivating a positive classroom climate, and building strong student-teacher relationships (Evertson & Weinstein, 2006; Simonsen et al., 2008).

IVT Development Activities

Three major development aims were executed during Year 1 of the study, including developing the vignettes, virtual students, and classrooms.

Vignettes. Four vignettes (one for each of the primary virtual students) were developed in teams led by the first and second author. The off-task vignettes were developed first, followed by the non-compliant vignettes. These hypothetical scenarios were designed to simulate provocative teacher-student interactions in K-8 classrooms. Vignettes were generated based on the primary character's constellation of behaviors (i.e., inattention and hyperactivity or aggression and non-compliance). The team created biographical descriptions of each character's behaviors, likes and dislikes, strengths and weaknesses, and general personalities before writing the vignettes. These biographical descriptions helped the team write vignettes that consistently reflected a characteristic set of behaviors, language, and gestures. Key consideration was also given to creating vignettes that reflected the developmental nuances of first versus sixth grade classrooms (e.g., academic tasks, instructional activities) and students (e.g., vocabulary, tone).

Vignettes were guided by research highlighting the importance of proactive monitoring, identifying the early cues of disruption, effective redirection, and altering the antecedents (triggers) and consequences (responses) to disruptive behavior (Evertson & Weinstein, 2006; Simonsen et al., 2008). Teacher responses to disruptive behaviors were guided by evidence-based strategies (i.e., praise, ignore, redirect, use of proximity, instructions, empathy, if/then statements) designed to decrease inattention and non-compliance and increase engagement

(Evertson & Weinstein, 2006; Junod et al., 2006; Kazdin, 2005; Simonsen et al., 2008). Early career teachers will be provided with three response options and enticed to select less effective options early on (e.g., attending to misbehavior, arguing with a student who is angry). Vignettes progress such that virtual students escalate (become more off-task and aggressive) or de-escalate (become more engaged and compliant) based on how teachers respond to a character's behaviors. This simulated interaction mimics the interactive (antecedent-behavior-consequence) cycle of disruptive behaviors in real classrooms and reflects the influence of the environment in maintaining them (Kazdin, 2005).

Lucidchart (www.lucidchart.com), an online flow charting software, depicts the sequence of interactions between the virtual character and early career teacher and will be translated into programmatic form by the computer science team (see Figure 1). Yellow diamonds illustrate an upcoming decision point; orange hexagons reflect decision points for early career teachers; blue squares represent character actions and responses; white parallelograms represent non-disruptive character responses; and red ovals represent the end of the vignette. Each vignette includes at least five decision points minimum and nine decision points maximum. Vignettes will be executed in Unity using the MASCARET framework (Buche & Querrec, 2011). Via the MASCARET model, UML Activity diagrams are interpreted in the simulator to follow the flowchart and makes it possible for the system to interpret the vignette using computer language.

By way of example, for a sixth grade primary character "Jordan" who is non-compliant and aggressive, after an early career teacher player receives information regarding the goals of the lesson and the instructions provided to the classroom, the vignette begins with non-disruptive virtual students working quietly at their desks (see Figure 1). Jordan walks in late after the bell rings, flicks another student on the arm, and drops his textbook, pencil, and notebook loudly on his desk. At this point, the early career teacher must make his or her first decision. **Option 1** Ignore Jordan, **Option 2** Call attention to the fact that Jordan is late again, and **Option 3** Welcome Jordan to the classroom and direct him to complete the assignment. Based on the early career teachers' initial decision, the vignette proceeds, and at each subsequent decision point, teachers receive three options for how to respond to Jordan.

Virtual 3D students. Year 1 also focused on developing 3D virtual characters (30 total, 15 per classroom). Primary considerations included creating virtual students who were racially and ethnically diverse reflecting realistic demographics in high poverty schools. Students were assigned a range of skin coloring, hairstyles, and body shapes sizes and were dressed in standard uniforms commonly worn in K-8 schools in high poverty communities. Table 1 illustrates the age, gender, and racial/ethnic demographic characteristics of the final set of virtual students.

The first phase of developing the virtual students included using stock photos of first and sixth grade children to guide the creation of the 3D models for each character. After a range of characteristics were identified using stock photos, the computer science team developed and modeled a mesh of body geometries (i.e., head, torso, arms, legs, eyes, hair, eyebrows, eyelashes), skin material, and pose. Those 3D face models were then sculpted to create a diverse set of proportions. Next, guided by the early stock photos, the computer science team designed objects for different hairstyles, including braids, bangs, ponytails. Texture maps were created for the school uniforms along with a skeleton for the characters to prepare them for animation. Finally, characters were rendered in Unity3D and shared with the advisory board for feedback.

Four primary virtual students are featured as the main protagonists in each vignette. These four students' behavior will be programmed (during Year 2) to interact with the early career teacher according to the various vignettes paths: two off-task primary characters (i.e., one first grader and one sixth grader) and two aggressive and non-compliant primary characters (i.e., one first grader and one sixth grader). The behaviors of the remaining twenty-six non-disruptive characters (13 per classroom) will be programmed to cycle through a set of pre-defined behaviors (e.g., reading, turning a page in a book, looking at the board).

Virtual 3D classrooms. Two classrooms (i.e., one first grade and one sixth grade) were developed and iteratively refined during Year 1. The first grade classroom was developed first, followed by the sixth grade classroom. Key considerations to enhance realism and authenticity included object placement, size, organization, textures, and lighting. Given the high poverty context, close attention was also paid to depicting a resource-limited classroom environment, including desks that appeared worn, books that appeared used, and limited material resources.

The first classroom was developed from scratch by the computer science team. Given the notoriously labor-intensive task of creating realistic 3D graphics, in order to accelerate the graphics development phase, the team purchased relevant 3D objects available from Turbosquid (www.turbosquid.com). Some Turbosquid objects (e.g. chairs, desks) met specifications for the classroom while other features (e.g. textures, proportions) required significant changes to adhere to visual requirements for IVT. Stock photos of first and sixth grade classrooms also guided early prototypes of the classroom and the computer science team also created vital objects unavailable from Turbosquid (e.g. a rocking chair and carpet area for the first grade classroom, cubbies for the sixth grade classroom, backpacks, school supplies, American flag).

Measures

Three measures were developed to assess the authenticity and realism of the vignettes, 3D students, and classrooms.

Quality of vignettes. Advisory board members rated the extent to which the primary and non-disruptive characters' behavior, actions, and dialogue were logical and realistic based on their age (first or sixth grade) and presenting problem (off-task or non-compliant) on a 4-point scale, from 1 (*Strongly Disagree*) to 4 (*Strongly Agree*). In addition, advisory board members rated the logic and realism of the teacher response options based on grade (first versus sixth) and presenting problem (off-task versus non-compliant). Advisory board members also provided an overall rating of the degree to which they agreed that the storylines were engaging and contributed descriptive feedback on vignette strengths and suggestions for improvements.

Quality of 3D virtual students. Advisory board members rated the extent to which the virtual students looked authentic with regards to developmental nuances for their face, body, clothing, and hair, with each dimension rated on a 4-point scale from 1 (*Poor*) to 4 (*Outstanding*). Advisory board members also provided descriptive feedback regarding what they liked along with recommended changes to the physical characteristics of each character.

Quality of 3D classrooms. Advisory board members also rated the quality and realism of the classroom physical arrangement (e.g., room size, desk arrangement, placement of furniture), wall décor (e.g., bulletin boards, student work displayed, classroom rules), materials/supplies (e.g., books, paper, notebooks), and physical appearance (e.g., lighting, shadows, color). Each dimension was rated on a 4-point scale, from 1 (*Poor*) to 4 (*Outstanding*). Advisory board members also provided descriptive feedback regarding what they liked and suggested additions, deletions, and changes.

Data Collection and Analysis

A rapid prototyping approach (Kelly et al., 2007) was used in which early concepts and prototypes were shared internally with the development team, who provided iterative feedback and made joint decisions regarding changes to the initial vignette, student, and classroom prototypes. As more developed prototypes were available, advisory board members interacted with prototypes on a secure website and completed measures previously described. All numeric and descriptive feedback from advisory board members was shared with the development team to guide iterative refinements. Iterative refinement ended when all members of the advisory board rated the virtual students and classrooms as *Good* or *Outstanding* on all criteria and *Agreed* or *Strongly Agreed* that the students' behavior, actions, and dialogue were logical and realistic based on their age and presenting problem.

Descriptive analyses compared authenticity and realism of the vignettes by presenting problem (off-task vs. non-compliant), grade level (first vs. sixth grade), and time of development. Descriptive analyses also compared the authenticity and realism of the students by gender and prototype version. Descriptives also compared the authenticity and realism of the classrooms by time of development.

Results

Vignette Authenticity and Realism

Vignette feedback from advisory board members was obtained five times during Year 1. Across all five time points, each advisory board member contributed feedback on each of the four vignettes at least once. When collapsing across all time points and advisory board members, raters either *Agreed* or *Strongly Agreed* that the vignettes were logical and realistic based on the character's age (Mean first grade = 3.73, SD = .39; Mean sixth grade = 3.78, SD = .32) and presenting problem (Mean Off-task = 3.80, SD = 2.97; Mean Non-compliant = 3.69, SD = .43).

Vignettes created later in Year 1 (November 2016) had higher mean ratings for logic and realism of the non-disruptive students' behavior and dialogue (Mean = 3.81, SD = .28), teacher response options, (Mean = 3.62, SD = .60), and engaging storylines (Mean = 3.76, SD = .40) when compared to vignettes developed earlier (March 2016) for logic and realism of behavior and dialogue (Mean = 3.71, SD = .51), teacher response options (Mean = 3.58, SD = .72), and engaging storylines (Mean = 3.50, SD = .66).

When comparing vignettes by the primary character's presenting problem, results indicated higher ratings for logic and realism of the non-disruptive characters' behavior and dialogue in the non-compliant vignettes (Mean = 3.70, SD = .43) when compared to the off-task vignettes (Mean = 3.6, SD = .35). Teacher response options were also rated higher for the non-compliant vignettes (Mean = 3.63, SD =.492) when compared to the off-task vignettes (Mean = 3.4, SD = .53). In addition, the non-compliant vignettes were rated as more engaging (Mean = 3.76, SD = .36) than the off-task vignettes (Mean = 3.44, SD = .39).

Descriptive feedback from advisory board members was generally positive and converged with high numeric ratings related to authenticity and realism of the vignettes. Descriptive feedback also highlighted additional areas for improvement related to the pedagogical aspects of the vignettes. For example, advisory board feedback suggested that the vignettes be revised so that the behavioral goals for the characters (e.g., increasing on task behavior) were more clear and logical. As an example, one advisory board member shared, *"This vignette was very hard to follow... It's not realistic to use class time to tell student to clean his backpack as he is already falling behind in reading and the goal is to get him on task*." Descriptive feedback also suggested the need to improve the logic and realism of some of the dialogue, interactions, and responses of the teachers and ensuring decision point options were predictable across vignettes. For instance, one advisory board member noted, *"I really liked the paths and I thought that the students' reactions and behaviors were pretty typical for first graders. However, I thought some of the teacher options were too harsh for a first grade teacher.*

I also thought that some decision point options were inconsistent…why was the teacher ignoring Sofia when she starts drawing on her desk?"

Character Authenticity and Realism

Three groups of virtual students were developed and introduced to the advisory board during Year 1. Group 1 was introduced in November 2015, Group 2 in December 2015, and Group 3 in January 2016. Group 1 included four male and one female character, three of whom were first graders and two of whom were sixth graders. Group 2 included two males and six females, five of whom were first graders and three of whom were sixth graders. Group 3 included eight males and nine females, seven of whom were in first grade and ten of whom were in sixth grade. Students introduced in Group 1 had more iterations (i.e., one to two sets of revisions to the original prototype's hair, face, body, and clothes) when compared to students introduced in Group 3, which did not undergo any iterations. Two characters (in Group 1) underwent two iterations, 10 underwent one iteration, and 18 characters underwent no iterations.

Descriptive analyses highlighted that overall, students were rated *Good* or *Outstanding* on authenticity of their face (Mean = 3.62, SD = .57), body (Mean = 3.76, SD = .44), clothing (Mean = 3.66, SD = .47), and hair (Mean = 3.58, SD = .57). When evaluating ratings of authenticity across face, body, clothing, and hair, only two of the 30 students were rated in the *Fair* range. Authenticity and realism ratings were generally high and also increased from Prototype 1.0 to Prototype 2.0 when comparing a character's face (Mean 1.0 = 3.59, SD = .59; Mean 2.0 = 3.62, SD = .54), body (Mean 1.0 = 3.72, SD = .48; Mean 2.0 = 3.85, SD = .37), clothing (Mean 1.0 = 3.66, SD = .48; Mean 2.0 = 3.67, SD = .48), and hair (Mean 1.0 = 3.51, SD = .60; Mean 2.0 = 3.69, SD = .52). Quality ratings for male students were higher than female students when comparing a character's face (Mean male = 3.65, SD = .55, Mean female = 3.59, SD = .58), body (Mean male = 3.79, SD = .41, Mean female = 3.73, SD = .48), clothing (Mean male = 3.68, SD = .47, Mean female = 3.64, SD = .48), and hair (Mean male = 3.65, SD = .52, Mean female = 3.52, SD = .62).

Figure 2 illustrates the evolution of one sixth grade male character, including physical transformations to his clothing, face, hair, and body based on feedback from advisory board members. For example, feedback for Prototype 1.0 (see Figure 2) highlights: "*His facial features should be softened so he looks more like a preteen. His clothes should be loose fitting and he should wear a uniform.*" Descriptive feedback informed revisions by the computer science team which were incorporated into Prototype 2.0, including reducing the size of the student and softening his facial features so that he looked more like a sixth grader. In Prototype 3.0, the student was featured wearing a uniform and advisory board feedback was overall very positive, "*This boy looks age appropriate. Face looks like an 11 year old.*"

Classroom Authenticity and Realism

Six first grade classroom prototypes and two sixth grade classroom prototypes were developed and iteratively refined during Year 1. Prototypes developed later in Year 1 (March 2016 for first grade, November 2016 for sixth grade) were rated, on average, as *Good* for authenticity and realism (Mean first grade = 3.50; SD = .71; Mean sixth grade = 3.56; SD = .59) when compared with prototypes developed earlier (September 2015 for first grade, May 2016 for sixth grade) which were rated, on average, as *Poor* (Mean first grade = 1.33; Range = N/A; Mean sixth grade = 2.96; SD = .60).

Figure 3 illustrates the evolution of the first grade classroom, including the initial classroom design (Prototype 1.0) which was described as "*fairly sterile for a first grade classroom*." One advisory board member also noted that the teacher's desk was "*too modern*" and out of character for classrooms situated in a high poverty community "*usually you see wood or metal but beat up*." Prototype 2.0 was described by an advisory board member as mixed, including the need for "*more wall hangings*" but that the "*flooring looks better, more beat up*." Subsequent prototypes were rated as "*much more realistic*" although concerns regarding lighting (i.e., "*not much natural light coming in*") were noted with adjustments made to the lighting so that it emanated through the windows as well as the ceiling.

Discussion

This study illustrated the development and iterative refinement process for IVT, a simulation-based training model in which early career teachers can enhance their behavior management skills with virtual students in a low-consequence-for-failure environment. The IVT interdisciplinary development team capitalized on the expertise of advisory board members who had extensive experience teaching in high poverty schools. Advisory board members provided feedback on the realism and authenticity of IVT vignettes, virtual students, and classrooms in an effort to improve upon IVT early in the development process.

Main Findings Related to Vignettes, Students, and Classrooms

Advisory board feedback suggested higher ratings for the non-compliant and aggressive vignettes when compared to the off-task vignettes across multiple dimensions, including logic and realism of the primary students' behavior, teacher response options, and engaging storylines. This finding may reflect differences between the types of interactions that occur between teachers and students who struggle with oppositionality and defiance as opposed to hyperactivity and inattention, the former of which is often characterized as social in nature and occurring in a relational context (Egger & Angold, 2004; Gray et al., 2012). The non-compliant and aggressive vignettes were also created later (November 2016) when compared to the off-task vignettes

(March 2016). This difference in timing may have facilitated the incorporation of important feedback as new vignettes were created. Descriptive feedback supported the positive numeric ratings and also highlighted additional areas for improvement related to enhancing the authenticity of teacher responses to students in terms of tone and developmental appropriateness.

The iterative nature of development and refinement of the students and classrooms proved to be useful across time as well. For example, students introduced in Group 1 underwent the most number of iterations (i.e., three) while students introduced in Group 3 underwent the least. Findings suggest the importance of iterative feedback by the advisory board to help the computer science team generate a set of students (28 of 30) that appeared authentic with regard to their body, face, hair, and clothing. Similarly, the first grade classroom (developed first) required six revisions while the sixth grade classroom (developed second) underwent two revisions. These findings suggest that as advisory feedback was provided, the computer science team was able to incorporate design revisions successfully which may have reduced the need for multiple iterations on subsequent prototypes.

Advisory Board Contributions

There is a rich literature pointing to the many advantages of inviting end-users to contribute early and often to the development of interventions, technologies, and professional development models that ultimately are intended to serve and support them (Hartson & Pyla 2011). Several considerations of research-practice partnerships, and discussions with school personnel participating in prior research with the research team, led to forming and relying on an advisory board as part of the iterative process for building IVT. Increasing priority on academic-community collaboration in health services and education research influenced the team's conceptualization of the role and goals of the advisory board. Specifically, active stakeholder voice was expected to improve the *process* of iterative development and the *product* that would result, yielding a high quality IVT system that is authentic, engaging and pedagogically rich.

Although end users for this study are early career teachers, their limited classroom experience minimized the extent to which they could comprehensively assess the realism and authenticity of high poverty classrooms and student-teacher interactions. Thus, we instead invited retired teachers, from high poverty schools, to serve on the board, thereby capitalizing on the views and experiences of highly experienced educators during the early stages of development (Morin, 2003; Santos & Chess, 2003). Their participation involved frequent and systematic opportunities to provide feedback and recommendations on the evolving vignettes, students, and classrooms. In this way, the advisory board served as a bridge between the technical team and content experts, always informing and often changing the dialogue and decisions in ways that better reflected the unique strengths and needs of early career teachers and the nuances of high poverty schools. Interestingly, the numeric ratings from advisory board members were generally quite high, even during early iterations; therefore, the team relied even more heavily on descriptive feedback to guide revisions.

Next Steps in IVT Development

The IES Goal 2 developmental mechanism funding this work has three years remaining devoted to assessing usability (Year 2), field testing (Year 3), and small randomized controlled trial (Year 4). Completion of the IVT website in Year 2 will begin with casting the vignettes into storyboards, which are pictorial translations of what the classrooms will look like, the sequence of interactions between early career teachers and virtual characters, and visual representations of characters using stick figures. Storyboarding will also facilitate decisions regarding the functional and non-functional requirements for IVT and the website user interface. Storyboards will inform a 2D prototype that will undergo expert heuristic evaluation by the usability engineer to assess the quality of the user interface and to identify usability problems early (Gabbard, Hix & Swan, 1999). A formative usability evaluation will follow, during which representative users (e.g., education students) will be invited to utilize the 2D system to identify potential usability problems that may not have been identified during expert evaluation (Gabbard et al., 1999; Hix et al., 1993). These additional opportunities for feedback will help ensure that the sequence of behaviors correspond to the vignette that the interactions are authentic before extensive animations and programming are executed. Year 3 will include initial field testing of IVT with a sample of early career teachers in high poverty schools to assess knowledge and skill transfer from the virtual to the live classrooms. Year 4 is a planned randomized controlled trial to assess the promise of the model in improving teacher effectiveness and student behavior.

Interdisciplinary Collaborations: Challenges and Opportunities

The existing literature highlights two common approaches to integrating technology into more traditional training models (Moreno & Mayer, 2007; Rooney et al., 2009). The first approach includes adapting a commercial off-the-shelf system for use with a new user and the second approach includes developing a new training system to address the unique pedagogical or curricular content needs (Dalgarno & Lee, 2010; Jacobson et al., 2008). Each approach requires interdisciplinary collaboration and has corresponding advantages and disadvantages (Rooney et al., 2009). Repurposing a commercial training system to support early career teachers to improve their behavior management skills (e.g., using TeachLivE developed by Dieker et al., 2008; 2014) could have been more efficient given the cost in time, equipment, and computational power required for 3D applications such as IVT (Dalgarno & Lee, 2010). Deadlines associated with Year 1 activities required the interdisciplinary team to make difficult decisions regarding how many times to iterate, particularly the 3D elements of IVT given the time-consuming nature of graphic design and the goal of creating highly realistic students and classrooms.

Despite the significant time and resource challenges, development and iterative refinement from the ground-up allowed the team to align the model with the unique needs of early career teachers and to incorporate important pedagogical elements guided by research highlighting the importance of proactive monitoring, effective redirection, and altering the antecedents and consequences to disruptive behavior (Evertson & Weinstein, 2006; Simonsen et al., 2008). This approach also allowed the team to incorporate specific technological specifications, for instance portraying a larger number of students in each classroom environment (i.e., 15 virtual students in IVT versus 5 students in TeachLive). In addition, we will also be able to create autonomous and automatic behaviors for the virtual students versus agents who are controlled by an unseen human using Wizard-Of-Oz methodology (Kelley, 1984). A ground-up approach also facilitated a web-based and open access training model that will be compatible with existing computing systems widely accessible by teachers.

Extensive interdisciplinary collaborations across computer scientists, psychologists, educators, and usability engineers was required in order to build IVT. These interdisciplinary collaborations provided unique opportunities to expand our mutual understanding of the unique focus, roles, contributions, and expertise that each discipline brings to the common goal of using simulation technology to support early career teachers in behavior management. These collaborations provided opportunities to model joint planning, joint decision making, and effective communication across disciplines. The project also revealed interesting research avenues for lifecycle activities for the design and development of 3D training systems that involve high quality graphics, advanced user interface and user experience design, and software engineering. These teams were challenged to learn from their specialized colleagues regarding the instructional objectives and strategies best suited to help early career teachers build their behavior management skills and the complexities of building a simulation training model (e.g., realistic 3D computer graphics, visual user interface design, computational behavior modeling).

Limitations

A number of limitations warrant mention. First, designing a simulation training model from the ground-up is both difficult and costly in time and resources. This limits the number of iterations that are possible in the context of development. The advisory board sample size was small and the total number of iterations and data points was limited. This study also relied exclusively on self-report measures from a single type of reporter (i.e., advisory board members) which are subject to bias. Ceiling effects related to advisory board ratings for the vignettes, students, and classrooms also made comparisons between prototypes more challenging. In addition, mean increases and decreases do not reflect statistical or clinically significant differences. Therefore, conclusions regarding changes over time in ratings of the classrooms, students, and vignettes should be taken with caution.

Conclusions

Developing early career teachers' knowledge and skills in evidence-based behavior management strategies is a critical professional development goal given the connection between successful behavior management and student achievement (Korpershoek et al., 2016). Bridging technology with evidence-based practices provides an unprecedented opportunity to support early career teacher competence and transfer of training from the virtual to the live classroom. Leveraging technology may help circumvent limitations to traditional teacher professional development given the pedagogical advantages of simulation, including exposure to realistic work scenarios that provide opportunities for practice and feedback in a low stakes training environment. As technology-based interventions continue to emerge the field of education, there is demand for systematic methodologies and tools to evaluate simulation training models (Alvarez & Michaud, 2008; Arnab et al., 2015; Jeremic, Jovanovic & Gaševic, 2009; Schrader et al., 2011). The procedures we used in the early development and refinement of IVT provides one model for soliciting feedback to enhance authenticity, realism, and representativeness of simulation training models.

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Table 1

Virtual Student Demographics

First Grade Students	
Gender	7 Female 8 Male
Race/Ethnicity	7 African American 8 Latino/a
Disruptive Students	1 Off-task (African American Male) 1 Non-compliant (Latina)
Sixth Grade Students	
Gender	9 Female 6 Male
Race/Ethnicity	6 African American 9 Latino/a
Disruptive Students	1 Off-task (African American Female) 1 Non-compliant (8 Latino)

Note. *N* = 15 first grade students (13 non-disruptive, 2 disruptive). *N* = 15 first grade students (13 non-disruptive, 2 disruptive).

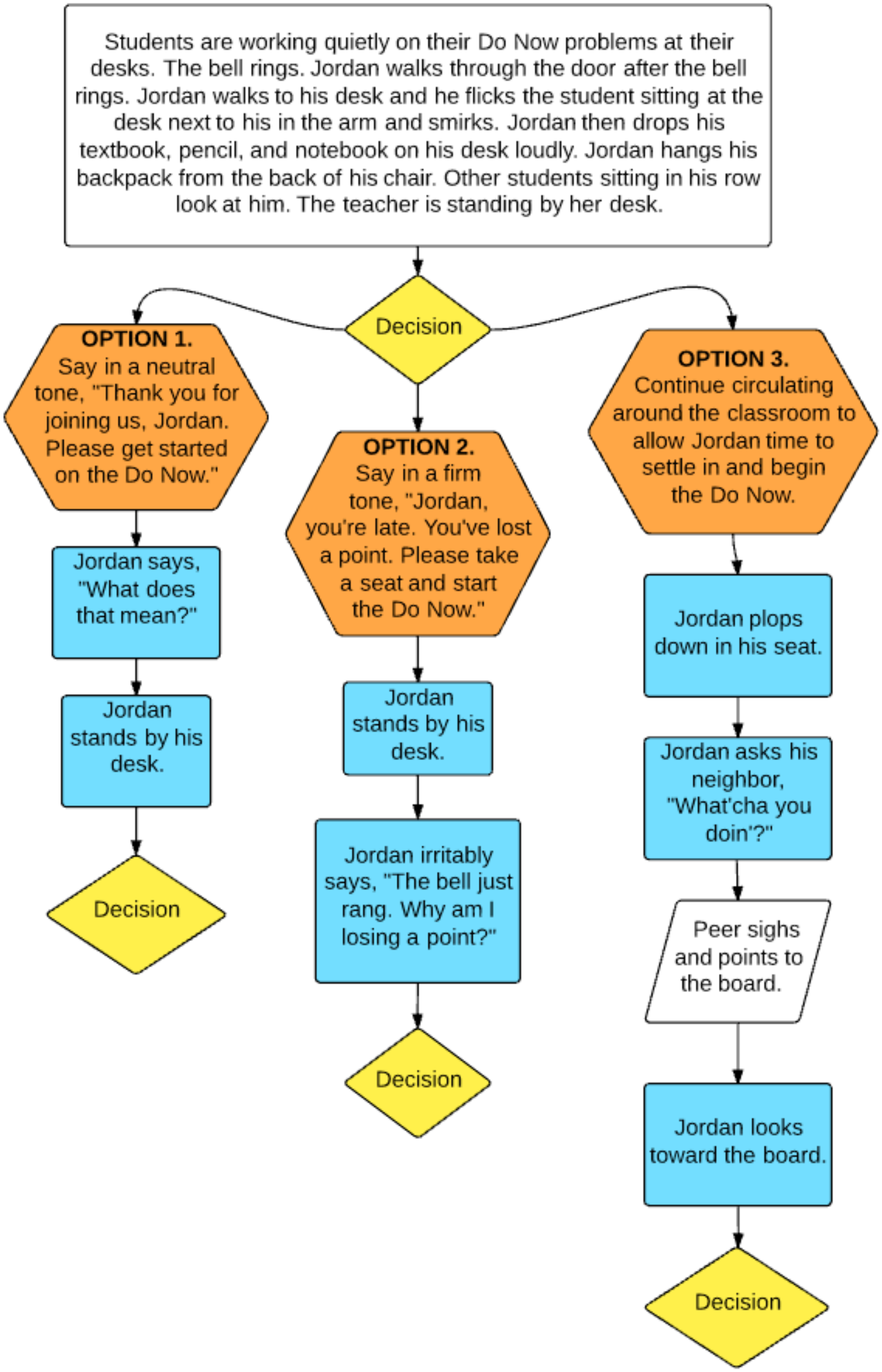
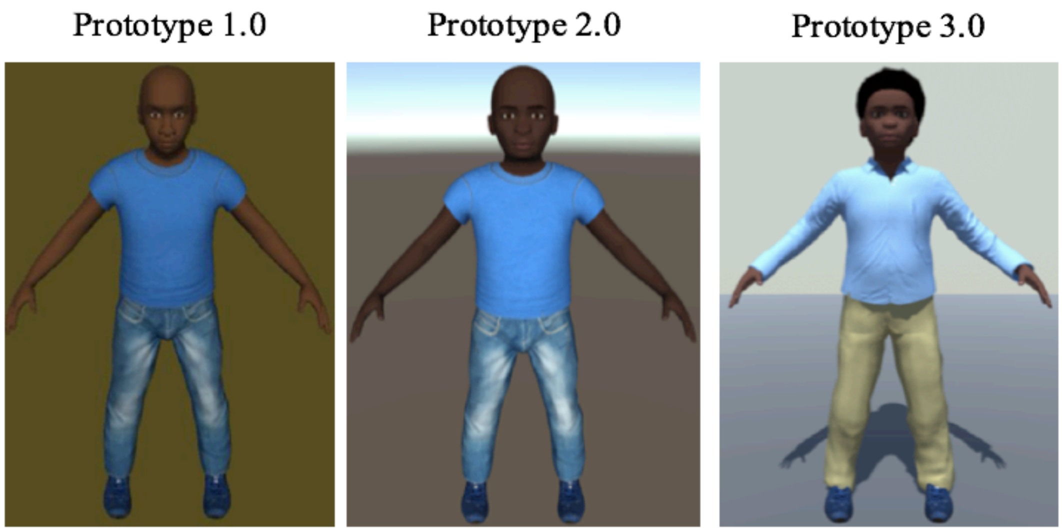


Figure 1. *Vignette illustrated in Lucidchart*



He needs hair, his facial features should be softened so he looks more like a preteen. His clothes should be loose fitting and he should wear a uniform.

Size looks right. I like his face... hair will help enhance realism.

This boy looks age appropriate. Face looks like an 11 year old

Figure 2. *Evolution of a sixth grade male character*

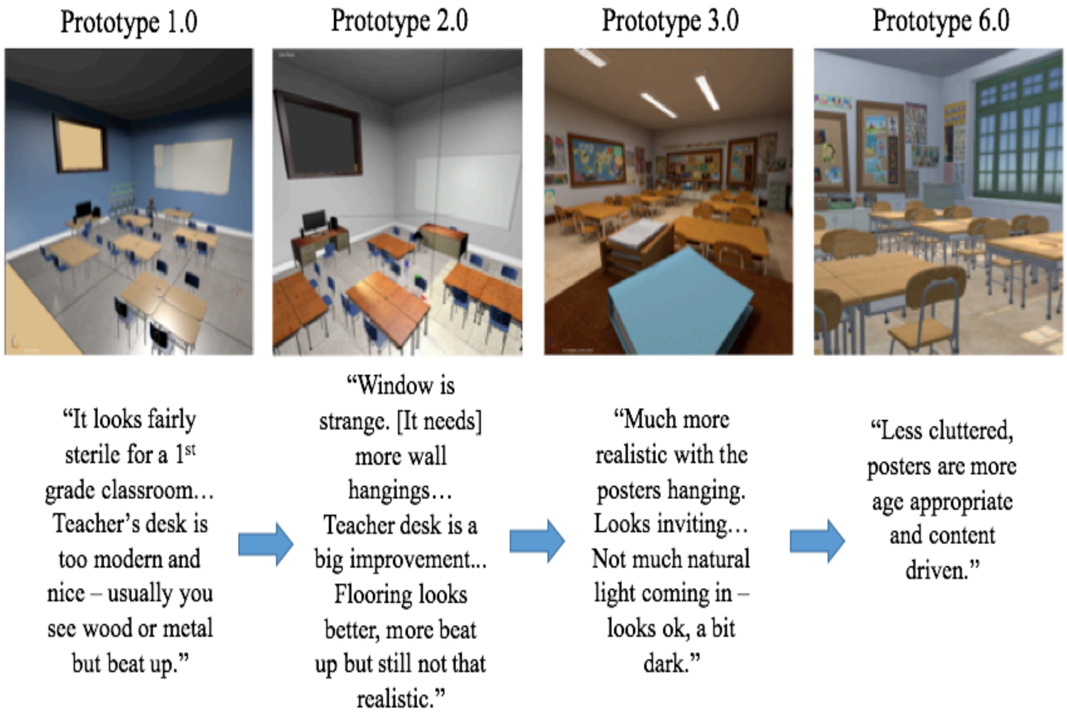


Figure 3. *Evolution of the first grade classroom*