

Reimagining the Math Classroom through the Integration of Transformationally
Play-Based Narrative Video Games

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Abstract

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Traditionally, many math classrooms focus on mathematical procedural knowledge and expect students to take that knowledge and know when and how to apply it to problem-solving situations. Consequently, this leads to a belief that being “good” at mathematics involves memorizing those specific procedures and arriving at the correct answer. Through a review of work written on two exemplar educational videogames, *The Adventures of Jasper Woodbury* and *Quest Atlantis*, I suggest a list of design commitments and features necessary for video games to support transforming classrooms to uplift all students as mathematically capable. I discuss what the role of the teacher may look like if such video games are integrated into the classroom and how these features may look to evolve to continue supporting all students. Finally, I address concerns around the design and implementation of transformationally play-based narrative-based video games and their place in the classroom as a tool to help transform what it means to do math.

Introduction

Common sense notions about mathematical ability suggest it is a gene that people can inherit. Either you have it, or you don't (Gutierrez, 2007). This belief is further reinforced by historical narratives related to 1) mathematical ability and racialized constructions of who is capable (Shah, 2019; Gutierrez, 2007) and 2) math classrooms focusing more on the procedures rather than the context in which those procedures are necessary or even relevant to students (Peterson, 2005). These narratives further cement the belief that math is a universal language. Moreover, the notion that math is a universal language perpetuates the belief that students do not enter the classroom with knowledge useful to help them learn math (Nasir, 2002; Saxe, 1988; Lave, 1988).

Therefore the pervasive pattern of achievement in traditional math classrooms continues to be reinforced: students who are successful in memorizing and regurgitating the information given to them by the teacher are treated as capable of doing math; those who are unsuccessful are fed the idea that they are not. But the reality is that mathematics is not neutral, and neither are the environments in which math is practiced (Shah & Leonardo, 2017).

Although most math classrooms continue to focus on memorization, there is work being done to transform the classroom. One example of transformation in the classroom can be found in work documented by Louie et al. (2014) at Railside school. Teachers and students worked together to co-construct what it meant to do math within this classroom. Rather than the teacher holding all the power, the students were invited to take an active role in their learning. Their thoughts and ideas were used to shape their understanding of mathematical concepts. For example, when facilitating group work, the

teacher would only entertain group questions, “a question of which everyone in the group is aware and no one can answer” (p. 67). By having this rule, each student within the group was positioned as being knowledgeable. If someone in the group did not know what question their group member was asking, then the teacher would not answer the question. This requirement helped support student-student interaction and group collaboration because it forced students to check in with each other before inviting the teacher over (Louie et al., 2014). Railside school transformed the relationship and power dynamic between students and teachers. Within the context of a math classroom, this opened up the possibility for students to discover concepts collaboratively and through their own experiences. Rather than solely measuring mathematical ability through speed and memorization, successful collaboration and expression of ideas measured students’ understanding. Such learning is fruitful because it creates the opportunity for students to identify with their learning and view themselves as capable of doing math.

Although stories like Railside show us what’s possible, mathematics teaching like that is still rare. Actively involving students in their learning often answers the question, “when will I ever use this in my life?” before students even ask it. Much effort and reform have focused on project-based learning, creating lessons around problems, and having students create the solution. While this is definitely a step in the right direction, we need to pause and think about who poses the problem (Boaler, 2008). What consequences result from students “solving” this problem? Often, the problems students are given still feel isolated from their lived experiences outside of a classroom and only highlight a specific mathematical concept (Jurow, 2005). However, many real-world activities offer

the opportunity to create meaningful problem-based learning experiences where the student's actions have consequences. Their knowledge and experiences guide the problem and solution.

Video games offer an opportunity to reshape math classrooms by creating spaces for transformational learning (Barab, Gresalfi, & Arici, 2009; Barab, Pettyjohn, Gresalfi, et al., 2012). Transformational play allows for the student's actions to dictate their learning path, and through interactions with other characters in the game, students are positioned as knowledgeable (Barab, Pettyjohn, Gresalfi, et al., 2012; Barab, Dodge, Ingram-Goble, et al., 2010). By implementing video games into the classroom, students can engage with the material that engages and uplifts the students' capabilities. Further, video games can incorporate a narrative into the game's design (Barab, Gresalfi, Dodge, & Ingram-Goble, 2010). This creates the opportunity for students to experience the consequences of their actions, highlighting that mathematics and learning, more generally, do not occur solely in a classroom and can impact situations outside the classroom. But, unlike having students physically go into the world and practice a developing skill, video games create a safe environment in which students can make mistakes, view the consequences, and then go back and try again (Gee, 2003; Gresalfi, Barab, et al., 2009).

So what does a classroom look like if we were to thoughtfully incorporate video games? How do teachers integrate gaming into their math pedagogy? This paper will discuss how the careful design of educational video games, more broadly known as serious games, can positively transform the classroom to redefine what it means to do math and who is capable of doing it. As a result, the role of the teacher exemplifies

more of a facilitator rather than a dispenser of knowledge; they work alongside the student to co-construct what it means to do math. More importantly, mathematical learning becomes more about learning how to critically think and problem solve rather than memorizing how to solve for x .

Guiding this argument has been a critical read of the research on two video games that have already been created and studied, Quest Atlantis and The Jasper Project. From these two games, I describe a set of features that I believe future educational video games should include to help teachers create math classrooms that uplift multiple ways of knowing and are more culturally relevant to students' lived experiences. From there, I discuss how such games could be implemented in the classroom and what the role of the teacher would be as students interact with the game. Finally, I discuss limitations around educational video games as a medium for reshaping classrooms to be more learner-centered. While video games are not *the* solution to transforming classrooms, I do believe they are an integral part of the solution. The following questions guided me as I worked to think how to reshape the classrooms through the integration of educational video games:

1. What role does transformationally play-based narrative video games play in building a student's mathematical ability?
2. What commitments and features should researchers adopt when designing play-based narrative video games?
3. What key issues need to be addressed if transformationally play-based narrative video games are to be more widely integrated into mathematics teaching and learning?

Background about Video Games

In and out of the research world, there are many different kinds of video games. The term serious game helps differentiate educational video games from commercial video games like Mario Kart (Girard et al., 2013). Specifically, serious games refer to immersive virtual environments designed with a specific purpose to educate its players (Saez-Lopez et al., 2015; Girard et al., 2013). Still, even the term serious games is a broad term used to describe every type of educational video game created. There are various ways that researchers have defined different types of serious games. For example, games that involve an interactive story-telling feature describe narrative-based games (Barab, Pettyjohn, Gresalfi, et al., 2012). Narrative games have the student take on the role of a game-based character, and throughout the play, the story will unfold (Barab, Pettyjohn, Gresalfi, et al., 2012)). In contrast, games like MinecraftEdu are categorized as sandbox or open-world games because of the freedom afforded to the player (Techopedia, 2017; Saez-Lopez et al., 2015). In games like MinecraftEDU, students have few restrictions on what they can and cannot do. In narrative games, actions can be limited to ensure the story unfolds in a way that designers intended (Barab, Pettyjohn, Gresalfi, et al., 2012). There are likely many other subcategories of each type of game and different types of serious games, but such elaboration is beyond the scope of this paper.

Both sandbox and narrative-based video games offer the opportunity for educators to create a generative, cooperative, and dynamic classroom. However, there are differences in the experience students can have depending on the type of game. Sandbox video games provide unrestricted freedom to students that allows them to

create their own reality and what that looks like (Techopedia, 2017). The focus of this paper centers around the benefits of narrative games. Unique to narrative games is the requirement for a narrative to be present. As a result, narrative games inherently provide students with a purpose and position the student as necessary to the evolution of the story. As students go through the game, they are invited and asked by other characters to make decisions that will affect the story. The types of questions characters ask of students are not simple questions. They require students to gather data and information and justify their answers to the community in the game. However, given that it is a game, students' decisions are not permanent; they can restart and try again. So, even when students realize they make a mistake, characters still seek out their help. Thus, mathematical ability is no longer about getting the correct answer as quickly as possible but instead about problem-solving, critical thinking, and learning from your mistakes. No matter the specific narrative, each time the student enters, they are sought out to help solve the particular problem. This allows students to see a variety of professions and contexts where mathematical practices occur. Rather than only doing math in a classroom, math appears in recreations of everyday activities. These aspects contribute to and support students in seeing the relevance of mathematical practices in their daily lives and as individuals capable of practicing in such practices.

The story-telling feature in narrative-based games ensures that every student encounters the same experience. Still, how the story unfolds will vary for each student depending on their actions. These actions can lead to fruitful conversations between peers where they can collaborate on how to proceed based on their individual experiences (Cognition and Technology Group at Vanderbilt, 1992a). Within a

narrative-based game, students are playing a character that is valued and needed for the success of the challenge presented in the game. By being in control of this character, students are positioned as a respected authority with knowledge valuable to the story's success from the very beginning (Barab, Dodge, Ingram-Goble, et al., 2010). In the rest of this paper, I focus on the features available in narrative games that can help reposition all students as mathematically capable. That being said, I also propose modifications to narrative-based games so that they can embrace some of the creative freedom typically associated with sandbox games.

In researching how video games can successfully transform mathematics classrooms, I came across two impactful narrative-based games. The first, designed by The Cognition and Technology Group at Vanderbilt, is *The Adventures of Jasper Woodbury (AJW)*, often referred to as *The Jasper Project* in research (Cognition and Technology Group at Vanderbilt, 1992a; 1992b). AJW is a video-based game, not a computer video game. This means that to implement the *Adventures of Jasper Woodbury* in the classroom, teachers would play the video for students and at the end, students would be presented with a task. It is not a typical computer game where the students interact with the game as the story unfolds and have direct control over a character in the game. But AJW is still a game centered around different adventures created to promote independent problem-solving over calculational mastery (Cognition and Technology Group at Vanderbilt, 1992a; 1992b). To achieve this, each adventure ended by presenting a challenge to the students based on the adventure that had just unfolded. AJW was intentionally designed so that each adventure provided students with a plethora of data that could be used to solve the problem (Cognition and

Technology Group at Vanderbilt, 1992a; 1992b). Although the problem was presented to the students, how students attempted to solve it was up to them. The challenge was not finding a solution but finding the best solution and justifying their decision. Typically students could come up with an answer fairly quickly but rarely was that solution the best one (Cognition and Technology Group at Vanderbilt, 1992a). AJW afforded students a generative learning experience by emerging students into the game and challenging them to find their own solution based on the data presented in the video (Cognition and Technology Group at Vanderbilt, 1992a; 1992b).

Another critical feature of AJW is its implementation of anchored instruction. Anchored instruction is an instruction that is situated in meaningful problem-solving contexts (Cognition and Technology Group at Vanderbilt, 1990). The problems presented to students were not just random equations or a word problem at the bottom of a worksheet. Instead, the problem unfolded as students watched the adventure play out. Delivering content through video allowed students to experience the adventure as it happened while enabling them to rewatch scenes with relevant data. The narratives of these adventures made the problems students needed to solve feel meaningful rather than the typical word problems found in textbooks (Cognition and Technology Group at Vanderbilt, 1990). For example, in one episode, students were challenged to find the fastest way to deliver items from one location to another (Cognition and Technology Group at Vanderbilt, 1992b). By the time the problem was posed to the students, there were three paths and three methods of transportation students could choose from to deliver the item. Again, the problem posed to students was not finding a solution but finding the best solution (Cognition and Technology Group at Vanderbilt, 1992a). Even

once students found the best solution, their work was not done. The game designers also included analog and extension problems for students to help with their ability to transfer their skills (Cognition and Technology Group at Vanderbilt, 1992a; 1992b). All in all, AJW leveraged video to create adventures to provide significant problems that forced students to critically think and justify their answers with evidence from the video.

The second game I focused on is Quest Atlantis (QA). QA is an innovative narrative-based serious game that focuses on the idea of transformational play and consequential learning within a multi-user gaming environment (Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005). Unique to QA is that it "immerses children in educational tasks in an adventure to save a fictional Atlantis from impending disaster" (Barab, Dodge, Thomas, Jackson, & Tuzun, 2007, p. 268). Thus, each quest is framed by a larger narrative—saving the world of Atlantis, motivating the students to successfully complete more quests (Barab, Dodge, Thomas, et al., 2007). More specifically, the game's designers created a world in which the storyline did not occur in one location or form but was co-created and given meaning through the actions decided by the participants (Barab, Gresalfi, Dodge, & Ingram-Goble, 2010; Barab, Pettyjohn, et al., 2012). When students first log in, they are directed to create their avatars and customize their homepage to develop "an online persona" (Barab, Dodge, Thomas, et al., 2007, p. 269). It is up to the students to ensure that Atlantis survives, and the only way to do so is through participating in quests. Each quest is different but requires students to employ disciplinary skills to solve the problem within the story (Barab, Gresalfi, Dodge, & Ingram-Goble, 2010). Once students have done this, they are transported to the future to see the consequences of their decision (Gresalfi et al.,

2009). As students complete quests, they earn "luminations" displayed on their home page. These luminations represent some of the core social commitments designers wanted students to learn on top of the disciplinary content (Barab, Dodge, Thomas, et al., 2007). Centered around Vygotsky's notion of play, QA attempts to simultaneously position the student as the observer, participant, and narrator of the game to enhance their learning experience (Barab, Pettyjohn, et al., 2012).

I focused on these two games because of the focus on mathematical problem solving and thinking found in AJW and the emphasis on transformational play, consequential learning, and social commitments embedded within QA. Equally compelling was the creativity and freedom for multiple ways of knowing and participation embedded within both games. Further, both games were developed using design-based research methods and went through multiple iterations over the years. By engaging in design-based research, both games were developed to impact the local community and advance theories of learning (Barab, Thomas, Dodge, Squire, & Newell, 2004; Cobb et al., 2003). Studies occurred in classroom-like settings working alongside students and teachers to influence game's design (Barab, Thomas, Dodge, Squire, & Newell, 2004; Cognition and Technology Group at Vanderbilt, 1992a). The following section discusses the fundamental components of designing future serious games that center mathematical problem solving, based on the features discussed above. Then, a discussion around how such games should be implemented and the role of the teacher is discussed. Next, I provide recommendations for how features found within AJW and QA can be reimagined to better support students' ability to think of themselves as mathematically capable. Finally, dilemmas concerning the design, implementation, and

adaptation of features for future video games are addressed. Video games on their own are not the solution, nor are they the only way to successfully redefine what it means to be good at math. Still, if designed carefully, they can be a powerful tool in aiding the transformation of classroom learning.

Video games as a Tool for Learning

To successfully transform math classrooms into culturally relevant and open to multiple ways of knowing, educators should focus on creating generative, cooperative, and student-centered classrooms. Generative learning involves creating an environment where students use their current knowledge to solve a problem presented to them rather than having a teacher deposit information, dictating the steps needed to solve the problem (Cognition and Technology Group at Vanderbilt, 1992a). Cooperative learning involves creating an environment in which students work together on a common task and, through discussion, can learn from one another (Cognition and Technology Group at Vanderbilt, 1992b). Rather than presenting a random equation and possible methods to solve the given equation, math teachers should center lessons around problems relevant to students' lives that build on their skills to create solutions (Cognition and Technology Group at Vanderbilt, 1992a; 1992b; Jackson et al., 2012). Finally, classrooms should focus less on the final answer and more on how students arrive at that answer, pushing students to articulate and defend their thinking. In doing so, the misguided belief that mathematical ability is connected to speed and memorization will be dismantled (National Council of Teachers of Mathematics, 2014; Shah & Leonardo, 2017). While there are many approaches to this, the importance and relevance of technology in students' lives cannot be ignored.

In today's world, there is no avoiding technology. To ignore the role of technology in a classroom is a disservice to students and teachers. Video games can be an engaging piece of technology that most children already have experience using outside of the classroom. Video games and the integration of technology in general help engage the students and provide valuable individualized data for teachers that can then be given to students (Gee & Levine, 2009). Video games are a form of generative learning because the student plays the game and their actions and knowledge dictate the unfolding events. Specifically, video games can be the result of a co-constructed world that allows students to embody the social practices and understanding necessary to successfully implement the concepts (Shaffer et al., 2005; Saxe, 1988; Nasir, 2002). Integration of video games is one way that changes how students can participate in classrooms (Barab, Gresalfi, & Arici, 2009). Through this play, students who may feel intimidated by a subject matter may participate in a way that replaces being called on in front of their peers (Shah & Leonardo, 2017). More importantly, a student's progress in relation to speed is not as visible to their peers. Video games allow students to progress through concepts at their own pace without the obvious visual cues of seeing someone submit their test and be done with their work. Video games do not entirely eliminate the notion of progress and the comparison of progress between classmates, but they may be one way to mitigate it. In doing so, video games can help remove the pressure to finish first or avoid finishing last, narratives that have historically been correlated with one's mathematical ability (Shah & Leonardo, 2017). Even though each student plays the game individually, they all engage in a shared playing experience. Because of this, teachers can put students into groups or have a whole class discussion facilitating

conversations students have around what decisions they made and why. Equally important, interviews with students have documented that they find learning through playing video games more meaningful and entertaining (Saez-Lopez et al., 2015). With the right kind of game and pedagogical support, educators can look at video games as a tool to help students identify as being mathematically capable.

Design and implementation of video games

Commitments of video games and their implementation

Driving the need to redesign classrooms is a belief that all learning is situated (Lave & Wenger, 1991; Banks, 2007; Boaler, 2000, Saxe, 1988). Classrooms should be environments where students can participate in practices relevant to their everyday lives (Lave & Wenger, 1991). Video games leverage the ability for students to engage in legitimate peripheral participation (Lave & Wenger, 1991). Specifically, they have the opportunity to engage in math as a community of practice. Students are situated as an expert within the video game but are also surrounded by other experts they can learn from. These other characters model how to effectively communicate ideas and other critical thinking skills. Further, the other students are also experts that the students can learn from. Through class discussions, students can observe and actively participate in different conversations. In their observations and participation, they can view how others display their mathematical thinking to their classmates or present their own thinking.

Serious games allow for rich narratives that incorporate contexts pertinent to students' lives and initial understandings (Gresalfi, Barab, et al., 2009). Metaphorically speaking, traditionally, mathematics classrooms have acted like the instruction manual

on how to play the game of life; they provide the rules and formulas needed to solve the problem. But, rarely do students get a chance to explore when to use the formulas. Often they are explicitly told to do so. Supposedly, knowing the rules and procedures is enough to enter life and be successful. However, while the "how-to" is important, it rarely makes sense until you apply it to its necessary content. Therefore, transforming the classrooms involves allowing students to play the game rather than just reading the rules (Gresalfi, Barab, et al., 2009). Through careful design, video games are a way to allow students to learn from their surroundings and increase their participation, taking on new forms as they progress through the game.

Video games have the opportunity to introduce specific skills (e.g., the formula for the area of a figure and situate such skills within a setting that emulates informal environments). Additionally, the experiential learning embedded within video games forces students to be active learners. For example, playing the game forces students to recognize when they have enough information to understand and proceed or when they need more (National Research Council, 2018, p. 12). Students also have the opportunity to then engage in learning by making inferences. Finally, based on their observations and information gathered, they make decisions based on what they think will happen (National Research Council, 2018, p. 50).

Moreover, in games like QA, where a narrative and storyline frame the individual quests, teachers can challenge students to decide which quest to take on. This kind of decision forces students to see how individual quests may impact the game's larger mission: saving Atlantis. In general, video games can provide problems that emphasize complex problem-solving, critical thinking, and connections to life outside the classroom

(Cognition and Technology Group at Vanderbilt, 1992b; National Council of Teachers of Mathematics, 1989). In analyzing the research surrounding AJW and QA, I articulate four commitments needed to ensure that future serious games successfully move mathematics classrooms beyond "how to solve for x." These commitments are: a learner-centered focus; redefined competence; expanding who is capable of doing math; and connecting concepts across settings.

A learner-centered focus

At its core, video games need to allow students to be treated as knowledgeable thinkers. The game "establishes the why, while the how and the what is developed through playing the game" (Gresalfi, Barab, et al., 2009, p. 24). Through playing the game, new understanding can be "fostered through discussion and collaboration with the child encouraged to express her own views" (Bruner, 1996, p. 57). Through this learner-centered focus, other characters in the game must approach the student as having knowledge valuable to solving the problem. Consequently, learning is built upon previous knowledge and requires a more profound understanding than purely procedural knowledge (Bransford et al., 2000). Although the students take on a character with a specific mission, they use their knowledge to progress through the story.

As stated throughout this paper, traditionally, math classrooms have focused on memorizing formulas and calculations. Such a focus is related to Freire's banking concept of education. However, this is problematic because it presents "knowledge as a gift bestowed by those who consider themselves knowledgeable upon those whom they consider to know nothing" (Freire, 1970/2020, p. 53). As such, competence means "a

collection of skills or abilities that are attributed to an individual" (Gresalfi, Martin, et al., 2008, p. 50). Consequently, the focus on memorization and regurgitation teaches students that "speed is a signifier of mathematical ability...the goal is not only to get problems right but to get them right as quickly as possible (Shah & Leonardo, 2017, pp. 60-61). A learner-centered focus can help reframe this concept because it positions the students in control of their learning. By allowing students to be their own main characters in the game, their knowledge and actions dictate how exactly the story unfolds compared to being told by the teacher which solution path they should follow and how to do so. Granted, even if designed with a learner-centered focus, a video game itself cannot guarantee that this commitment is upheld. How teachers facilitate discussions between games and answer students' questions must also seek to help them by building from their experiences. While a learner-centered focus is vital in the design of games, equally important is for future designs to support a new definition of competence.

Redefined competence

To successfully empower students to feel mathematically capable, it is essential to redefine competence. Students should not be treated as empty vessels that need to memorize information imparted on them by teachers, but as individuals with valued knowledge and experiences capable of solving problems. (Freire, 1970/2020; Gresalfi, Martin, et al., 2008). Here, competence means "what students need to know or do in order to be considered successful by the teacher and other students in the classroom" (Gresalfi, Martin, et al., 2008, p. 50). This definition is not limited to just whether or not what students know is "correct" but includes identifying mistakes and misconceptions or

sharing any solution regardless of its incorrect or correct (Gresalfi, Martin, et al., 2008). Gresalfi, Martin, et al. (2008) provide a framework for conceptualizing competence that involves negotiation between the teacher and students over the type of agency a task affords, what students are held accountable for, and who they are accountable to. Even with this framing, math classrooms can still accidentally support only one way of thinking. Thus, redefining competence alone is not enough to ensure that a classroom is generative, collaborative, and dynamic. Even with the best intentions, it is possible for this reimagined definition to still emphasize memorization and arriving at the correct answer as the only way to be seen as competent. Part of the power behind this definition is the space given for competence not to be rigid but rather malleable. This is because it opens up the possibility for other forms of participation to be seen as competent. Such other forms of participation do not involve being right but asking questions to further understand. Thus, in this framing, competence is not decided just upon the student's ability but based on how their participation is accepted within the classroom (Lave & Wenger, 1991; Wenger, 2010). Although tools and artifacts like video games may support the reshaping of how competence is seen, how teachers have students engage with such games is essential for these new forms of participation to be seen as examples of competence.

Expansion of who is capable of doing math

Video games should aim to create a space where students have the opportunity to try things out without the pressure of "getting it right." Consequently, learning and their intelligence on a subject matter can be positioned as malleable rather than stagnant (Good et al., 2003). Firstly, video games should push to create a space to

evaluate students' understanding without carrying the weight and pressure associated with formalized testing (Steele & Aronson, 1995). Positioning learning and intelligence in this way reduces the likelihood of creating an environment susceptible to stereotype threat (Steele & Aronson, 1995). Standardized tests tend to carry a lot of weight in unnecessarily defining student competence. When students historically marginalized in mathematics take standardized tests, there is added pressure to speak back to stereotypes rather than just learn. Thus, video games should emphasize that evaluation is not a definitive diagnosis of a student's ability. Instead, evaluation should focus on providing feedback and opportunities for students to revise and improve their work as needed.

Next, shifting focus from the pressure created by specific evaluation methods, often the classroom environment and opinions of their peers can impede students' learning. Because mathematical ability has traditionally been connected to speed and memorization, specific ideas about what it means to be good at math have emerged (Shah & Leonardo, 2017). Students of certain groups can often feel self-conscious when they turn in an assignment and fear affirming a certain stereotype. Shah & Leonardo (2017) provide two vignettes where it is expected that one student (Indian) finishes early and does well. The other (African-American) is questioned for being in a Precalculus course, an advanced course for his grade year. Both these vignettes highlight how pre-existing racial discourses are implicitly embedded into mathematics classrooms and hold the possibility to influence a student's actions (Shah & Leonardo, 2017). Videogames can disrupt some of these pre-existing racial discourses.

Given that each student is playing the game individually and could be playing a different quest than their peer, there is no physical attention drawn to a student who submits work early or is the last to turn in an assessment. Thus, students need not worry about the message they are sending by being "fast" or "slow" (Shah & Leonardo, 2017). Of course, this does not eliminate the possibility for progress or comparison between students, but it can help reduce the occurrence. However, integrating video games alone does not ensure that negative racial discourses are eliminated. On the contrary, if not careful, video games can perpetuate those harmful discourses.

For video games to be a tool to uphold the commitment of expanding who can do math, the narratives taken up by games should be careful of the racial narratives they may carry. Designers should seek narratives that do not perpetuate certain negative racial stereotypes but instead highlight how everyone can be "good" at math. Beyond that, attention should be given to the ways students discuss the game and the characters within the different quests/adventures. Given that video games can let students communicate virtually, proper guidelines and safeguards must be put in place to address any harmful language or action. Video games on their own will not solve the issue of racism. However, if designed well and carefully, video games can be utilized as a tool to teach and support anti-racist practices to students. For example, one lesson could have students investigate the effects of machine-learning programs to decide if a person would recommit a crime. In this lesson, students have the opportunity to see that some racial groups who "have historically been disproportionately targeted by law enforcement are more likely to be given a higher recidivism score — which can influence how long they are sentenced for" (Okwuosa, 2021). This lesson could

conclude with students writing a letter to lawmakers where they either support or reject the use of such programs. By expanding who is capable of doing math with the definition of competence and a learner-centered approach, teachers can help reshape the classroom to create opportunities for all students to thrive.

Connecting concepts across settings

Finally, videogames should aim to create a variety of missions where students can connect concepts across settings. Students will be able to connect the skills they learn from the videogame, but an opportunity for them to connect skills they already have is valuable. As mentioned, traditional math classrooms present one-way math is done. This is often limiting because it ignores the ways students encounter and practice math outside of the classroom. Carraher et al. (1985) observed how the strategies students use to solve arithmetic problems vary depending on the context and environment when presented said problems. When out in their communities and in an environment such as selling food items, students confidently worked through various problems without employing a standard procedure. When presented those same problems without the context but now in an environment of a school and the problems were written out rather than verbalized, students transitioned to applying the standard algorithm (Carraher et al., 1985). This example is not meant to highlight one way of solving as better than the other. Still, instead, it is intended to show that students are not always making the connection between both settings and viewing the skills to solve these problems as the same.

Without help in making this connection, students are unlikely to view any of their daily practices as mathematical. It is understandable why when students engage in

mathematical tasks outside of the classroom; they struggle to see that they are “doing” mathematics. Subsequently, without this connection, their only experience of “doing” math occurs in classrooms when they learn standard algorithmic procedures (Nasir, 2001). If they struggle to learn and memorize these procedures, it is understandable for them to identify as not being good at math. Video games can be a tool to create an environment different than a classroom that can disrupt students thinking beyond the traditional norms of a mathematics classroom. This disruption of ways in which students traditionally engage in mathematics opens up the possibility of employing practices they have learned from their communities and having these practices positioned as a form of mathematical practice (Ma, 2016). Again, all of this opens the opportunity to reshape what it means to be “good” at math and who can be “good” at math.

To successfully uphold these commitments, features seen in both AJW and QA should continue to be implemented in future games. In the following section, I name and discuss these features and how they were implemented within AJW and QA. However, future games should not merely replicate what has been done in the past but rather use these features as inspiration to find more ways to create a learning experience that is more culturally relevant and dynamic. This list is not exhaustive nor the definitive answer to features necessary for video games but rather a starting point for future work to build on.

Noteworthy features identified within AJW and QA

To embrace these four commitments, I argue that, at a minimum, the following features exemplified within AJW and QA should be included in the design of future serious games. First, serious games should be **narrative-based**. When placed within a

story, students can adopt the identity of the character they play (Barab, Dodge, Thomas, et al., 2007). Students can pretend and take on roles they otherwise would not think applied to them within a fictional game. Students will often "see themselves as able to take on such an identity and meaningfully use disciplinary content" (Barab, Gresalfi, Dodge, & Ingram Goble, 2010 p. 19). Often, schools provide students solely with the facts and rules needed to operate in the world without showing them how to use that knowledge as a tool. Games are mediums in which disciplinary knowledge is a tool to understand the world (Barab, Gresalfi, Dodge, & Ingram-Goble, 2010). As students progress through the game, new content is delivered organically and mediated by the actions of the students (Squire, 2006). For example, the types of conversations students have with characters during a quest will impact the action a student takes; based on those actions, future discussions will look different for each student (Barab, Gresalfi, Dodge, & Ingram-Goble, 2010). Narratives provide a meaningful frame for students to stay within when learning and applying new knowledge.

Secondly, video games should focus on creating contexts that embrace **transformational play**. Transformational play involves the student "taking on the role of a protagonist who must employ conceptual understandings to understand and, ultimately, make choices that have the potential to literally change a problem-based fictional context" (Barab, Pettyjohn, et al., 2012, p. 519). Incorporating transformational play positions students to understand the utility and value of the content and as a person capable of applying the content (Barab, Pettyjohn, et al., 2012). As a result, students are allowed to practice new concepts and skills in an environment that they can identify with. Through transformational play, students act as the narrator, observer,

and participant of the action. Instruction becomes anchored within a situated context where understanding of context knowledge is necessary to navigate through the story (Barab, Pettyjohn, et al., 2012; Cognition and Technology Group at Vanderbilt, 1990). The student's actions dictate the story's narrative, which they watch unfold as they participate in the game. Most importantly, transformational play allows for video games to be a designed experience where the experience itself is designed by the student (Squire, 2006). Although designers of the game establish the framework and specific learning goals of each quest/adventure, the student's actions dictate how they learn those goals. In this way, what is learned is organically produced by the student's actions and decisions, based on an environment provided by the game and teacher.

Third, AJW and QA do well in the attention and care for integrating **the student's identity** within a game. In general, narrative-based video games can contribute to a sense of authentic purpose and provide a relatable fictional community for players to interact with (Pinker et al., 2017). Nasir (2002) defines identity as "constructed by individuals as they actively participate in cultural activities" (p. 219). Further, learning is more than mastering a set of skills but becoming a particular person (Wenger, 2010). Video games need to allow students to see themselves as doers of math through socialization and interaction to build mathematical understanding (Boaler, 2000; Nasir, 2000; Pinkerd et al., 2017). Within AJW and QA, as students are allowed to exercise authority, they are often given multiple points of view. They then have to decide which one they agree with (Gresalfi, 2009, Cognition and Technology Group at Vanderbilt, 1992a). Although students are not physical players within the world of Jasper Woodbury, each adventure ends with a question posed to the student, inviting them into

the world and adventure (Cognition and Technology Group at Vanderbilt, 1992a). As students play the game, they are positioned as mathematically competent, creating a space for students to identify as capable of doing math. Their self-perception of their non-game selves begins to be influenced by their in-game actions (Barab, Dodge, Thomas, et al., 2007). Thus, following the example of QA, games must look to build narratives not merely to provide content but to instill students with meaning.

Further, games like QA that require students to create an avatar helps students see themselves personally within the game. In each quest, the student may take on the role of a specific character. However, the achievements they receive by completing a quest are awarded to *their* avatar (Barab, Dodge, Thomas, et al., 2007). Thus, students are reminded that their actions are a form of mathematical practice. A virtual world like Atlantis in QA creates a space for students to see themselves and their peers as capable of doing math rather than potentially distant examples like engineers, scientists, and past mathematicians. Further, the narrative design of games allows for other professions and people more connected to the communities of students to be positioned as mathematically capable. Mathematical ability becomes attainable rather than this exclusive skill available to only a select few.

Arguably, one of the most compelling features found in AJW and QA is how each allows for **multiple ways of knowing**. Because classrooms have traditionally centered practices that were very different from students' lived experiences, they rarely attempted to connect what they learned in the classroom to anything outside of it (Boaler, 2000). Both AJW and QA successfully positioned "texts as tools and students as full participants in a textual conversation" (Warren et al., 2019, p. 282). Designers of both

AJW and QA explicitly created environments that did not pigeonhole students into just one way of knowing. Instead, they embraced the diverse ways students come to know and how these practices relate to non-classroom contexts (Barab, Thomas, Dodge, Squire, & Newell, 2004; Cognition and Technology Group at Vanderbilt, 1992a).

Specifically, integrating a video game allows students to engage in productive hybridity (Ma, 2016). This means that students have the opportunity to bridge their “home and community practices with school practices, thus transforming the learning environment and creating new opportunities for childrens learning” (Ma, 2016, p.337). For example, playing a video game is a practice that typically does not occur in a classroom.

Moreover, the tasks presented in different quests mimic situations that arise in society, such as the reelection of a governor. To solve quests, students must employ school practices— using mathematical thinking to accomplish the task. This disruption of traditional participation and learning enables them to "participate in activities that support the development of new mathematical understandings and forms of reasoning" (Ma, 2016, p. 338). Video games are a form of disruptive learning. Students need to use "out-of-school knowledge" (the physical act of playing a video game, interacting with others, etc.) while still centering the experience around learning disciplinary skills.

Finally, an incredibly compelling feature found in QA but not AJW is the incorporation of **consequential engagement**. Consequential engagement allows students to view the consequences of their actions in the future through the game's design. (Gresalfi, Barab, et al., 2009). As students finish the task presented in each quest, they are then transported in time to view the consequences of their actions. Frequently classrooms focus heavily on *how to* employ a procedure (procedural

engagement) and *why* such methods work (conceptual engagement) but rarely are the effects of such procedure addressed (Gresalfi, Barab, et al., 2009). In presenting the consequences, students can see how content knowledge is relevant beyond the classroom. As such, this type of engagement holds the power of addressing "why do we have to learn this?". In addition, incorporating a feature that allows students to visually see how their actions affect the narrative provides a more meaningful opportunity than imagining it (Barab, Dodge, Ingram-Goble, et al., 2010). The best example of this is the Quest, Normal Village within QA. Students entered a community to interpret the facts given by the Mayor in the village and another character within the game. Based on their opinion, the town will decide whether or not to keep the Mayor in power (Barab, Dodge, Ingram-Goble, et al., 2010). Units like Normal Village attach stakes to students' decisions; as students progress through the narrative, it changes based on how they can participate. To successfully implement consequential engagement, designers must intentionally seek to create opportunities that tie students' procedural and conceptual knowledge to the context so that students' actions have legitimate consequences to the world (Gresalfi & Barab, 2011). Without consequentiality, students do not have the opportunity to realize the impact of their decisions.

Role of teacher

Given the commitments and features described earlier in this paper, these kinds of narrative video games can be a tool that helps teachers. Narrative videogames can help reorganize the curriculum into big ideas, approach math topics by engaging students in group-worthy tasks open to multiple representations, and push students' thinking and justification about their mathematical thinking publicly and independently

(Louie et al., 2014). The game should support the teacher as a facilitator, allowing their facilitation to take on a new form by transforming the learning environment. The Online Support Roles framework (OSLR) outlines ten roles educators can adapt to support students' learning when implementing digital learning. These roles are audience, encourager, evaluator, friend, instructor, learning broker, model, monitor, promoter, and resource provider (Nacu, Martin, Pinkard, & Gray, 2014). During and in between participating in quests/adventures, teachers hold an advantageous position in supporting students' learning. Although teachers do play an essential role in successfully implementing such games, they are often not supported by the system (i.e., school administration and school district) to do this well. Video game designers need to consider how to make these roles available to teachers that consider other factors at play besides the game itself.

Thus far, this paper has focused on how video games can help transform the classroom and support emergent mathematical practices. Although video games have many affordances, it is unlikely that they will solve every problem. It is possible that video games could continue to perpetuate the idea that doing math only involves memorization and procedural understanding. There are factors outside of the actual implementation of the game that teachers and districts should consider first. Given that some procedural knowledge is necessary, narrative-based video games, as I have discussed here, maybe a great supplemental resource to contextualize the procedural processes students learn. Thus, designers involve educators in the research design process of building future games. With the help of educators, designers should look for ways to design video games so that they complement the curriculum already being

used. Eventually, designers and educators may want to explore the idea of having the video game be the entire curriculum; however, for that to occur, significant time and effort should be given to how to support teachers in this transition. Even as a supplemental source, designers should work with district leaders to ensure enough easily accessible resources to help teachers understand how the game works. Further, teachers should have reasonable time to learn about the game. Given the plethora of responsibilities teachers have outside of classroom instruction, it is not reasonable for designers and district/school leaders to demand the implementation of serious games without providing support. More importantly, this support should be provided within the bounds of the contractual hours teachers already agree to. Because this may mean it may take longer before a video game enters a classroom, they should be seen as a tool for helping transform the classroom, not the solution.

Consequently, for video games to be a part of the solution, teachers must find them beneficial. To ensure that teachers want to use the video games, district/school leaders need to allow teachers time (within their contracted hours) to learn about the games. Setting up and launching complex tasks within a classroom is a difficult task that takes a lot of planning on the part of the teacher (Jackson, Garrison, et al., 2013). Video games relieve some of the difficulty by providing the actual task. However, teachers must still spend time thinking about introducing and defining contextual and mathematical ideas so that students will engage in the activity.

As a supplementary aide in instructions, integration of the video game should be strategically thought out. Video games have the opportunity to contextualize the procedural tasks students are used to learning in math classrooms by providing relevant

problem scenarios. As mentioned earlier, educators should be part of the design team to ensure that video games are designed to complement a given curriculum. Beyond that, teachers must adequately launch these complex tasks before releasing students to explore the game or begin a specific task. Precisely, teachers should aim to implement what Jackson, Garrison, et al. (2013) defined as the four key aspects of a high-quality setup. First, teachers must introduce and discuss contextual features. For example, in a game like QA, which has an adventure challenging students to decide which candidate to support in the elections and collect data to support their decision, teachers may want to consider discussing what an election is, how someone gets elected, and why we have elections (Barab, Gresalfi, Dodge, & Ingram-Goble, 2010). Next, teachers need to discuss and explain any mathematical concepts students may encounter or be unfamiliar with. For example, using the same QA adventure, teachers need to understand what students know about tables, graphs, and data collection methods relevant to this problem and address any potential misunderstandings that may arise. Thirdly, teachers and students should work together to co-construct a common language around the tasks and artifacts students will engage with and produce throughout the game. This helps make students feel comfortable discussing the actions they take with each other (Jackson, Shahan, et al., 2012). Finally, mathematics is filled with specific terminology that can be confusing and intimidating; co-creating a common language enables students to engage in mathematical discourse even if they do not use the exact wording (Jackson, Garrison, et al., 2013).

Implementing these key aspects is vital to promoting student engagement and participation with the video game. These three key aspects should also be implemented

when introducing the video game in general. Although students are likely to have some experience with a commercial video game, teachers should still take time to adequately present the video game, defining contextual, technical, and mathematical understandings students may need to successfully interact with the serious game.

Both teachers and video games can work together in practicing the final key aspect; maintaining cognitive demand. The narrative-based feature of the video games described in this paper helps teachers not suggest one specific solution path to students. Given that students can interact with various characters, all with different opinions, the game can ensure that there is not one clear solution path. However, teachers must be prepared that students will approach them when they get stuck. To maintain the cognitive demand, teachers should provide students guidance on proceeding without explicitly providing a solution (Jackson, Garrison, et al., 2013). Taking inspiration from Railside schools, teachers may want to consider grouping students and allowing them to collaborate while they engage in quests. Thus, if students have a question, they can turn to their groupmates for help before asking the teacher for help (Louie et al., 2014). Additionally, teachers may decide to engage in other talk moves; re-voicing, restating, applying reasoning, using wait time, prompting students, and using whole-class discussion, small-group discussion, and partner talk as necessary when implementing any of these aspects (Chapin et al., 2003; Jackson, Garrison, et al., 2013). Finally, the video game should support the learning goals and mathematical practices teachers hope to cultivate and teach their students. Specifically, the features and commitments of video games discussed here can help teachers seeking to transform what it means to be good at math.

Although teachers need to find moments between adventures/quests to interact with the students, teachers should also be active participants in the game. Like the students, teachers should create their own avatars in the virtual world of the video game. This allows the teacher to be an active audience member and view what students are doing online (Nacu, Martin, & Pinkard, 2018). By creating their own avatar, teachers can build relationships with the students while playing the game and adopting the friend role. In addition, having an avatar allows teachers to show approachability and engage in off-topic conversations (Nacu, Martin, & Pinkard, 2018). Moreover, having an avatar enables teachers to monitor and model accepted behavior for online environments.

On top of creating an avatar, as seen within QA, when students "submit" their work to different characters in the game, the work is actually going to the teacher (Barab, Pettyjohn, et al., 2012). In moments like these, teachers have the opportunity to exemplify the role of encourager and evaluator. As an encourager, teachers' feedback should still encourage and uplift the students' ability to identify as mathematical thinkers. When acting as an evaluator, teachers should embrace multiple representations (Nacu, Martin, & Pinkard, 2018; Louie et al., 2014). This is not to say that teachers cannot correct or directly instruct students when they express an incorrect mathematical idea. Instead, feedback should focus on helping students reevaluate their approach without providing a specific solution path (Jackson, Garrison, et al., 2013; Nacu, Martin, & Pinkard, 2018; Gresalfi, & Barab, 2011). Providing feedback is essential; without it, students are unlikely to achieve a deep and correct understanding of the concepts (Cameron & Dwyer, 2005). However, it is crucial that in providing feedback, teachers

remember that students are not empty vessels to fill knowledge into but instead allow students to struggle with their ideas and build from the knowledge they do have (Freire, 1970/2020).

Introducing and participating in the game is not enough. Teachers should facilitate a whole-class discussion after presenting the game and supporting students through the quest. In these moments, teachers have the opportunity to allow "student presentations at the overhead" (Louie et al. 2014, p. 50). This means giving students a voice and mathematical authority to share their ideas with the class and justify their thinking while the teacher listens (Louie et al., 2014). In doing so, teachers have the opportunity to learn what students have discovered from engaging with the game and what they may still need to work on. In addition, a whole-class discussion allows students to collaborate and discuss strategies implemented while playing their game (Barron et al., 2014). Further, in these moments between playing, the teacher can structure "group worthy tasks" centered around analog and extension problems from the most recent adventure/quest (Louie et al., 2014; Cognition and Technology Group at Vanderbilt, 1992a). This allows teachers to provide students with opportunities to connect the skills addressed in the quest across different topics.

Finally, district and school leaders should help create a community for teachers implementing the same game to connect outside of the classroom instruction. By engaging in conversation with one another, teachers can seek help on issues that arise when they implement the game and have discussions with students (Barron et al., 2014). Establishing professional communities allows teachers to collaborate on tasks and discussions they want to implement to support the video game. "In order for

teachers to have deep understandings of what it means for students to do math together, teachers themselves must engage in doing mathematics together" (Louie et al., 2014, p. 235). Moreover, much like pushing for teachers to create their own avatar, the process of collaborating with other teachers forces teachers to "walk the walk, engaging in the same types of practice in which they are asking students to take part" (Louie et al., 2014, p. 235). Considering teachers' numerous responsibilities, participation in this community should not be required. However, school leaders should find time within teachers' contract hours to allow teachers to engage and plan with other teachers on how to best implement the video game. Suppose district and school leaders cannot find a way to adequately support teachers without requiring teachers to work extended and unpaid hours. In that case, these leaders should reevaluate the work beyond the instructional time they have assigned to teachers before even bringing the video game. The suggestions to implement a video game as described in this paper are not meant to add more work onto teachers' plates. Yes, the successful implementation of this serious game will initially take work, especially at the beginning, which is why teachers should be given adequate time to make this transition.

Expanding possibilities for video games in classrooms

Simply adopting the features narrative-based, transformational play, integration of identity, pathways for multiple ways of knowing, and consequential engagement into future videogames is not enough to ensure their success. Although research on both QA and AJW has shown the features as they were conceptualized initially were successful, future researchers should look to push the boundaries of each feature. Future games should provide a broader range of narratives for students to engage. In

doing so, researchers should incorporate narratives that represent communities other than those considered Western, Educated, Industrialized, Rich, and Democratic (WEIRD) (Henrich et al., 2010). Traditionally, research has been plagued by using a WEIRD sample. Such practices exclude the multiple ways of knowing students bring to the classroom and effectively invalidate their learning (Henrich et al., 2010). One way to ensure that narratives are more diverse is by allowing students to design narratives for other students to attempt. In doing this, students are positioned as valuable and credible sources of knowledge. They can think critically about how concepts may apply to different situations, aiding in their ability to transfer knowledge (Gresalfi & Barab, 2011). Giving students this opportunity also pushes what transformational play can look like within a virtual world. Not only are students acting as the narrator, observer, and participant within adventures/quest, but through designing their own quest/adventure, students are the first narrator, observer, and participant of this quest (Barab, Pettyjohn, et al., 2012). They must think about the consequences of different solutions to their problem and whether students have the necessary information to participate in the quest (Gresalfi, Barab, et al., 2009). Most importantly, through such an activity, students can bring their interests and values into the classroom and present that to their peers.

A second way the game's features could be pushed further is the opportunity for students to engage with tools they use in quests into an environment detached from any quest/adventure. For example, Hooper & Freed's (2013) initial inquiry around the design of their tool, the "spirograph," shows the fruitful experience participants had when allowed to explore a tool and then come up with questions around their explorations. Building on the virtual world QA created outside of the individual quests, future

designers may look to create a space for inquiry around the tools used within quests (Barab, Dodge, Thomas, et al., 2007). Within this space, players can collaborate around questions they come up with. In imagining the implementation of such games at the high school level, an added feature could involve students choosing the tools available to them during quest/adventures. Before starting a quest/adventure, students could see a preview of it and then decide which tools to add to their inventory for that quest/adventure. Tools can be unlocked as players progress in the game. This sort of freedom can make the quest/adventure more challenging and create the opportunity for a meaningful class discussion where students can justify which tools they chose and why.

Finally, future games should better attend the different roles made available for teachers within the game itself. It is easy to create a space where teachers can act as mentors, encouragers, evaluators, and instructors, as seen within QA (Nacu, Martin, & Pinkard, 2018; Gresalfi & Barab, 2011). Games should give teachers better support to be learning brokers and resource providers. This may look different for each type of game. Still, teachers should have the ability to provide other learning opportunities for students to engage with that can support their learning and interests (Nacu, Martin, & Pinkard, 2018). This is important because it allows teachers to help students identify with the game and view themselves within it (Barron et al., 2014).

Even the way video games support any of these roles can be improved upon. Simply setting up a space for teachers to provide feedback or resources is not good enough. Given that districts tend to ask teachers to play many roles beyond classroom time, designers need to consider the time it will take for teachers to take up these roles

properly. One example can be allowing for pre-filtered responses to be set up so that teachers do not have to constantly be typing out responses for each student. A feature that allows teachers to create their own responses should also be made possible. Along the same lines, designers may want to consider providing teachers with a list of resource links, so they do not have to go hunting for it themselves. Finally, settings should be made so that teachers can uptake the role of monitor without having to physically be logged into the game or observing every action made by each student. Given the amount of time the designers may spend developing and creating video games, I think it is necessary for them to think beyond how to simply incorporate the roles outlined by the OSLR framework (Nacu, Martin, Pinkard, & Gray, 2014). Designers must give attention and consideration around how to make these roles manageable, sustainable, and implementable by teachers without adding more onto their already heavy load.

Dilemmas

Thus far, I have discussed narrative-based video games' commitments, features, and implementation in classrooms. I now turn the discussion towards dilemmas and issues when engaging in design-based research to create new serious games. Generally speaking, design-based research is a "series of approaches with the intent of producing new theories, artifacts, and practices that account for and potentially impact learning and teaching in naturalistic settings" (Barab & Squire, 2004, p. 2; Design-Based Research Collective, 2003). Extending the scope of design-based research, Barab, Dodge, Thomas, Jackson, & Tuzun (2007) discuss the "importance of critical design work, highlighting the broader opportunity for design-based researchers to explicitly

acknowledge and actualize social agendas in their work" (Barab, Dodge, Thomas, et al., 2007, p. 265). Future work around the design of serious games should seek to implement the five steps of critical design work: building a rich understanding, developing critical commitments, reifying commitments into the design, expanding the impact, and making theoretical contributions (Barab, Dodge, Thomas, et al., 2007). By implementing these five steps, researchers must ask questions on how to support students and teachers in regions where access to the internet may be difficult? What would the cost be to implement an educational-based video game, and how can we make it more accessible? How will the game impact the current curriculum teachers are using? What kind of training needs to be provided to teachers so that they are set up to be successful? Ignoring these questions ignores the larger context that impacts the classroom and, consequently, student learning.

Aside from the game's actual design, future work around video games and their implementation into the classroom should center around garnering support for their use of video games in the classroom. Although teachers, students, and even parents have acknowledged how engaging games can be, a majority of parents still feel that any game, including video games, does not belong in the classroom (Saez-Lopez et al., 2015; Girard et al., 2013). Given the current forms of assessing new curriculum and video games, it can be challenging to garner public support for their use (Barab, Dodge, Thomas, et al.; Girard et al., 2013). Part of this public opinion is because, unlike AJW and QA, which were designed with the theory of learning in mind, many serious games have not been. Future serious games must attempt to incorporate an explicit theory of learning into the design so that arguments around games being a "waste of time" are

combated (Shaffer et al., 2005; Saez-Lopez et al., 2015). However, a game designed around a theory of learning is not enough. For future games to enter a classroom, districts and teachers need to be convinced a specific video game aids a child's learning. Distal assessments are one measurement used to garner support for adopting a video game and curriculum. Such assessments can help highlight how the activity helps aid students' understanding of state standards. However, because of the use of distal assessments, which implement random selection over standard oriented items, it is common for questions to appear attached to a specific curriculum, or in a specific way, often not addressed in video games. It usually takes multiple iterations of the game before seeing distal achievement (Hickey et al., 2009).

Since it takes many iterations, developing a game can take much longer to produce than a curriculum catered to the types of questions on distal assessments. Whether the fact that it takes longer or not to develop a game is a good or bad thing is beyond the scope of this paper, but the length of time needed to design a game should be explored as well. Distal assessments are not embedded into the game but are something students participate in after playing a game to evaluate the game's design. Such tests can be problematic because students' knowledge and capability of doing mathematics are judged on this singular test. Designers and educators should clarify to students that their participation in the distal assessment is not an assessment of their knowledge or capability. Instead, it is an assessment of the game and how it supports students. Given that the assessment measures the effectiveness of the video game, researchers must be careful not to let such outcomes impact the design to the point

where the video game caters specifically to the distal assessment rather than focusing on the commitments described earlier.

This paper argued for the need to redesign mathematics classrooms to be more generative, collaborative, and dynamic. However, much like the standardized tests used to measure students' achievement each year, the current assessments used to evaluate serious games reinforce the rhetoric that mathematical knowledge involves the ability to memorize and quickly reproduce procedures (Nasir, 2002; Boaler, 2000, Shah & Leonardo, 2017). If researchers and educators genuinely want to create student-centered classrooms and spaces for multiple ways of knowing, assessing future serious games and curriculums must mirror these values. Hickey, Ingram-Goble, & Jameson (2009) argue that once serious games can provide enough evidence on their impact on distal learning, it might be possible to remove the need for distal tests altogether. I believe that researchers should seek out different formats of distal tests. Future assessments used to evaluate serious games should include elements that evaluate the games' ability to foster a generative, collaborative, and dynamic experience. Could the fact that students can complete quests/adventures be evidence for learning? Could the quests/adventures designed by students be used as evidence for learning? These are just a couple of questions that I pose for future research to consider.

Finally, video games alone are not *the* solution to successfully making a classroom a generative, cooperative, and dynamic environment for students. But, video games can be a part of the solution and a step in the right direction. However, in addition to some of the concerns mentioned above, designers, leaders, and educators

must consider the work needed from teachers to implement the games successfully. If the video game only adds to the teacher's workload without eventually replacing anything, then it may be best to refrain from using the video games at all. Researchers should also explore other ways to transform mathematics classrooms to complement what teachers are already doing. Ideally, researchers should aim to create various ways to transform the classrooms for teachers to decide what will work best in their classrooms. This paper discusses one potential tool, video games, because of their design's attractive and dynamic features. Still, there are most definitely other tools that can be equally helpful. Math classrooms should be a space where students develop problem-solving skills and build confidence in their mathematical abilities. All students are capable of being good at math; video games are one tool that can help students make this realization.

Conclusion

Everyone is capable of being good at math. Unfortunately, traditional classrooms do not always set students up to feel this way. I have always wondered why people did not think they were good at math, especially when they would provide examples riddled with mathematical practice. But then, it hit me; classrooms rarely offer activities that help students connect their daily lives and the skills they learned in math classrooms. Additionally, we treat math as a biological trait that can be easily assessed based on multiple-choice standardized tests. If classrooms are meant to prepare students for the "real" world, why do many math classrooms remove any semblance of the "real" world when teaching students? But everyone's world outside of the school is different, so

burdening teachers with the task of creating engaging problems relevant to all students is not realistic.

However, as described above, video games may be an avenue to explore that can help teachers and students bring stories into the classroom in a meaningful and emergent way. Although I state implementing video games in classrooms as some easy task, I acknowledge that it is not. There are many complexities to consider deeper than the design, such as the training to help teachers learn about the game, the way videogames can complement an existing curriculum, and the sort of technological literacy students may need before playing the game. However, video games on their own will not guarantee to transform mathematical classrooms to be generative, cooperative, and dynamic. Instead, I see them as a powerful tool that can help open the conversation or provide an example of where to start in creating such a classroom. Knowing how to solve for x is excellent—knowing why and the impact of your solution's value on something can be even more powerful. We are all capable of doing math, and it is the heterogeneity we bring to solving problems that creates the opportunity for innovative solutions to problems. Classrooms should be a place where students are given the space to practice without fear of permanent consequences to be better prepared for when they encounter such challenges outside of the classroom.

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