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Article

Elementary Science Instruction: Examining a Virtual Environment for Evidence of Learning, Engagement, and 21st Century Competencies

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Abstract: This mixed methods study examined the effectiveness of a virtual world curriculum for teaching elementary students complex science concepts and skills. Data were collected using pre- and post-content tests and a student survey of engaged learning, An additional survey collected teacher observations of 21st century competencies conducive to learning. The study involved a five-day intervention of fifteen 4th grade students in a small Midwestern school using a virtual science computer game from Arizona State University. Thirty elementary teachers from Australia, England, and the United States were surveyed on classroom observations of their elementary students working in the virtual world environment. Research questions guiding the virtual learning study were: (1) do pre- and post-content tests show significant learning in the virtual environment; (2) are students academically engaged during the learning process; and (3) are students actively demonstrating relevant 21st century competencies. The study supports prior research in game-based learning showing measureable learning results, highly engaged, motivated students, and observations of student behaviors conducive to learning science in school, namely collaboration, problem solving, critical thinking/inquiry, global awareness, and technology use.

Keywords: science; virtual environment; game-based learning; engagement

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1. Introduction: Responding to New Science Standards with Virtual

In areas of math and literacy, education reforms in recent years have pressured schools to show achievement results according to common state standards, increased teacher effectiveness, and innovative professional development, and standards have emerged to guide that instruction. Now educators in science and technology are experiencing a surge of expectations as well: an emphasis on science, technology, engineering, and math (STEM), brought into sharper focus and wide distribution in April 2013 with the release of the Next Generation Science Standards (NGSS). With this increased focus emphasizing key dimensions of science learning across grade levels, expectations have increased for educators to teach STEM skills in elementary through high school [1–4]. Given the focus on STEM and the arrival of the Next Generation Science Standards, educators are in the accountability spotlight to identify curriculum, methods, and resources to meet these new expectations.

Achieving success will depend on variables such as equity of student access to high quality curriculum and resources, as well as the presence of STEM-knowledgeable, effective teachers. But in addition to stand-in-front-of-the class teacher-led instruction, effective scenarios for teaching science include using project-based learning, increasing science labs and field trips, and using technology-supported learning tools such as simulations and virtual environments which can be implemented in the classroom [5,6]. Researchers have shown that in virtual environments, students can have experiences in identity roles doing real tasks of scientists in situations not possible in a traditional classroom. In recent years, research in educational virtual environments at the elementary and middle school level, has shown promise for increased academic achievement, enhanced engagement, and development of 21st century competencies such as inquiry, critical thinking, collaboration, communication, and technology use [7–9].

2. Importance of Engaged Learning

The term *engagement* has been defined in many ways by different researchers, depending on the context of the study. In cognition terms, engagement relates to a student’s inclination and effort toward comprehending and learning academic topics, self-regulating his or her actions, and exhibiting academic strategies. When students are observed exhibiting extended time on a task requiring careful thinking and are focused on authentic, meaningful tasks, this, according to Corno and Mandinach [10], is evidence of engagement. An engaging, authentic learning situation, as described by Jones, Valdez, Norakowski, and Rasmussen [11], will include challenging work, immediate feedback, learning choices, and social interactions.

We know that student learning is directly affected by student engagement [12,13]. In an era of heavy standardized testing targeting math and literacy, researchers have noted a detracting symptom—an over focus on assessment can negatively affect student motivation and engagement. Yeh [14] found that low student engagement exists across the U.S. educational system and concluded that creating engaging learning for students should be a priority goal in education. Problems of low student engagement in the current test-heavy environment have been a serious barrier to learning in schools across the United States, especially in low socioeconomic areas. Longitudinal studies of student engagement in early elementary years showed that problems with engagement have negative long-term effects on achievement. The Beginning School Study [15,16] showed that engagement in first grade was related to achievement test results as students progressed through Grades 1, 2, 3, and 4, as well as subsequent decisions to drop out of school [17]. Clearly, being engaged is a prerequisite to learning.

2.1. Learning Theory—Situated Learning

Researchers examining situated cognition [9,18,19] have argued that a major reason for student disengagement in schools, and why students may perform below expectations, is partly because the curriculum is disconnected from their lives. In other words, many classroom skills acquired based on a rote approach, fail to transfer to real life. According to situated cognition research, the disconnection lies in the separation of curriculum content from the situations or context in which that content would normally be used. The researchers argue that meaning is lost in this decontextualization of content—so ultimately engagement, learning and student achievement are minimized [17–19].

2.2. Games Can Engage Students

Finding new methods and materials to foster engagement, as well as upgrading teacher skills to use these new materials and methods, has become an important goal for educators. With the growth of Internet applications and tools, the increase in broadband availability, an increasing number of K-12 teachers are expected to incorporate technology into classroom instruction. Researchers contend that as teachers should for new methods, they should be considering looking games and virtual environments because these activity forms are highly engaging and present students with chances for deeper learning and problem-solving opportunities not typically found in school classrooms [20,21, 22].

In a study of elementary students, aged 9 to 12 [22], students showed a clear preference for playing video games in their leisure time. The researchers observed proficient behaviors in self-regulation, qualitative thinking, and decision making, all desired characteristics of successful students. From what was learned about the students' involvement with video games, the researchers argue that video games represent a learning form that engages students and deserves attention from educators. But computer learning approaches in elementary and middle school have typically used games designed for factual content and explicit test practice [9]. Multiple-choice and fill-in-the-blank software for standardized test practice in math, reading, and other subjects has been available to schools for years, while outside of schools, noneducational commercial video games continue to rise in popularity and sales. Given that youth spend significant time with video games, researchers argue that commercial gaming companies are, in a sense, educating our young people. And, although commercial games with educational potential do exist, there remain too few examples that would satisfy teachers and parents, and support engaging academic learning [23].

With technology advancements and the rising popularity of Internet-based multiuser games, skills-based educational games are no longer the only option for schools. Examples of educational virtual learning environments can be found at Arizona State University (*Quest Atlantis/Atlantis Remixed*) Harvard University (*River City* and *EcoMUVE*), North Carolina State University (*Crystal Island*) and the California Institute of Technology (*Whyville*). Each of these incorporates avatars in a virtual world, communication/collaboration among players, using tools, simulations, and academic content including science, math, economics, and literacy. One reason these worlds are effective is because students assume the role of the experts working in an authentic virtual circumstance; that is, the students are working in similar conditions as real-world experts [24,8]. Also central to these virtual worlds is the concept of play, where students are free to experiment with learning and try new identities or roles [7,19]. Play itself is an important component of learning [25], and observations of children at play, have shown that in assuming new roles, children exhibited levels of thinking and performance beyond their age levels. Gee [21] and Klopfer [9] argue similarly that games provide students with opportunities in risk-free scenarios to explore and experiment as both novice and expert, engaging in activities and using competencies that are key to being a successful student.

Dede's [26] virtual world work on the transfer and usability of knowledge, points out that intentionally designing virtual experiences situated in specific tasks, activates the human senses, and creates a feeling of presence, of actually being in the virtual setting, while interacting with its characters and facing its challenges. Dede extends the case for digital environments to include the idea of multiple perspectives: learning is enhanced when a student is able to change his point of view or frame of reference at will. This can be accomplished by "seeing" an object or location from the inside, such as a laboratory in a virtual world, or viewing that same object or location from a distant point in the virtual world, available for exploration and choice, rather than the being isolated in prearranged lessons. The student has control of what lies ahead, can change direction, and can adjust progress—opportunities not found in a regular classroom situation. The virtual environment selected for this study exemplifies Dede's contention.

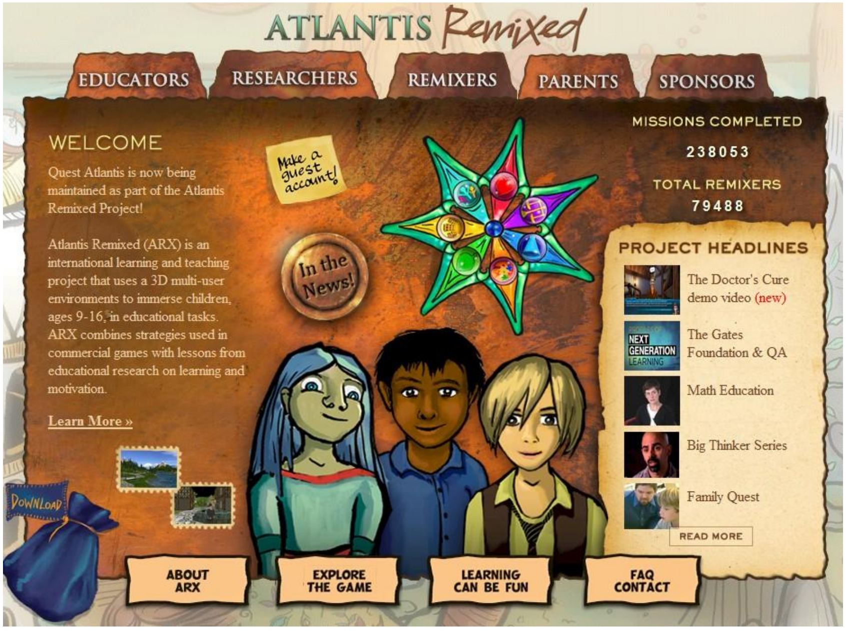
3. Choosing a Virtual Environment for the Study

The virtual learning environment chosen for this study was Quest Atlantis/Atlantis Remixed (QA/ARX), a university-based research project focusing on learning and teaching. The purpose of this paper is not to describe the full details and instructions for using QA/ARX, but to provide enough information on it to show how students used it to learn in the study. It is a virtual environment designed for students, ages 9 through 16, and is available free from Arizona State University. Figure 1 displays the opening screen of the project site. It provides access for educators, students, and interested parents to download the program and learn its features. In contrast to commercial games, QA/ARX offers an overview of the program, related downloadable text materials, links to educational research papers and videos, training instructions, and connections to related educational resources intended for teacher collaboration and learning [23].

The program is currently in use on six continents by teachers and students in Norway, Croatia, Canada, New Zealand, Israel, Australia, Italy, Turkey, China, Denmark, Britain, Japan, and the United States—the number of users is estimated to be more than 60,000.

The designers leveraged commercial gaming formats to make learning spaces without violent interactions in order to position students in identities or roles where they manipulate content in real contexts by *being* scientists, writers, recyclers, counselors, and other responsible roles. During the orientation to the virtual world, students create their own avatar and choose skin color and clothing for the virtual adventure. Students are shown how to use navigational guides in virtual spaces, how to teleport to different worlds, and how to go through the process of choosing missions in a variety of academic content areas such as science, math, literacy, and social studies.

Figure 1. Introduction screen of Quest Atlantis/Atlantis Remixed (QA/ARX).



3.1. Learning Science in a Virtual World

This study is concerned with student learning. Content knowledge has been the major focus of testing in schools, but the education experts, who authored the National Education Technology Plan [27], concede that content is not enough. Learning is a complex phenomenon; it includes more than just exposing a student to facts and expecting those facts to be retained. Deeper learning requires connections among the learner, the context of the learning, and the content of the learning [18,19, 21].

This study uses a virtual world scenario of a science challenge not typically found in a 4th grade curriculum—sustainability science and the study of genetics. As part of a narrative, students learn about the idea of sustainability, of serving today's needs without wasting resources needed by people in the future. Along with sustainability learning, students are introduced to the concept of genetics. While most 4th graders might have a sense of genetics from observing traits in their own families, such as eye and hair color, the academic language and vocabulary of genetics are typically unknowns to this age group, since the content is taught in later grade levels. Students in this study were invited to take on the identity of a scientist, and to complete tasks that involved learning how to use scientific tools and concepts in order to breed virtual dragonflies of a specific size and color, and to understand the probability of such occurrences given the genetic characteristics of the mother and the father dragonfly. In the virtual environment narrative, a particular dragonfly called the drako is a pollinator for the Cassip flower which in turn is the source of a rare medicine used to treat serious illnesses. Both the flower and drako are in jeopardy as the environment is being altered by as machines clearing land for new construction. The student player is needed to help change the world, to find alternative solutions to ensure that the drako survives which in turn will ensure a critical medicinal supply needed for the future. Students start the mission by reading the Task List (Figure 2):

Figure 2. Mission Task list.

The study occurred over a five day period in a classroom equipped with eleven Internet-connected computers. Quest Atlantis was implemented during an extended morning learning centers time with each student working for 2 or more hours online. Students began the quest by teleporting to a virtual location called the Sustainable Science Conservatory on Healthy World, and there they are asked to locate certain characters at specific directional locations. The students were experienced QA/ARX players, so teleporting and navigating in virtual worlds was already a competency they possessed. As the mission progressed, the students visited the Conservatory, and talked with in-world programmed characters (Figures 3–5) Ithnus, Uther, and Ekon as they learned about genetics and breeding dragonflies. The in-world characters helped tell the story, and offered choices and assigned tasks to students.

Students received no additional prompts from teachers while navigating or proceeding through the virtual world. Students navigated the environment collecting virtual dragonflies, using mating tanks, working with genetics machines, and solving trait matrices called Punnet Squares in order to produce specific genotypes of dragonflies. Figure 6 shows the Punnet Square tool students used for designing specific dragonfly offspring.

Figure 3. Ithnus—sustainability scientist.

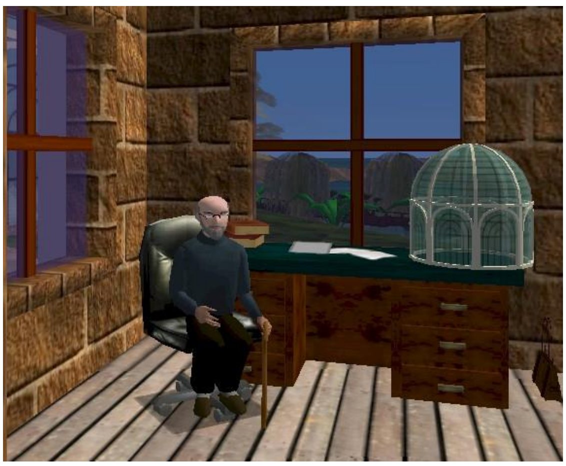
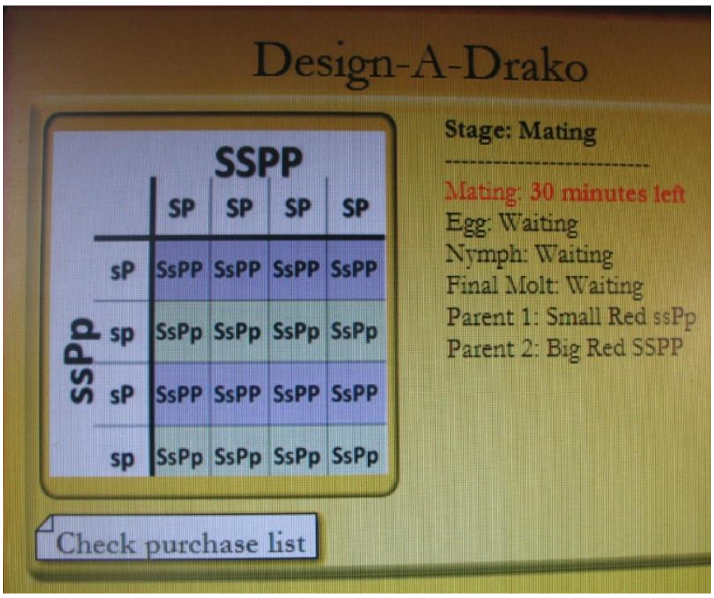


Figure 4. Uther—breeder scientist.

Figure 5. Ekon—genetic engineer.

Figure 6. Punnet Square for dragonfly mating.



In the virtual science experience, Dr. Uther (a programmed character) teaches students to match dominant and recessive characteristics among red and blue dragonflies to produce at least one small blue dragonfly. In the process, students were involved with learning new vocabulary, gene splicing, breeding, and finding cures for diseases. As tasks were completed, students had to submit written observations of their activities explaining what they had learned. As students interacted with the in-world characters, they made choices with each encounter, which charted their own pathways within the narrative, defining individual learning trajectories, a design feature intended to make player actions result in consequences on the environment as well as on their own learning. Because their actions have a consequence, students understood that they had a direct effect on what happened next in the virtual experience. While living the role of a scientist, they were reading for meaning, comparing ideas, solving problems, collaborating with other students in-world, deciphering puzzles, operating scientific machines, making choices based on time and resources, and writing and reflecting on the content of the mission—and all while they were playing a game.

4. Methodology and Research Design

This mixed-methods study examined the effectiveness of learning experiences by elementary students using an educationally designed 3D virtual environment. This study used quantitative student pre- and post-test data, an engagement survey, and survey data of teacher observations of students working in a virtual learning environment. Three questions guided the study of learning in the QA/ARX virtual environment: (1) do students show significant pre- and post-test science learning; (2) are students academically engaged during the learning process; (3) are students actively practicing relevant 21st century competencies. The researcher triangulated to determine how results from the different data sets compared. Triangulation is known to be effective when the strengths of one approach can offset the weakness of the other approach [28]. The researcher used multiple perspectives and theories to interpret the data and enhance the understanding of the connections among engagement, 21st century competencies, virtual worlds learning, and social-learning theories. Janesick [29] corroborated this style of interpretation.

4.1. Test Data—Pre/Post-Test Results

In one test, students were introduced to six hamsters with varying descriptions of fur length, presence of a tail, and color of fur. Matching genotypes were provided for each of these. For example, test directions showed students that BB or Bb represented a long tail, while bb was a short tail. RR or Rr was presence of a tail, while rr indicated no tail. Directions instructed students to use the genotypes in identifying specific hamsters that would be associated with changing genotypes. A graphical organizer, typically used in genetics courses, called a Punnet Square was incorporated to show how genotypes can be paired to result in specific traits. Finally, students were introduced by test examples to the fact that some phenotypes such as color and size were dominant and some recessive, thus further affecting possible offspring combinations. After 5 days of work in the virtual world, where students talked to virtual scientists, learned about breeding processes, captured virtual dragonflies, and used scientific breeding tools to create certain sizes and colors of dragonflies, a posttest was given.

A common and widely used method for evaluating differences in means between two groups is the paired samples *t*-test [30]. For the test data in this study, the *t*-test was used to check for a difference in students' pre- and posttest scores. Before and after working in the Drakos mission, the fourth grade students were tested on their knowledge of genetics. Tables 1–3 show the data from the pre- and post- *t*-test scores. Provided are results from paired samples correlations, paired sample statistics, and paired samples test comparisons. Shown are improvements with the pretest to posttest mean increasing from 6.633 to 10.133. Pretest to posttest standard deviation changed from 2.0219 to 4.3072. The paired-samples *t*-test indicated that scores were significantly higher for the posttest subscale ($M = 10.1$, $SD = 4.30$) than for the pretest subscale ($M = 6.63$, $SD = 2.02$), $t(14) = -3.42$, with $r = 0.46$ and $d = 1.04$. The gain is small, but statistically it is significant. Students showed improved results on the posttest following the 5 days of using QA/ARX to learn the genetics content. See Supplementary A for the pre- and posttests used.

Table 1. Paired Samples Correlations.

Paired Samples Correlations			
	N	Correlation	Sig.
Pretotal & Posttotal	15	0.400	0.140

Table 2. Paired Samples Statistics.

Paired Samples Statistics				
	Mean	N	Std. Deviation	Std. Error Mean
Pretotal	6.633	15	2.0219	0.5221
Posttotal	10.133	15	4.3072	1.1121

Table 3. Paired Samples Tests.

<table>
<tr><th colspan="9">Paired Samples Test</th></tr>
<tr><td rowspan="4">Pretotal & Posttotal</td><th colspan="5">Paired Differences</th><td rowspan="3">t</td><td rowspan="3">df</td><td rowspan="3">Sig.2-tailed</td></tr>
<tr><td rowspan="2">Mean</td><td rowspan="2">Std. Deviation</td><td rowspan="2">Std. Error Mean</td><td colspan="2">95% Confidence Interval of the Difference</td></tr>
<tr><td>Lower</td><td>Upper</td></tr>
<tr><td>−3.5000</td><td>3.9596</td><td>1.0224</td><td>−5.6928</td><td>−1.3072</td><td>−3.423</td><td>14</td><td>0.004</td></tr>
<tr><td colspan="9">Effect Size Calculation: Cohen's d = 1.0402658399709133 Effect-size r = 0.461445</td></tr>
</table>

These pre- and posttest scores illustrate that student learning in a virtual worlds environment can be accountable, as in traditional educational measuring methods. The engagement survey showed the students' reaction to a challenging, nontraditional learning situation, the Drakos mission. The pre- and posttests show the connection between a traditional format for obtaining knowledge (testing) with a nontraditional method of exposing students to intended content (genetics). The outcome is clear by the data—students not only reported being engaged in the virtual worlds environment while learning about genetics, but the knowledge they learned in the virtual environment transferred to a traditional written test, and significant gains were shown.

4.2. Engagement Survey

Engagement is critical to learning. It is a part of the process that keeps a student connected and involved in an experience such that he or she will persevere with challenging situations [17, 31,32]. Understanding engagement is important to this study based on research findings stated earlier tying performance and general satisfaction to engaging educational experiences [15, 16, 22, 33].

Table 4 shows the student responses of the engagement survey.

Table 4. Student Engagement Survey Responses.

Statement *N* **= 15**	**Agree a lot 47%**	**Agree 32%**	**Agree a little 11%**	**Disagree a little 6%**	**Disagree 3%**	**Disagree a lot 1%**
1. I was engaged in this activity	10	4		1		
2. I was concentrating during this activity	8	4	1	2		
3. I felt in control of the situation	9	2	1	2	1	
4. This activity was challenging	6	4	3		1	1
5. I was skillful at this activity	7	3	3	1	1	
6. This activity was important to me	10	1	1	2		1
7. I was succeeding at what I was doing	6	6	3			
8. I was satisfied with how I was doing	4	8	3			
9. I felt as if I were inside the environment	9	5	1			
10. I felt as if the environment were real	8	4	1	2		
11. I felt as if the characters were real	3	6	5	1		
12. I felt as if I and the characters were together in the same place	4	10		1		
13. I felt as if the events were happening at the same time I was there	6	5	2	1	1	
14. I felt as if I were participating in the events	8	6		1		
15. I felt as if the events were really happening	7	5	1		2	
Response Frequency (225)	105 (6)	73 (5)	25 (4)	14 (3)	6 (2)	2 (1)
Statistics	Mean 5.1	Median 5.0	Mode 6.0	Standard Deviation 1.10		

Table 4 shows a mean value of 5.1 with a small standard deviation of 1.10, indicating tightly grouped values around the mean. The most frequently occurring value, the mode, was 6. The median value for this survey was 5. When values were grouped by agreement and disagreement, the two resulting sets clearly show that 90% of students indicated they were engaged *versus* 10% indicating they were not engaged.

4.3. Survey of Teacher Observations by Competency

To compare with the data from the pre- and posttests and the engagement survey, qualitative data regarding observed 21st century competencies were obtained. Survey participants were thirty elementary teachers from Australia, England, and the United States, all of whom were experienced using the QA/ARX virtual learning environment in elementary school settings. The skills targeted in the survey questions were selected as desired learning behaviors from definitions of 21st century competencies based on the work of other educators and researchers [26, 34–36]. Because this survey was newly developed, it required validation. Experts in educational technology, multiuser virtual environments, and game design were consulted on the validity of the survey tool. After their review, expert feedback on content, as well as adjustments to the survey, was implemented in the survey.

The survey, as shown in Table 5, targeted the following range of 21st century skills: technology use, communication, global awareness, collaboration, critical thinking/inquiry, and problem solving. See Supplementary B for the survey content.

Table 5. Teacher Observations by Competency—Survey Responses.

21st Century Competency Observed by Classroom Teacher	%
Technology Use	98
Communication	92
Global Awareness	91
Critical Thinking/Inquiry	87
Collaboration	84
Problem Solving	83

Technology Skills:

The strongest overall observation was in technology skills at 98%. Virtual worlds programs such as QA/ARX are accessed on a computer and require students to use a wide range of interfaces in order to configure an avatar, select missions, choose response pathways, send telegrams, type in a chat screen, respond to polls, pull down actions and view commands, add objects to a virtual backpack (Q-Pod), respond to missions with a text editor, and upload documents and graphics.

Communication:

Communication skills are facilitated by the technology interface, enabling students to communicate with their classroom teacher, in which assessment comments are entered by the teacher. A successful entry on the part of the student ensures completion of a mission task and allows the student to continue, otherwise, a teacher may write a comment asking a student to revise a written response and resubmit. Communication skills are also exercised in telegrams and chatting. Students have the ability to communicate with anyone currently in the virtual world—sometimes other students, sometimes teachers from other classrooms.

Global Awareness:

Global awareness was the third rated 21st century competency observed by teachers at 91%. Global awareness is fostered throughout the set of quests and missions, is part of the sustainability/ecological narrative, and is experienced in the everyday interactions in-world by students and teachers. The virtual environment is real-time and is shared by students and teachers from six continents. Students are likely to encounter players from Australia, England, the United States, South Africa, Japan, Turkey and other countries. While the main language used in Quest Atlantis is English, opportunities for language sharing happens frequently as students and teachers interact.

Critical Thinking/Inquiry, Collaboration, and Problem Solving:

The next range of 21st century competencies were observed as follows: critical thinking/inquiry at 87%, collaboration at 84%, and problem solving at 83%. Because these three competencies were close in ratings, and because they are often weaved together in practice, they are presented as a group in this section. Critical thinking/inquiry, collaboration, and problem solving are typical student practices applied in understanding tasks with each new mission, when using scientific processes/equipment in the laboratories, making pathway decisions, conferring with real-world classroom peers, co-questing with peers, and using the real-time navigational system for avatar movement. By design, the missions take students through the practice of 21st century competencies as they play the game. Note that problem solving, while rated high at 83% by classroom teachers, was the lowest of the percentage ratings. This is an area that could benefit from further study to determine what teachers perceive specifically as problem solving activities, and could be related to the level of experience and familiarity that a teacher has with the content of a particular quest.

As students practice these competencies, they are, in effect, cultivating the competencies that enable them to understand and use the content of the missions. Colvin [37] refers to this kind of learning as *deliberate practice*—the idea of *what* a person specifically practices, and in what environment, constitutes a large part of what a person embodies and learns. Earlier research corroborates this idea, including Barab and Duffy's contention that practice fields cultivate learning and understanding through complex interactions with the environment. Brown *et al.* ([18] argued similarly for a "doing and knowing" perspective; that is, knowledge is situated in the culture and learning is achieved through actions and activity with that environment or culture. A student engaged in a mission such as Drakos is situated squarely in the practice field described by Barab and Duffy [38] as, "From an instructional perspective, the goal shifts from the teaching of concepts to engaging the learner in authentic tasks that are likely to require the use of those concepts or skills" (p. 30). In short, student competencies enable learners to connect with content-rich environments and with learning experiences in general.

5. Limitations of the Study

In self-reporting cases, such as the qualitative data gathered from students and teachers, the possibility exists for inaccurate results. The researcher cannot control for participants who may respond in a way they think they are expected to as opposed to responding without bias. Such studies are limited by the manner in which participants respond to the survey based on their personal perceptions. Students and teachers might feel they are being evaluated for their knowledge or skills, or could feel they might be expected to respond in a certain fashion. Additionally, while this study uses one exemplary educational program (QA/ARX), it is not the researcher's intention to promote one virtual environment over another, but to show that similar environments exist in which similar experiential learning and results can be expected. It is up to educators to determine the technology resources for their classrooms.

6. Conclusions and Discussion

The purpose of this study was to cast light on effective engaging virtual-world approaches for learning science, and cultivating 21st century competencies. Based on the information from the literature on engagement, educational gaming, virtual environments, student achievement, learning theory, 21st century competencies, and on the analysis of quantitative and qualitative data, the following conclusions can be made from this study:

1. Pre- and Post-tests showed that students acquired content knowledge from working in the virtual world.
2. The virtual environment is highly engaging for students according to data from both students and teachers.
3. Working in a virtual environment fosters deliberate practice of 21st century competencies in students.

6.1. Knowledge is Transferred from Virtual to Real-world Application

This study showed that students learned genetics content through their experiences in the Drakos virtual mission, and the evidence of that learning was shown in a traditional testing format. Students gained knowledge of dragonfly phenotypes through immersive virtual world experiences, then transferred their understanding to a posttest requiring a basic understanding of genetics. With the focus of today's schools overwhelmingly on standardized testing, educational gaming may be perceived as inappropriate for meeting accountability requirements. This study has shown otherwise. Evidence from the literature on virtual world learning benefits [39,40,23,21,41] confirms that participants consistently gain knowledge at high levels, and further, use their acquired knowledge and experiences to continue their personal learning paths (i.e., they only move forward in the game if they learn and succeed with each mission task). Gee [21] wrote extensively on the intrinsic engagement of virtual learning coupled with the acquisition of in-world knowledge and competencies that are not only readily useful in the real world, but are quickly becoming requirements by companies seeking competent innovative, collaborative workers.

6.2. Virtual Environments Enhance Student Engagement

As shown earlier, engagement is critical to learning. It is a part of the process that keeps students connected and involved in an experience such that he or she will persevere in challenging situations.

Survey data in this study show that students experienced high levels of engagement while working in the virtual world as students had opportunities for choice, socialization, exploration, and individual curriculum pathways (differentiation). Actions by students in the virtual environment have consequences and meaning that enhance engagement with learning activities and associated content [19,39]. Peer teaching and collaboration happen naturally as students solve problems and navigate the terrain of the virtual environment, teleporting to different worlds, encountering role models, negotiating meaning, and all while learning academic content embedded in the mission narrative.

6.3. Virtual Learning can Cultivate 21st Century Competencies

Examples of learning situations in the virtual world along with observational data from teachers show students demonstrating 21st century competency behaviors while working in QA/ARX. The importance of these competencies is supported in the literature from the perspective of practice fields [38], learning by doing [42], situated cognition [18], collaborative learning in communities [19,34] and deliberate practice [37]. In the act of using these competencies, students are better able to understand and use associated academic content. Learners find themselves challenged to complete missions, which directly and subtly take the learners on a practice path to embark on systematic use of technology, critical thinking/inquiry, problem solving, collaboration, communication, and global awareness.

As educators are considering new, engaging ways to expose students to science (and STEM) experiences, this study seeks to contribute possible ideas, resources, and directions. This study works in tandem with recent Next Generation Science Standards (NGSS) to support deeper learning in science. Additionally, recommendations at the national level suggest a broader approach to learning beyond traditional classroom methods. The U.S. Department of Education's National Educational Technology Plan [27] points out that academic content can be taught and learned in a variety of ways using educational technology and should include a focus on competent behaviors: "Twenty-first-century competencies and expertise such as critical thinking, complex problem solving, collaboration, and multimedia communication should be woven into all content areas" (p. 13). Included in the recommendations for engaging students are virtual worlds, games, and other interactive, exploratory technologies with embedded academic content. The information from this study may help educators make selections for learning approaches in science that include virtual worlds among other active learning scenarios.

Conflicts of Interest

The author declares no conflict of interest.

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