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Tech-Savvy Girls:

Learning 21st-Century Skills Through STEAM Digital Artmaking

Christine Liao, Jennifer L. Motter, and Ryan M. Patton



Redefining the educational model of science, technology, engineering, and math curriculum (STEM) to also include art to become STEAM (Fournier, 2013; Guyotte, Sochacka, Constantino, Walther, & Kellam, 2014) is a current method to encourage students to actively participate in 21st-century learning (Saxena, 2014). The skills emphasized for 21st-century learning include critical thinking and problem solving; collaboration and communication; and creativity and innovation (Partnership for 21st Century Skills, 2007). Encouraging students to pursue a STEM career has become an important U.S. educational policy that emphasizes teaching these 21st-century skills along with STEM knowledge in the discourse of future economic growth.

Much criticism has been given to the gender and minority imbalance in STEM fields (President's Council of Advisors on Science and Technology, 2010; Snyder, 2014) with only 25% of the U.S. STEM workforce composed of women (Beede et al., 2011), and 10% composed of Blacks and Hispanics (National Science Board, 2010). Many attempts have been made to encourage minorities and females to participate in STEM careers (Dean, 2000; Marklein, 2012; Robehmed, 2013). These initiatives recognize that students meaningfully engage with STEM subjects when an active learning curriculum is used, directly applying student knowledge to what they are learning (Freeman et al., 2014). However, these kinds of programs are not widespread.

As an art education model, STEAM supports students to make connections between subjects, using 21st-century tools and problem-solving methods to cross disciplinary boundaries, allowing students to creatively see the world in new, open-ended, and personal ways (Bequette & Bequette, 2012; Wynn & Harris, 2012). Students who make art projects using computer code, electronics, or even the Cartesian coordinate system, inherently apply STEM knowledge and skills in their artwork. As Peppler (2010) suggests, being able to create in the digital media arts is an important 21st-century literacy. For art educators using a project-based approach to active learning through hands-on digital art projects

can directly show links between STEM knowledge and art to create a STEAM curriculum, offering students a way to see how a well-rounded education builds connections across disciplines, individuals, and the world around them (Jolly, 2014).

Several art educators have written about working with female students from diverse and underserved backgrounds to create digital artworks, such as working with girls to make videos with personal narratives (Traflet, 2012; Wolfgang & Ivashkevich, 2014) and develop new technical skills and knowledge (Grauer, Castro, & Lin, 2012). Other art educators reported working with K–12 students to create digital works with social media and other forms of creative software (Castro, 2012; Fugelstad, 2014; Keifer-Boyd, 2007; Patton, 2013). Looking at these art education projects as forms of STEAM education, these efforts are understood as alternative approaches to STEM learning, outside of directly teaching STEM knowledge. To spark the interest of girls, especially minority girls, as creators of technology, Penn State's 2010–2011 Tech Savvy Girl's camp focused on digital artmaking to develop middle school girls' 21st-century skills. Girls from rural central Pennsylvania and inner-city Philadelphia participated in the camp to directly engage with the knowledge and skills necessary for STEM-related careers.

The courses we describe below, Digital Stories taught by Jennifer Motter, My Avatar Movie and My Avatar Games taught by Christine Liao, and Games 4 Girls taught by Ryan Patton, encouraged girls to create with technology and explore different forms of digital artmaking through activities tied to storytelling, personal experience, and technology literacy by making animations, machinimas, and video games. Through our examples, we propose a STEAM curriculum framework with digital artmaking at the center. Creating animations and games are two strategies in this curriculum framework. By highlighting how the course content and activities engage students in 21st-century learning and analyzing learning outcomes through our survey, our goal in this article is to show how creating digital media enables girls to learn essential skills for the 21st century and see the creative possibilities in pursuing STEM-related careers.

Creating Animated Digital Stories and Machinima Movies

Creating animations to tell stories is our first strategy for a STEAM curriculum centered in digital artmaking. Using different tools and techniques, the courses Digital Stories and My Avatar Movie are both designed to help girls convey personal experiences and ideas through animated narratives. Digital storytelling is the practice of using a computer as a medium for artistic creation and storytelling (Chung, 2007; Robin, 2008). Digital storytelling typically has a narrative structure and focus, but also consists of digital

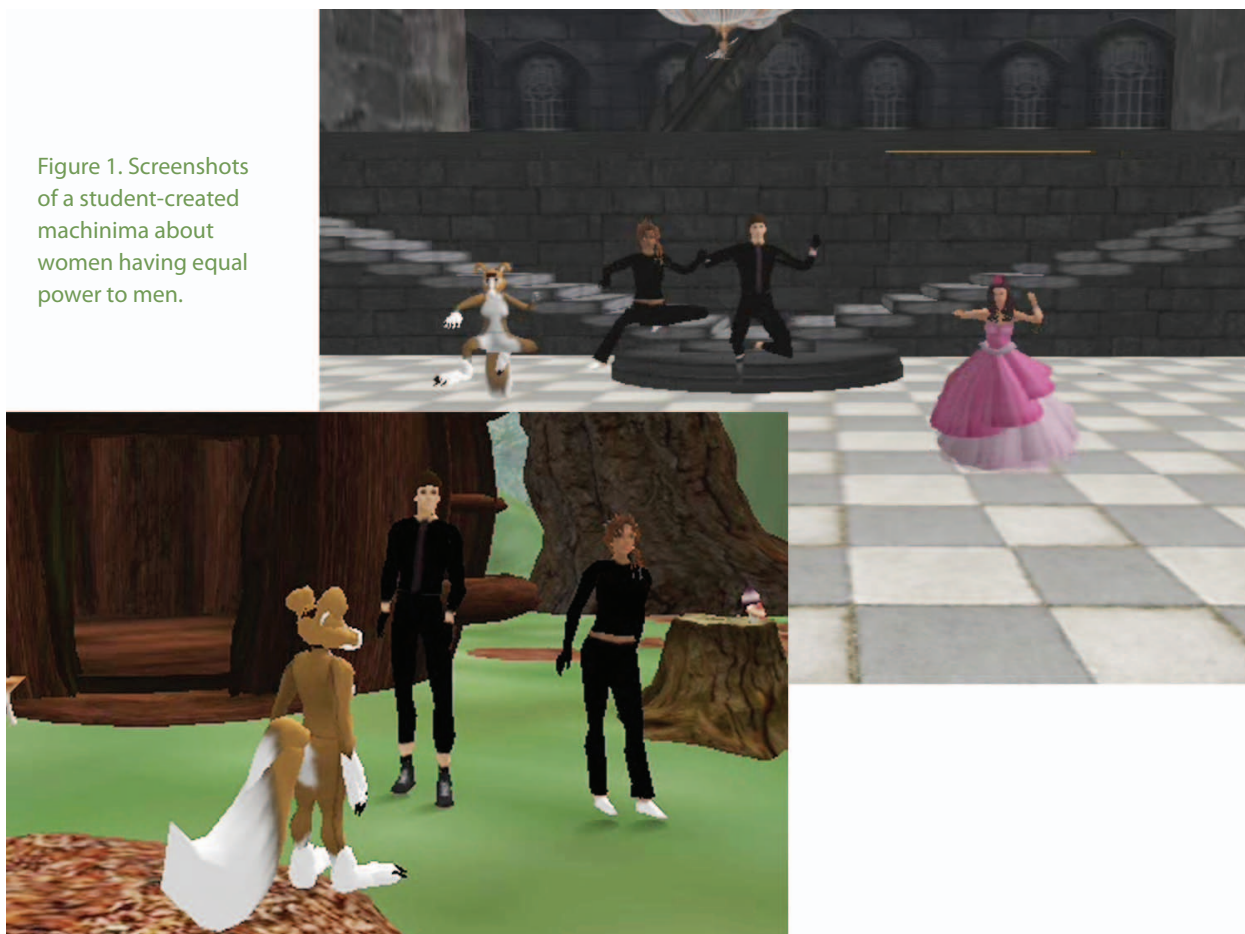
images, text, video, and audio. Topics explored via digital stories range from personal experiences, to documentaries, to contemporary issues (University of Houston, 2011). There are many tools¹ available to create digital stories. The Digital Stories course utilized Adobe Flash to create animated stories while My Avatar Movie used OpenSim² to create machinima animations recording real-time rendered 3-D avatars/characters, objects, and scenes in the virtual environment.

In order to show middle school girls how women can be leaders using digital technologies and creating positive changes and how to express their ideas through digital artmaking, Digital Stories presented a curriculum to collaboratively create meaningful animated digital stories about girls/women's leadership experiences in educational settings, and workplaces and the My Avatar Movie course targeted creating stories involving social justice (Figure 1).

Creating these animations requires collaboration between students. Creating digital stories required students to serve as leaders within small groups of 4–6 students while collaboratively distributing responsibilities and performing tasks as a team (Falloon, 2010). By working with technology and other girls to create collaborative new media artworks, students learned how their abilities can play influential roles in the technology-driven 21st century.

In both animation courses, we first engage students in critical thinking, provide guiding questions, and introduce artists' or other students' works that tell meaningful stories about social justice.

Figure 1. Screenshots of a student-created machinima about women having equal power to men.



Making STEM curriculum more relevant to students' lived experiences, our STEAM curriculum encouraged girls to think about how to tell stories of women's leadership. Examples of Kara Walker and Kiki Smith were introduced and discussed as contemporary artist-storytellers who deal with conflict and race in their work. For example, students were asked guiding questions such as "How are women represented in Walker's *Darkytown Rebellion*, 2001?" These art examples guided students to question and think about the role of women in stories. After discussing visual storytelling, students shifted their focus to critically think about women's leadership. The girls identified a positive leader as someone who represents the following descriptors: good listener, caring, humble, motivating, intelligent, creative, and many others. Similarly, in the My Avatar Movie course, the introduction to animation using machinima included examples created by machinima artists, Global Kids,³ and other students. The Global Kids films *A Child's War* (Global Kids, 2007) and *Race to Equality* (Global Kids, 2008) were shown. In order to encourage 21st-century learning, students were asked to critically think about situations/experiences involving injustice and how they would make positive changes to develop their stories.

Learning to create animation enabled the girls to learn 21st-century skills of collaboration as well as develop critical and creative viewpoints. As students worked in teams to create their animations, they were assigned different roles. Creating an animation using OpenSim involves multiple steps similar to traditional moviemaking, therefore, acting, directing, and producing roles were divided among the students. Students in Digital Stories and My Avatar Movie engaged in discussion about content collection such as camera angles, storyboarding, and audio engineering for digital story creation. These steps are critical to ensuring students successfully develop their group projects and enhance their collaboration skills as 21st-century learners.

Digital Stories
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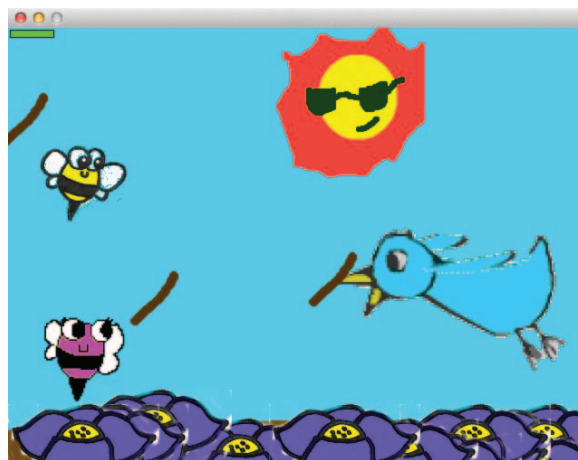


Figure 2. Screenshot of the student-created game *Adventures of Billy Bee and Wanda the Wasp*.

Game Making

Games as a form of art production can be found in the history of art in the rules-based work of Dada, Surrealism, Fluxus, and Situationism (Flanagan, 2009). Game making as digital artmaking is another strategy in our STEAM curriculum framework. Students in the Games 4 Girls and My Avatar Games courses created their own characters and the underlying programming, allowing game characters to move and interact with other game objects and environments. Students used the software programs GameMaker and OpenSim as platforms for creating games by navigating how digital game making could reflect their personal interests and tell stories (Figure 2 and Figure 3). The coding and technology skills required to make a game becomes more personal and relevant to students when they can express their own ideas and interests in their projects. By creating games as programmable digital art, students learned how to make personal art projects using creative computer code (Maeda, 2004; Peppler & Kafai, 2005).

Both game courses explored game design in different ways. The Games 4 Girls course used the abstracted terms of *move*, *avoid*, *release*, and *contact* (MARC) as a way to broadly interpret game actions common across many video game genres and what those actions could mean in different contexts (Patton, 2013). Within the GameMaker software environment, MARC helped frame how students could program the character's movements and actions with other objects to avoid or engage (Figure 4). The MARC concept was kept abstract enough to allow for multiple interpretations, allowing students to question, examine, and critique rules embedded in daily life, and could be used as content for different types of 2-D games. Similarly, girls in the My Avatar Games course engaged in play through the connection to their game-playing character—their avatars. This allowed students to tell stories in a more personal way. Collaboration was the central approach in this course. Students created a treasure-hunting game in OpenSim for their final team project. The team members had different roles including building the game world, its objects, and creating interactive code scripts. Each group created a story for their game,



Figure 3. Screenshots of the student-created treasure-hunting game about finding medicine for a sick elder.



Figure 4. Screenshot of the student-created game *Ninja Cow*.

guiding the player to find the missing objects or treasure. Both courses used game design to teach 21st-century skills including critical, creative thinking, and collaboration.

Students learned 21st-century skills of technology literacy by programming, critical thinking, and problem solving to develop systems in their games, and initiative by completing their game projects. In the Games 4 Girls course, when students moved beyond the MARC actions in the introductory game making process, they built on their games with additional features like sound, gravity, health bars, and timers. This enabled students to gain a deeper knowledge of how computer code works and confidence with creating complex programmable media. In My Avatar Games, students learned not only the skills of programming code scripts, but also how their scripting affects their game objects and how they can design different narratives with computer code. In both courses, by creating interactive game systems, students could see how individual elements affect other parts of the game. As students learned how systems are created in games, they also saw how games map onto everyday life and began to understand the complexity of how systems function.

What Did Students Gain From STEAM Digital Media Making?

All students in each course successfully developed a complete project, showing how our breakdown of instruction and guiding activities works well, sending positive messages of how girls can create with technology. Girls in the animation courses learned how to collectively engage in meaningful digital art creation by exploring roles of leadership with 21st-century knowledge and skills, increasing their confidence to pursue future technology-related careers. Girls in the game courses learned to express their interests through game making and developed their ability to create programmable, digital content. The student-made digital games playfully collaged people, objects, animals, and concepts in ways that support students' personal narratives of the relationships between game objects. By learning how to create digital games, students were exposed to the possibilities of programmable digital media as a creative form for the art classroom as they prepare for 21st-century methods of artmaking and their future professions.

As students learned how systems are created in games, they also saw how games map onto everyday life and began to understand the complexity of how systems function.

We realize there are many challenges for art teachers to implement a digital art curriculum. Hurdles for teachers include equipment, time and pacing, balancing the need for traditional forms of artmaking, and professional development support for learning how to teach a digital art curriculum. On a positive note, most of the software for the courses described here is cross-platform, open-source, or free, allowing art teachers with small budgets to use these technologies. Although there are challenges for art teachers to implement a curriculum like this, our research results below provide evidence that a digital art-centered STEAM curriculum would benefit middle and high school students and could be motivation for art teachers to take on the challenges.

Our research goal is to understand if our digital artmaking curricula effectively motivates middle school girls to explore digital technologies further; appreciate and participate in teamwork; and gain interest in pursuing STEM careers. We conducted pre- and post-surveys with students before and after the courses, asking them questions about the curriculum and their interest in STEM. The overall survey results showed that students' ability and interest to further explore digital technology, perspective in teamwork, and understanding of STEM careers all improved after the courses. Below is a synthesis of our findings.

1. Students gained different perspectives and insights on technology as well as the understanding that women can also make a difference using technology.

Learning to create digital media, such as animations and games, allows students to learn what it is like to work in technology fields. According to the post-survey results from all the courses, students appeared to develop a deeper knowledge of technology-related careers, became motivated to continue learning about technology, and challenged technology-related stereotypes. In one course, a student wrote: "I think that the computer and its systems are really cool and I might want to do something like that in the future for a job." Another student expressed that "I always thought guys were the ones to take up these careers, usually when people think of STEM they think of geeks, or nerds. Now after the camp I realize girls can do this career too, and are just as smart as guys in this." The experience of creating digital media enabled girls to feel they can have a significant role in technology by participating in a field traditionally dominated by men. Students in all courses realized digital artmaking was difficult at first, but enjoyed the process and seeing the end result was rewarding. Students' reflection of their experience demonstrates the effectiveness of the courses to cultivate their interest in working with computer technology.

2. Students learned that collaboration and teamwork skills are essential to digital media creation.

The survey results from all courses indicated these experiences helped students gain collaboration skills and realize teamwork can enhance their projects. One student mentioned she not only learned the software, but also learned "making a movie takes a lot of teamwork, time, and concentration." Another student reflected she liked the fact she could "work with other people and get to

listen to others opinions.” A third student responded she liked the collaborative process because “we are all creative so with all of our ideas we can make a better game.”

3. Students gain digital media skills empowering them to understand that everyone can learn how to use the computer as an expressive art medium.

When students started the Tech Savvy courses, their confidence in working with digital media making was at 48.5%. After the courses, students confidence increased to 76%. Students remarked learning new digital skills by creating their own animations and games was a fun and engaging experience. Across all four courses, the percentage of students who indicated they plan to take more technology courses in the future increased by 16%. These results support the hypothesis that using computer technology for self-expression and visual communication may increase students’ interest in continuing to take computer or technology classes, raising their confidence in STEM knowledge through digital media creation.

Conclusion

When developing a digital art-centered STEAM curriculum, an instructor does not have to teach a specific digital tool; rather, the curriculum can come from a big idea (Walker, 2004) or another conceptual framework that materializes through digital art. As digital tools change rapidly, our goal in this article is not showing

how to use these particular technologies or propose teachers follow our curriculum; instead, we propose a STEAM curriculum framework that encourages teachers to put digital artmaking as a central activity to creatively explore the possibility of how technologies can be used for 21st-century artistic purposes. The Tech Savvy girls were encouraged to explore technology and STEM careers further because of their positive experiences creating digital media. As a student from My Avatar Games course stated, “I think it is a great way to learn new things about technology, and it opens up a world of opportunities for me. Above all, it was the best ‘camp experience’ I’ve had.” We believe digital artmaking helps students learn and experience technology in creative, artful ways. A STEAM curriculum provides the opportunity to show connections between STEM and art can be thought about, used, and explored in relevant and personal ways for 21st-century learners. ■

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A promotional banner for the 2017 NAEA National Convention. The top section features a blue square logo with a white stylized 'A' and 'E' on the left, followed by the text '2017 NAEA NATIONAL CONVENTION' in large, bold, blue capital letters. Below this, a dark blue horizontal bar contains the text 'March 2-4, 2017 | New York, NY' in white. The background of the banner is a grayscale photograph of a dense city skyline, likely New York City. Overlaid on the right side of the skyline is a vibrant, abstract splash of paint in various colors including red, purple, blue, green, and yellow. A paintbrush with a wooden handle and a tip covered in multi-colored paint is shown as if it has just finished creating the splash. At the bottom of the banner, a dark blue horizontal bar contains the text 'DOWNLOAD YOUR REGISTRATION FORM @ www.arteducators.org' in white capital letters.

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- ¹ Video editing, presentation, and animation applications such as Final Cut, Keynote, and Adobe Flash may be used to create digital stories.
- ² OpenSim is a virtual environment that allows multiple users to interact through digital avatars in real time. Students create their own avatars to represent themselves in OpenSim. Students also create 3-D objects for different purposes such as building their own imaginative world or create accessories for their avatars. OpenSim is a free, open-source program that can be set up by educators.
- ³ Global Kids, a non-profit educational organization, used Teen Second Life to teach students machinima creation to address social justice issues ("Global Kids Online Leadership Program," n.d.).