Using Video Game Design to Motivate Students

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Because video games are so popular with young people, researchers have explored ways to use game play to engage students in school subjects (Peppler & Kafai, 2007; Rockwell & Kee, 2011; Small, 2011). Motivating students in science is especially important because of declines both in the number of young people who choose science careers and in the number of adults who have a sufficient grasp of science to make thoughtful decisions (Bell, Lewenstein, Shouse, & Feder, 2009).

To counter these trends, informal science educators have adopted video games and simulations as teaching tools and have called for research on how games can motivate youth to engage with science (Honey & Hilton, 2011). Video games that provide level-building capabilities (Reiber, 2005) can be particularly useful in fostering informal science learning.

To add to the knowledge base, we studied how students used level-based video game development in an out-of-school time (OST) setting to learn science content. Building on prior efforts (Evans & Biedler, 2012; Evans, Norton, Chang, Deater-Deckard, & Balci, 2013; Evans, Pruett, Chang, & Nino, 2014), we explored how the project incorporated the video game to support learners' science motivation. This work with a commercial

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off-the-shelf video game is an example of how a learner-centered, technology-infused approach can advance the theory and practice of informal science learning (Honey & Hilton, 2011).

The Mission Evolution Project

Mission Evolution was designed as an afterschool partnership between investigators at a large research university and staff at a nearby high school in rural southwest Virginia. Students collaborated with their science teacher and university instructional and video game design experts to play *Spore Galactic Adventures*™ (*SGA*).

SGA, an expansion pack of the video game *Spore,*™ was selected for this project because it allows students not only to play the game but also to design their own game *levels*. In its simplest form, a game level, or mission, comprises a start state, an end state or goal, and obstacles presented as a series of acts that prevent players from reaching the goal. Using the level builder, players can design a mission that has up to eight acts, in which the "captain" (or protagonist) and crew members encounter challenges that may require socializing with or fighting against up to 10 species of antagonists. Antagonists can be generated by the player or downloaded from Sporepedia, an online warehouse of characters and items such as dwellings and weapons. Players can select features such as dialogue, physical appearance, atmosphere, protagonists, rewards, and music.

The purpose of using *SGA* in Mission Evolution was to teach students specific concepts of evolutionary biology, such as speciation (the evolutionary process that results in new species), mutation, adaptation, extinction, and natural selection. This objective aligned with the Virginia learning standards of the students' school biology curriculum. Another objective was to teach students to use sound game design principles, such as giving players goals that are difficult yet achievable. The project thus challenged students to create games that were both scientifically accurate and fun to play. When the students had finished their games, the science teacher rated the games' scientific aspects, and the university video game experts rated the design aspects.

Mission Evolution engaged students in a self-regulated environment. Students had creative control over their learning, establishing their own goals and monitoring their own progress with minimal, yet supportive, guidance. We anticipated that this project would motivate students to learn science and participate in science-related activities.

Motivation Frameworks

The design and study of Mission Evolution were guided by the principles of the MUSIC® Model of Motivation (Jones, 2009, 2015). We chose the MUSIC model because it applies current motivation research and theories to educational settings and provides a means to assess the effect of instruction on students' motivation. The MUSIC model consists of five key components: e*M*powerment, *U*sefulness, *S*uccess, *I*nterest, and *C*aring. Research consistently demonstrates that, to engage students in learning, instructors must ensure that students:

1. Feel empowered to make decisions about some aspects of their learning
2. Understand why what they are learning is useful for their short- or long-term goals
3. Believe that they can succeed if they put forth the effort required
4. Are interested in the content and instructional activities
5. Believe that the instructor and others in the learning environment care about their learning and about them as individuals (Jones, 2009)

Each of these components has been shown to predict students' motivation and engagement (Jones, 2009, 2015).

To examine the effects of Mission Evolution on student motivation, we also used the three *genres of participation* identified by Ito et al. (2009): hanging out, messing around, and geeking out. These categories capture the ways youth appropriate digital media and technologies, notably video games, to socialize, interact, and learn. *Hanging out* is a genre of participation in which technology serves merely as a social lubricant to bring like-minded youth together. *Messing around* characterizes youth who approach digital media with a purpose and growing shared interest. In the final phase of development, *geeking out*, youth demonstrate a degree of expertise that, though it often goes unrecognized in school settings, provides a sense of self and increased confi-

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dence, which in turn can lead to interest-driven learning. Although Ito and colleagues (2009) provide rich descriptions of hobby-based use of digital media, additional evidence of purposeful uses for school- and career-related topics would contribute to the literature.

Method

Phases of Mission Evolution

Mission Evolution was staged in three distinct phases that followed the semester schedules of the high school. In Phase 1 (spring), the video game experts conducted a series of three afterschool meetings with the students and teacher that provided a quick-and-dirty introduction to *SGA*. These meetings gave students the knowledge and skills they needed to succeed in the next phases; *success* is one of the components of the MUSIC model.

In Phase 2 (fall), students played the Cell and Creature stages of *Spore* in structured afterschool workshops. This practice helped students understand how evolution was treated in the game while becoming familiar with the *Spore* world, characters, and mechanics. This phase incorporated most components of the MUSIC model: It promoted *empowerment* by providing students with some choices and fostered *caring* in a supportive environment that allowed students to *succeed* at building their skills in an *interesting* activity.

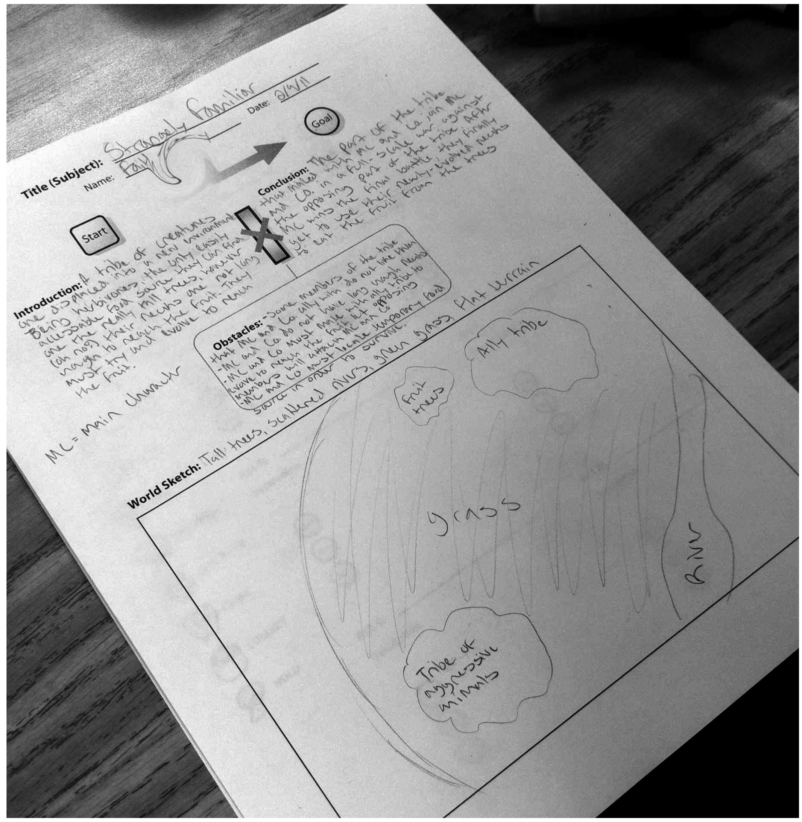

Figure 1. **A student uses a storyboard template, adopted from industry practice, to sketch out her game about speciation, titled *Strangely Familiar.***

Finally, in Phase 3 (the following spring), students designed, built, and tested their games. Students experienced more *empowerment* in the form of choices and decision-making ability. They *successfully* worked on an *interesting* activity in a *caring* environment. Finally, the activity was *useful* because it helped students learn more about biology, taught them science and technology skills that could be relevant to future goals, and enabled them to help other students learn biology by playing the games Mission Evolution students had designed.

In Phase 3, eight 10th- and 11th-grade students participated in afterschool workshops in their science classroom once or twice a week for eight weeks. Workshops varied in length from 60 to 90 minutes, and participation was voluntary. In the workshops, the students designed and developed games based on a scientific concept they

Table 1. Sample Games Produced by Students in Mission Evolution

GAME TITLE	DESCRIPTION
Down the Rabbit Hole 1 and 2	How DNA mutations help a species develop camouflage abilities to increase species fitness
Apocalypse	Survival of the fittest members of a species; how mate selection based on genetic variation can strengthen the species over time
The Chita-Tánga	How migration can necessitate adaptation to enable species members to survive and reproduce

Table 2. Interview Questions and MUSIC Components

MUSIC COMPONENT	INTERVIEW QUESTION
Empowerment	How much control do you have over what you're working on? What things do you have control over?
Usefulness	How useful is this activity for your goals this year or in the future? In what ways is it useful?
Success	How successful do you think that you will be at this activity? Why will you be successful?
Interest	How interested are you in working on this activity? How much do you enjoy this activity? What about it interests you? How important is this activity to you? Why is it important?
Caring (teacher)	How much does your teacher want you to succeed at this activity? How much does your teacher like to help you on this activity? How do you know? How much does your teacher care about you? How do you know?
Caring (students)	How much do other students want you to succeed at this activity? How do you know? How much do other students care about you? How do you know?

selected themselves, such as DNA mutation, adaptation, competition, and survival. Three of the games are described in Table 1. The 11 workshops were organized as follows.

- Sessions 1 and 2: Learn to complete expert logs for *Spore* analysis
- Session 3: Learn how to storyboard games, receive the rubric to be used to evaluate the games, and think about how playing *Spore* can contribute to the game design
- Sessions 4 and 5: Storyboard game designs (see Figure 1) and get feedback from the design experts
- Sessions 6, 7, and 8: Build games in *SGA* and get more design feedback
- Session 9: Demonstrate games to a "jury" of experts and receive feedback
- Session 10: Finalize games and receive final round of feedback
- Session 11: Celebrate with a party

During the sessions, students were supported by the school science teacher, a graduate student in computer science who helped with game design and technical issues, and a graduate student in science education who helped to verify the rigor and accuracy of the scientific concepts and their treatment in the games. This structure provided scaffolding without directing students to make specific choices as they designed, developed, and tested their video games. It embodied the MUSIC model, providing students with *empowerment* in a *caring* and *interesting* environment that supported their *success* in an endeavor that at least some students found *useful*.

Research Design and Data Collection

Following a design-based research approach (Brown, 1992; Edelson, 2002; Lamberg & Middleton, 2009), we incorporated participant-observer techniques and periodic semi-structured interviews to investigate how the students, supported by their teacher, applied concepts in evolutionary biology to build their video games. We treated this project as a co-design activity involving the science teacher, her students, and researchers and graduate students from the nearby university.

To examine students' levels of motivation, we interviewed them at three intervals: during sessions 4 and 5, during sessions 7 and 8, and at the end of the project. The interview questions we developed (Table 2) assessed students' perceptions of the components of the MUSIC model. We recorded the interviews and then transcribed and analyzed the text. We also recorded field notes of our observations of project sessions and interviewed the science teacher at the end of the project. We then used all these data to identify themes.

Case Studies of Three Students

We selected three students as case studies to illustrate how students approached Mission Evolution with differing agenda, how the project affected students' motivation and interests, and how students' engagement varied by their genre of participation (Ito et al., 2009). Each student's perceptions are presented in the order of the MUSIC model components: empowerment, usefulness, success, interest, and caring.

Jack

Jack was a 17-year-old White male in 11th grade. When asked about his *empowerment* in the project, Jack reported that he had a lot of control: "We are pretty much doing whatever we want along the guidelines and get to control every aspect we can." He added that he had control over "the look of the game, the actual objects in the game, and how the game works."

Jack found the project *useful* for his future goals, particularly because he was interested in game design as a career. He also talked about how what he learned would be "really useful for figuring out what I would do in a similar situation like a work environment."

He reported that he was *successful* in this project: "We have a tangible product because we actually have a game that is playable." The game provided concrete feedback that allowed him to judge for himself whether he was successful. The project also appears to have provided a reasonable level of challenge for him. He said it was "challenging, but not too difficult." "The only real difficulty is trying to figure out how to do what you envision with the technology provided. The technology is good, but it has constraints such as every [software] program would. Other than that, it's not hard."

When asked how *interested* he was in the project, he said, "My favorite thing to do is design." He added, "Trying to incorporate a learning environment into game design is a really good idea. Really fun to execute, 'cause it's always fun to create stuff." These comments reflect Jack's interest in participating in the design aspects of this project; it also indicated his longer-term interest in design. In fact, Jack ordered his own copy of the software so he could work on it on his own time. After noting that "sometimes I don't even do my schoolwork on my own time," Jack said that he stayed up until 2:00 a.m. working on his *SGA* project. "I've put in a reasonable amount of effort," he added, "which is sometimes unusual for me."

Jack seemed to feel that the environment was relatively *caring*. He noted that the teacher was helpful, that she wanted him to succeed, and that she made sure that everything was going smoothly. He also reported that she cared about students enough to ask about their well-being. When asked whether other students cared about his success in the project, he said that he believed that they wanted him to succeed. He did not give the impression that he worked closely with any other students, but he did say that students "bounced ideas off each other."

Mia

Mia was a 15-year-old White and Native American female in the 10th grade. Mia's interview responses indicated that she felt *empowered* in the project: "I have complete control. I have control over what aspects of science I put into it, what the plot line is, and the characters." Mia also found the project *useful* for her goals: "It's going to be a big deal in the future when I try to go for college and medical school."

She said that she had been *successful:* "I'm … very satisfied with my game I have designed and the work I have put into the whole project." She said that the most challenging aspect of the project was time management.

Mia was *interested* in the project because it incorporated "both gaming and science, which are two things I'm very interested in." Her interest extended beyond the designated project time, perhaps indicating that she had begun to develop longer-term interest. She said that the project had been "really important to me. It's the only thing I do outside of school." She felt that she put a great deal of effort into the project: "I've been to every meeting and I've gone extra times during lunch. I skip lunch to work on this project."

Mia said that the teacher *cared* "quite a bit" about the students, adding that the teacher was always there to help if something went wrong or if students needed something. Mia said that, though there was some competition among students, "I'm sure they don't want me to fail, or anyone else to fail." She mentioned that students would share praise when something went well, such as "Whoa, that's pretty good!"

Walter

Walter was a 15-year-old African-American male in 10th grade. Walter said that he was somewhat *empowered* during the project. When asked how much control he had, he responded, "I guess a fair amount…. There may be some things you may not be able to do, but things you can work around to get your desired goal."

The project was *useful* to him: "I did want to learn a bit more of biology this year…. As a project, it did help; it taught me a few side things along the way. In the future, I'll probably be able to incorporate what I learned in different situations and future education."

Walter said he felt *successful* in the project: "We did finally each create a game.… That was our priority and our goal." His success seemed to be tied to his ability to meet the challenges of the project, which also led to increased *interest*: "I wasn't too interested in the beginning. I wasn't really sure exactly what we would be doing. As we progressed, it was more and more challenging. Yeah, I was more interested in it." Although Walter did not find the project to be very important to him, he could see how it could be important to other people: "It was slightly important because we had set a goal and we planned to reach it.… It teaches people and still incorporates gaming, which is important to some people." Walter missed several sessions in February because the workshops conflicted with training for his sports team. Though he would stop by the Mission Evolution room before practice to say hello to students and staff, he did not seem to be invested enough to allow the project to interfere with an activity he apparently found more enjoyable.

Walter felt a special appreciation for his teacher's *caring*: "I think she's very dedicated to [the project]. It was on her time, not the school's.… She does care a lot." Walter also felt a strong sense of community in the classroom: "I think [my classmates] want everyone else to succeed. We're moving toward the same goal. We're just trying to push each other and help each other to get there faster and more effectively."

Observations of Students' Participation

Our program observations suggest that Jack, Mia, and Walter approached this project with varying agenda. Jack, an adept 11th-grader who had participated in earlier workshops, used his graphic arts skills and knowledge of video games to develop a sophisticated product that balanced science knowledge with game mechanics. In an example of the genre of participation Ito et al. (2009) call *geeking out*, Jack used his time during the workshops to help others overcome obstacles to make their storyboards work in the game medium.

Mia, by contrast, was quiet and reserved, yet artistically talented; she dedicated most of her workshop time to game design and development. Her preferred mode of work was to sit at the edge of the long workbench, headphones in place, focusing intensely on her game. We see this behavior not as isolation, but as a quest for excellence on the part of an intensely engaged student. In a sense, Mia struck a balance between *messing around* and *geeking out* (Ito et al., 2009).

Finally, Walter approached the project mostly as a social gathering, spending equal amounts of time working on his game design and chatting with classmates. His demeanor indicated that he did not take the experience very seriously. Despite missing several sessions in the spring, Walter completed his game, a technically and artistically sophisticated treatment that dealt with the science in a rigorous way. In terms of the genres of participation, Walter seemed to slide effortlessly from *hanging out* to *messing around* and occasionally to *geeking out*.

Students' Motivation and Engagement

These case studies show how students can participate in the same project but engage with it at different levels depending upon their abilities, personalities, and goals.

All three students reported that the project *empowered* them by giving them choices. Two specific aspects of Mission Evolution were designed to encourage this sense of empowerment. First, the structure of the informal learning setting allowed students to choose a concept from the high school evolutionary biology curriculum and decide how to implement it in their game designs, supported by the science teacher and the university video game experts. Second, the way the game technology was implemented provided choices, but with some structured guidance. For example, students began by playing the Cell and Creature stages of *SGA,* whose concepts related to concepts from their biology class. Then they worked with *SGA* tools and tutorials that were intuitive enough to use with minimal support. Before students started their own game designs, the experts provided a worked example to show how the concept of divergence could be illustrated in game play.

Although all three students reported that the project was *useful*, it appeared to be more useful to Jack and Mia than to Walter. Jack and Mia both suggested that their learning could be helpful in their careers. This perceived usefulness probably motivated them to engage in the project. For Walter, the project was somewhat useful for learning biology, but he did not relate this new knowledge to his personal goals. This lack of connection to future usefulness may be one reason he seemed less engaged in the project than Jack and Mia were.

All three students said that they were challenged by the project in a way they enjoyed because, ultimately, they *succeeded* in meeting the challenges. Facing and overcoming obstacles seemed to be a motivating experience for all of them. This finding suggests that the project presented an appropriate level of difficulty—neither so easy that they were bored nor so hard that they gave up before they could succeed. All participants were familiar with basic game interfaces and mechanics, but even playing the Cell and Creature stages of *SGA* presented a challenge because there wasn't enough time to both learn the game and complete the stages during workshops. The experts helped with this challenge by introducing the stages in a way that gave students a running start. Once students moved from game play to learning *SGA* game mechanics so they could implement their own designs, they encountered more challenges. Again, the experts were there to help; some students, like Jack and Mia, had enough invested in overcoming the challenges to spend their own time on the project.

The project *interested* all three students, but in different ways. Jack was interested in the design aspects, Mia in the gaming and science aspects, and Walter in the challenges and the final product. One strength of the project is that its multiple facets could draw in students with diverse interests.

The project *interested* all three students, but in different ways. Jack was interested in the design aspects, Mia in the gaming and science aspects, and Walter in the challenges and the final product. One strength of the project is that its multiple facets could draw in students with diverse interests. An important finding is that Walter became more interested over time. His interest in overcoming the challenges of game design was key to his engagement, given that he did not believe the project would be useful to his future. The work that Jack and Mia put into the project outside of the workshops shows that they were more interested and found more value in the project. This interest and value is important because researchers (Hidi & Renninger, 2006; Jones, Ruff, & Osborne, 2015) contend that, when students value activities, they are more likely to engage in similar activities in the future.

In terms of *caring,* students said the learning environment was a friendly one in which students got along and helped each other when they could. All three students said that they felt strongly supported and cared for by the science teacher. This support, coupled with the congenial peer environment, may have contributed to students' motivation.

Recommendations and Conclusions

Findings from our project design, observations, and case studies lead us to recommendations to help program leaders who want to use students' interest in video games to build science motivation and engagement.

Our first recommendation is to select a game and try it yourself. (See the box on the next page to get started.) Assess what students can learn from the game and how difficult it is. A game that is too difficult or too easy will not fully engage students. Consider whether the objectives are appropriate and are correlated with the objectives of the school curriculum, if such alignment is important to your program.

Second, think about the five components of the MUSIC model as you select a motivating and engaging game. Does the game give students control over level design? Can the content and design process be useful toward students' personal goals? Will game design provide an appropriate level of challenge while allowing students to succeed? Is the process interesting and enjoyable? Does the game allow for some type of caring relationships with others?

Of course, you must determine whether your program can supply the software and hardware needed for the game. You must also think about the skills required—both content knowledge and technical skills. Have the students learned the subject matter in school? Will you need to teach or review the content to ensure that all students have the knowledge needed to play the game? What about technical skills? A good way to assess both the content and technology skills needed is to have a couple of students play the game and report any problems. If students are going to need technology help, do the program staff have the capability to support them? If not, you can invite partners to join the project: teachers, parents, university students, community members—even more knowledgeable students. Anticipate the problems that students or staff might encounter and prepare to address them as best you can.

To help students move from game *play* to game *design*, a first step is to choose a game with a level editor. We selected *SGA* for our project because the expansion pack added a level editor to the *Spore* game. Level editors give students a development environment in which to design their games. Perhaps more importantly, we also provided instruction on what constitutes "a game," using materials provided by the game producer, as well as templates derived from game design resources. One of the

VIDEO GAMES THAT INCLUDE DESIGN ASPECTS

Here are some games, as of May 2017, that both have educational value and allow users to design new levels or missions.

- *Civilization*: https://www.civilization.com
- *Gamestar Mechanic*: https://gamestarmechanic.com/teachers
- *LittleBigPlanet*: http://littlebigplanet.com
- *Minecraft Education Edition*: https://education.minecraft.net
- *Roblox*: https://www.roblox.com

You can find more options by searching online. Try adding the phrase "user-generated content" to ensure that the games include design capabilities.

most approachable resources we used was Jesse Schell's (2014) *The Art of Game Design: A Book of Lenses*.

To increase students' engagement, you may want to design sessions to allow students to hang out, mess around, and geek out. Like our case study participants, students may seek different ways to participate in game design. The genres of participation allowed us to appreciate these differences. Although the OST program did need to abide by the school's timeline restrictions, students were free to hang out, mess around, or geek out during certain portions of each session. We saw hanging out as a legitimate genre of participation that provided value to the experience, rather than being off-task behavior. Each genre has a function that contributes to learning under the right circumstances.

As with any learning activity, identifying specific goals is crucial. It may be fine to let students simply play around and learn whatever they learn. If you have specific learning objectives, you should articulate these objectives to students and develop assessments that provide feedback about their progress. For example, students can share their work with facilitators or peers at certain milestones or can meet with facilitators on a regular basis. Regular feedback, provided in a caring environment, will keep students focused on their goals—whether playing around or meeting specific curriculum objectives.

Students' experiences in Mission Evolution suggest that commercial video games, particularly those that provide level-building capabilities, can help OST programs motivate students to engage in science content. Viewing the project through the lens of the MUSIC model and genres of participation helped us to understand some of the factors that affected students' motivation and engagement. We hope other OST projects will explore the use of video games, not only in science but also in other content areas.

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