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Game Design Through Mentoring and Collaboration

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The findings from an after-school program entitled Game Design through Mentoring and Collaboration (GDMC) funded by the National Science Foundation's Innovative Technology Experiences for Students and Teachers (ITEST) program. A total of 139 middle and high schools students in the Washington, D.C. metropolitan area to learn the basics of professional level 3-D modeling and animation software and logic of game design and programming. The features of this program create a community of students interested in, and skilled with, technology, to foster this interest around the task of designing computer games (and the associated skills of programming, 3D modeling involved), and to help foster awareness of higher education and career pathways related to their interest in technology. The findings show that this is a highly attractive program for our target population of students who are traditionally underserved and underrepresented in science, technology, engineering and math (STEM) fields.

BACKGROUND

Technology holds great potential for traditionally underserved communities to access rich learning environments. Through scaffolding learner performance, technology can provide avenues for diverse learners to get their needs met and begin to improve their conditions (Clark, 2005). This may be particularly true in STEM areas where students from these communities are traditionally underrepresented: Clark (2003) shows that providing students with access to technology increases their self-efficacy in not only technology use, but also in math and science. Technology use may also foster greater general interest and attentiveness to academic tasks, for instance, Clark et al. (2005) shows that using technology to access learning tasks and content may increase the time students spend on academic tasks.

One of the ways that technology may create these learning effects is that when technology is used as a tool that encourages exploration and experimentation it is associated with stronger student engagement which is associated with better learning outcomes (Becker, 2000; Sandholtz, Ringstaff, & Dwyer, 1997). Roschelle et al. (2000) suggests that technology enhances learning in children by supporting four essential characteristics of learning: active engagement, participation in groups, frequent interaction and feedback, and connections to the real-world.

Gaming technology may present unique opportunities as an entrypoint into STEM learning for underserved youth. Games are a ubiquitous part of youth culture; in 2005, 83% of youth aged 8-18 reported owning at least one gaming console (Kaiser Family Foundation, 2005). Recent studies of gaming practices of teens have found gaming to be prevalent across racial and ethnicity groups and across different socioeconomic levels (Pew Internet & American Life Project, 2008). Researchers are increasingly interested in the learning benefits of gaming technology, particularly looking at how games can be used to build understanding of complex systems and strengthen analytic thinking, create reasonably authentic simulations of complex real-world problems, and engage learners who might be harder to reach through traditional academic routes (e.g., Gee, 2003, 2004 2007; FAS, 2006; Shaffer, 2006). Games not only provide unique learning benefits, they also are seen as an engaging entry point to STEM disciplines. The Federation of American Scientists report on educational games describes how "games could be used for the expansion of cognitive abilities, as well as a platform for developing new or practicing existing skills" such as problem solving, setting and achieving goals, managing complexity and team building "in the context of real world goals, rules, and situations" (FAS, 2006). "Gaming could help to address one of the nation's most pressing needs-strengthening our system of education and preparing workers for 21st century jobs" (FAS, 2006, p. 3).

Five distinguishing features in games that are attractive to learning have been identified.

1. Clearly defined goals help the learner to understand the purpose.

2. A player has many opportunities within the game to apply what's been learned.

3. Games have features that arouse and sustain the learner's curiosity, and authentic challenges are presented that motivate the learner.

4. Successful games and the process of educational game design provide relevance through "contextual bridging" which will connect instruction to important needs and real-life situations.

5. The game or tools available to the learner in game design provide support or scaffolding in the form of cues, prompts and hints to build

confidence and help students progress until they are able to successfully control their own path of learning (FAS, 2006).

While much of the focus on games and learning has been on playing games, this project extends student learning by putting students in the role of game designers. When designing games or game elements, students are challenged to become metacognitive about how games function: how games use audio, visuals and text to communicate ideas, what helps users understand a game, what makes a game fun. The process of designing educational games also gives students control over their own learning by letting them decide on the theme, features, and content of the game. Designing games involves analytic and conceptual thinking and problem-solving in addition to the technical skills involved (Salen & Zimmerman,2003; Shaffer, 2006). In addition, the professional level tools used in the GDMC program are not limited to use in game design. For instance, students learn 3D modeling using Maya, a professional level software that is used to create models and simulations in architecture, engineering, medicine, physics as well as in game design. In Sheridan, Clark & Peters (2009) we describe how the simulation aspect of Maya use encourages scientific inquiry through experimentation and trial and error, visible feedback on how inputting different parameters affects the operation of models, and the ability to rapidly create and test out hypotheses about how virtual worlds work.

This focus on design, inquiry and simulation demands an environment that allows for open-ended projects, where the software becomes a tool for exploration and experimentation, a mode of technology use that researchers identify as important to student engagement (Becker, 2000; Sandholtz, Ringstaff, & Dwyer, 1997). To foster this exploratory environment, we draw on research on studio environment. Hetland, Winner, Veenema & Sheridan (2007) identify three key structures that operate in a studio classroom: Demonstration-Lecture, Students-at-Work, and Critique. Demonstration-Lectures are characterized by a greater focus on multi-modal delivery of information: students see multiple examples of the content and processes to be learned to help them more clearly understand what is to be learned and help them envision possibilities for their own designs. Demonstration-lectures also tend to be fairly brief, focusing on information that is immediately useful to the work students are doing immediately following the demonstration. Students-at-Work comprises the bulk of the studio classroom: students work on open-ended projects under the guidance of an instructor, and, in the case of our program, multiple student mentors. The role of the instructor/mentors during Students-at-Work time is to observe carefully student learning, and use “in the moment” adaptations to help students troubleshoot technical challenges, improve their design, and reflect on next steps in their work. This requires teachers to be flexible and knowledgeable, but it allows for more differentiation of student learning. Finally, Critique, is a crucial studio structure. In critiques, students have the opportunity to observe, compare, interpret and evaluate their own and each others' work. A critique may be as simple as a few minute pause where students stop what they are doing to take a look at each others' work, or it may be fairly formal and extensive where students exhibit and discuss their work before their instructors, mentors and peers. Critiques can be held at any stage of the design process, from initial conceptions to completed projects (Hetland et. al, 2007). Critiques are also essential in the establishing the "real-world" factor of game design: games are meant to be played by other people, who will have their opinions on the style, functionality, and interestingness of the game. In this design studio environment, students learn the skills of modeling, programming, and using software and to adopt the "epistemic frame" of being a designer (Schaffer, 2006).

PROGRAM DESCRIPTION

After-school Program

The *Game Design through Mentoring and Collaboration* (GDMC) program builds on an existing program, the *Institute of Urban Game Design* (IUGD). The IUGD program was founded in 2005 and was in operation for 2 years prior to becoming involved with GDMC. The IUGD was originally meant to serve freshman and sophomore students at McKinley Technology High School. In collaboration with GDMC, it expanded to offer classes to middle and high students across the DC- Metropolitan area. The classes that are held at IUGD include the major aspects that are essential to designing the latest games, such as 3D modeling and animation as well as computer programming. Specifically, the classes offered are: Maya (3D modeling and animation), GameMaker (2D game design logic), Alice (introductory computer programming), and Civilization (3D game logic). Flash animation and MissionMaker (3D game design logic) have also been taught on a more limited basis.

In its first year, the GDMC program included a fall semester and a spring semester. Each semester had 10 sessions held every Saturday for two hours. There was a 10:00-12:00 session for beginning and intermediate students and a 12:00-2:00 session for more advanced students. Typically 30-60 students come on a given Saturday, and they are separated into 2-4 classrooms so that each student has access to a computer with the appropriate software to work on their designs.

Within a two hour session, students generally switch classrooms so that each student gets instruction in 3-D modeling and 2-D game design/

programming each Saturday. The tuition for the 10-week semester is $150 dollars, typically paid for by the students' families. A payment plan or a reduced tuition rate can be negotiated with the site coordinator.

As an example of a 3-D modeling project using Maya in the GDMC program, students learned to model the key components of a basketball game: how to create various polygons they might need (e.g., a sphere for the ball, a torus for the hoop), how to arrange these in the 3-dimensional space, how to program the animation so that the ball can bounce and make a shot through the hoop. This type of project while providing an overall structure and focus, is quite open-ended, allowing for students to focus on different areas of interest and work at the level they need. A beginning student may only focus on basic shape creation, positioning and simple animation. An advanced student interested in creating more realistic animations might focus on details of the how the ball moves, such as how it subtly distorts when it hits the ground, realistic patterns of bouncing. Another advanced student may focus more on refining the style of the game: creating realistic colors and textures for the basketball, creating a design for the court.

As an example 2-D game design project using GameMaker, students learn to create the "platform" type of game, where a character jumps on various structures to retrieve objects and gain points and proceeds to increasingly difficult levels. In this project, all students need to learn the basics of how to create the game environment, create a character and program its movement options, create objects to be retrieved and establish a system for awarding points and moving between levels. However, beyond these basics, students may focus on vastly different aspects of the game design process. One student may be primarily interested in creating a certain theme and atmosphere for their game and spend time detailing the look of the background and characters. Another student may be really focused on figuring out how to make each level progressively more challenging.

During the summer, the GDMC focused primarily on professional development. We held a 4 week daily full-day session where new instructors instructed classes of high school students involved in a Washington D.C. Department of Employment Services youth summer work project, and a group of 25 high school students with prior experience in 3-D modeling and game design (and usually prior experience as a student in the IUGD/GDMC program) were employed as student assistants/mentors. Student mentors were expected to develop their skills in each of the types of software used in the GDMC project, and also to practice mentoring other beginning high school students as they worked on design projects. Graduate students in education observed each class, took field notes and gave periodic feedback to the mentors and instructors on pedagogy. In addition to this supervised practice, instructors and mentors received advice and informational materials on how to teach in a studio classroom. Professional development activities were informed by our observations of the GDMC classroom throughout the year.

Program participants

Participants in the program were recruited by a variety of means: visits by instructors and past student participants to nearby middle schools, passing out of flyers to schools and businesses, exhibitions at local D.C. events, and word of mouth. Survey responses on how they found out about the program revealed that thirty-six percent of the students reported that they heard about the GDMC program from a parent, 25% saw an flyer that was distributed, 13% heard about the program from a friend, and 7% found out about it at the NBC4 Health and Fitness Expo. The program attracted students ranging from 5th to 12th grade, primarily African-American boys. More detailed findings on the demographics, backgrounds and interests of program participants are discussed in the survey data analysis section.

METHODS

Research goals

In this initial year of the program, our research efforts primarily focused on descriptive efforts to understand 3 key aspects of our program:

1. We wanted to gain insight into what types of students were attracted to coming to a voluntary Saturday program: their background, their interests, and their reasons for deciding to attend. Since our goal was to attract students from traditionally underserved and underrepresented groups in STEM education, we wanted to ensure that this program was effective for this end.

2. We wanted to understand more about the STEM related attitudes, motivation, achievement and self-efficacy of the students who participate in the program. Since the program is advertised to attract students who are interested in gaming, would these students also be interested in STEM subjects more broadly?

3. We wanted to more carefully document the types of learning students engaged in while participating in the program. In particular, we wanted to identify and document ways a focus on game design could also support learning in STEM areas more broadly. We also wanted to gain the some insight into the student perspective: to discover their ideas

about what they learned, which aspects of the program they considered interesting and valuable and which aspects they might not.

Data collection methods

• A survey to measure STEM self efficacy, interest, attitude, and achievement, as well as STEM career awareness and interest was administered at the beginning of the spring semester. This survey also provides baseline knowledge of students who attend the GDMC sessions (See discussion of survey instrumentation below).

• Field observations were conducted to learn more about the students who attend GDMC, and their exposure to and interest in STEM content. Observations also were conducted to understand how the GDMC classes were taught, to identify potential issues around implementation, and to document the types of learning demonstrated in the class. Field observations were conducted by the authors, graduate student assistants and an external evaluator. This analysis draws on field observations of 8 of the 10 2 hour sessions in the Spring 2008 semester. Descriptive field notes were written, and a summary sheet that identified key instructional aims, evidence of engagement with different aspects of STEM content, and other researchers' insights into their observation.

• Focus group discussions were held to learn about what students enjoyed about the GDMC program, what they would change about it, what skills they learned, and if they would recommend the program to their friends.

INSTRUMENTATION

Survey

A survey was developed by the evaluator to collect student information during the first session (February 23) of the spring semester. The survey sought the students' attitudes toward, interest in, and self-efficacy regarding (STEM) content. Questions about program recruitment, STEM career awareness and interest, and STEM achievement were also included in the survey. Relevant demographic information was also collected from the graduates. Sixty students were present on the first session and from those 60, the program obtained parental consent for 44 students to take the survey for a response rate of 73%. The 60 students included in the survey does not include students who may have attended in the fall semester but not in the spring, nor students who started the spring semester after the first session.

The total number of students who attended the program for at least a portion of the fall or spring semesters was 139.

The survey included 15 questions in a combination of multiple choice and open-ended formats. These questions were used primarily to obtain information about students' demographics, how students learned about the program, how long the students had participated in the program , what students hoped to learn from through their participation, and student achievement within STEM content. Also contained in the survey was a 4-point Likert scale matrix with 41 statements about math, science, and technology. The items used in the Likert scale were determined by the primary goal of the project, which is to increase motivation, achievement, and exposure to STEM content of students from urban public schools. The students were asked to report their beliefs regarding the 41 statements. The students were also presented with a table that included STEM occupations. The students were asked how much the jobs interested them. The survey was used for the Spring semester primarily to obtain baseline information about GDMC participants.

Descriptive statistics were used to interpret the multiple choice and four-point, Likert-type response items on the survey. The negatively worded items were reverse-scored. Percentages, means, and standard deviations were obtained. Subscales were created for STEM self efficacy, attitude, and interest. The open-ended questions were coded to determine categories and themes within the data, as were the student responses to the focus group questions. A reliability analysis of the Likert-type response items was conducted using Cronbach's alpha and was .88.

SURVEY DATA FINDINGS

Participant characteristics

African-American males comprised the majority of program participants. Ninety-three percent of the students were male and eighty percent of the respondents were African American. Of the remaining students, 9.1% were Caucasian, 2.3 % were biracial or multiracial, and 9% reported other or did not respond to the item.

The program was successful in extending the range of student participants beyond McKinley Technology High School students: 35 different schools are represented in the program. The program was also successful in extending its reach to attract middle school or younger students, the median age attracted was 13.1 years old and over 40% of the students were in grades 7 or 8 (See Figure A). Seventy-five percent of the students reported that this was their first semester in the program, 18% reported that they had attended GDMC for 1 previous semester, and the remaining students had attended GDMC/IUGD for at least 3 semesters or more.

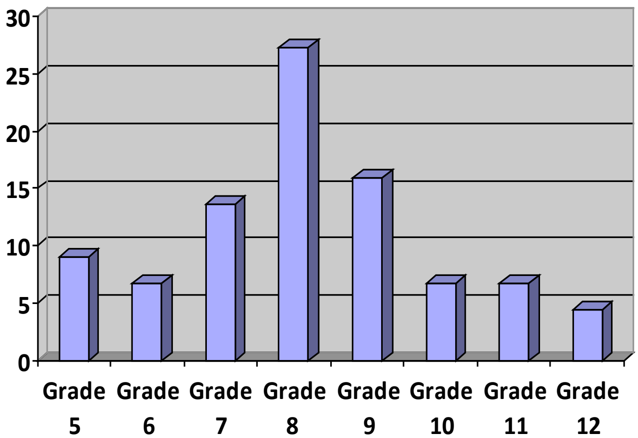

Figure 1. Percentage of students enrolled in IUGD by grade (N=44)

Students were also asked to report their academic grades for math and science classes, as well as their overall academic grades. Students reported fairly high grades: over 80% of students reported an overall grade average of B or above, and no students reported a D or Failing average. Students reported the highest grades in math, with slightly more than ¾ of the students reporting A's or B's, and 45% stating that they received an "A." Nearly ¾ of the students also reported getting A's or B's in science, however the grades were more heavily tilted towards B's rather than A's for science than math. The percentages of grade distribution can be found in Table 1.

Table 1.

Percentages of grade distribution (N = 44).

Grade	Math	Science	Overall School
A+, A, A-	44.7	29.3	23.7
B+, B, B-	31.6	43.9	57.9
C+, C, C-	18.4	24.4	18.4
D+, D, D-	2.6	2.4	0
F	2.6	0	0

Participant Current Interests

Students were motivated to participate in the program primarily due to their interest in games and technology. Access to technology and technology use was high for the program participants. Nearly all (98%) of the students reported that they had a computer at home, 33% reported they used the computer for 1-2 hours per day, and 30% of the students reported they used the computer for 4 or more hours per day.

Students were asked, in open-ended format, what they hoped to learn at GDMC. Eighty percent of the students said they attended because they wanted to learn more about designing video games. Some responded more specifically. One student wrote: "I hope to learn how to make 3-D figures" while another student wrote: "To learn more on animating objects and characters." Some students reported that they hope to learn skills that will help them in the future. One student wrote: "I hope to learn how to use the program 'Maya,' which I have at home (a demo) and hopefully get a summer job teaching. I want to learn to animate and model" and another student wrote: "to design game to make game of my own and get a good job."

Participant Career Interests

Students were also asked about their interests in a number of STEM occupations. The occupations with the highest percentage of students who reported that he job interested them were associated with computer technology: game design (78%), software development (41%), web development (36%), and technology specialist (35%). Of the occupations not associated with technology, engineering was the most attractive with nearly half the students reporting that it interested them a lot or that they considered it a possibility. Occupations associated with the biological sciences (i.e., Environmental Scientist, Biologist, and Medicine) were rated the least interesting to participants among the options listed. The percentage of student who rated STEM occupations can be found in Table 2.

STEM attitudes, interest and self-efficacy

The means of the student responses on the Likert-type scale items that addressed attitudes, interest, and self-efficacy in Technology, Math, and Science were also analyzed. Overall, students showed positive attitudes, strong interest, and high self-efficacy for Technology, Math and Science. The items with the highest percentage of students reporting the item was "A lot like me" were technology items (see Table 3): I am good at playing video games (93 %); I enjoy computer games (91%); I wish we used computers more in my classes at school. (84%); and I would like to learn more about technology in college (80%). Students also reported a high percentage of

"Not at all like me" for negatively worded technology items: I do *not* think learning about technology is useful (95%); I do *not* like to work on the computer (85%); I do *not* do well when I have to use a computer for a class assignment (84%) and I feel nervous when I have to use a computer (82%). The overall mean for statements associated with a positive attitude towards, interest, and/or self-efficacy in technology was 3.57, while the mean for negative statements towards technology was only 1.29. (See Table 3).

Table 2.

Percentages of STEM occupations (N = 44),

Job	It interests me a lot.	It is a possibility.	It interests me just a little.	It does not interest me.	I do not know what this job is.
Engineer	23.8	25.64	20.51	17.95	12.82
Architect	13.16	21.05	23.68	28.95	13.16
Environmental scientist	2.63	15.79	21.05	44.73	15.79
Game designer	78.00	19.5	2.3	0.0	0.0
Technology specialist	35	22.5	17.5	12.5	12.5
Web developer	35.90	28.21	17.95	7.69	10.26
Biologist	0.0	10.26	30.77	48.72	10.26
Chemist	12.82	10.26	25.64	41.03	10.26
Physicist	13.16	7.89	21.05	50.00	7.89
Mathematician	13.51	10.81	21.62	48.65	5.41
Software developer	40.54	32.43	8.11	10.81	8.11
Medicine (e.g. doctor, nurse)	10.53	7.89	23.68	52.63	5.26

While not as high as the technology items, students considered statements associated with a positive attitude towards, interest or self-efficacy in math as generally being a lot like them or usually like them. The overall mean rating of positive statements towards math was 3.25, falling between "Usually like me" and "A lot like me." The mean rating of negative statements towards math was 1.72, falling between "Not like me at all" and "A little like me." Ratings for science were somewhat lower, but still skewed towards positive responses, with the mean rating of positive statements about science of 2.85, falling between slightly below "Usually like me," and the mean rating of negative statements about science of 1.71 falling between "Not like me at all" and "A little like me." Detailed percentages, means, and standard deviations of the 41 items can be found in Tables 3, 4, and 5.

Table 3.
Percentages, means, and standard deviations of technology items without reverse scoring (N= 44).

Item	% of 4*	% of 3	% of 2	% of 1	M	SD
1. I enjoy computer games.	90.9	4.5	2.3	2.3	3.84	0.56
2. I can explain how to use a computer to someone who needs help.	51.2	27.9	16.3	4.7	3.26	0.90
3. I would like to learn more about technology in college.	79.5	13.6	6.8	0.0	3.73	0.59
4. I have ideas for designing new video games.	76.7	9.3	7.0	7.0	3.56	0.91
5. I do not like to work on the computer.	9.8	0.0	4.9	85.4	1.34	0.91
6. I think you need to know how to use technology to get a good job.	68.2	13.6	11.4	6.8	3.43	0.95
7. I do not do well when I have to use a computer for a class assignment.	4.7	0.0	11.6	83.7	1.26	0.69
8. Technology is difficult for me to learn and use.	0.0	2.8	30.6	66.7	1.36	0.54
9. I wish I knew more about computers and technology.	77.3	11.4	4.5	6.8	3.59	0.87
10. I feel nervous when I have to use a computer.	4.5	4.5	9.1	81.8	1.32	0.77
11. I do not think learning about technology is useful.	5.0	0.0	0.0	95.0	1.15	0.66
12. I wish we used computers more in my classes at school.	84.1	6.8	6.8	2.3	3.72	0.69
13. I know a lot about technol-ogy and using a computer.	38.6	38.6	18.2	4.5	3.11	0.87
14. I am good at playing video games.	93.2	4.5	2.3	0.0	3.91	0.36

*4= A lot like me, 3= Usually like me, 2= A little like me, 1= Not at all like me

Table 4.
Percentages, means, and standard deviations of math items without reverse scoring (N= 44).

Item	% of 4*	% of 3	% of 2	% of 1	M	SD
1. I always try my best in math class.	54.55	36.36	6.82	2.27	3.43	0.73
2. I enjoy taking math classes.	47.73	25.00	18.18	9.09	3.11	1.02
3. I would like to learn more about math in college.	33.33	23.81	35.71	7.14	2.83	0.99
4. My teachers think I do *not* understand math very well.	4.76	11.90	9.52	73.81	1.48	0.89
5. I am *not* good at math.	4.7	9.3	11.6	74.4	1.44	0.85
6. I believe that what I learn in math classes is useful in the real world.	59.1	25.0	11.4	4.5	3.39	0.87
7. I get good grades in math.	56.8	27.3	11.4	4.5	3.36	0.867
8. I am good at solving math problems.	63.4	24.4	7.3	4.9	3.46	0.84
9. I do *not* like going to math class.	14.6	26.8	14.6	43.9	2.12	1.14
10. I usually give up when solving a math problem.	0.0	11.6	27.9	60.5	1.51	0.70
11. I feel confused during math class.	2.4	19.0	23.8	54.8	1.69	0.87
12. When I am older, I want a job that does not use math.	16.7	14.3	31.0	38.1	2.10	1.10
13. It is easy for me to pay attention in math class.	43.2	29.5	25.0	2.3	3.14	0.88

*4= A lot like me, 3= Usually like me, 2= A little like me, 1= Not at all like me

Table 5
Percentages, means, and standard deviations of science items without reverse scoring (N=44).

Item	% of 4*	% of 3	% of 2	% of 1	M	SD
1. I understand mostly everything in science class.	45.5	27.3	22.7	4.5	3.14	0.93
2. I believe that what I learn in science classes is useful in the real world.	65.9	11.4	18.2	4.5	3.39	0.95
3. It is easy for me to answer questions in science class.	40.9	22.7	25.0	11.4	2.93	1.067
4. I wish I did *not* have to take science classes in school.	11.4	11.4	29.5	47.7	1.86	1.03
5. My teachers would say that I am good at science.	43.2	29.5	18.2	9.1	3.07	1.00
6. I think that learning about science is fun.	34.1	25.0	25.0	15.9	2.77	1.10
7. I do *not* get good grades in science.	6.8	2.3	27.3	63.6	1.52	0.85
8. I do *not* like going to science class.	6.8	15.9	36.4	40.9	1.89	0.92
9. I enjoy learning about a new theory in science class.	25.6	34.9	18.6	20.9	2.65	1.09
10. I feel confused during science classes.	14.0	4.7	32.6	48.8	1.84	1.04
11. I would like to go to college to learn more about science.	34.1	11.4	20.5	34.1	2.45	1.28
12. I enjoy taking science classes.	37.2	27.9	20.9	14.0	2.88	1.07
13. It is difficult to pay attention in science class.	4.8	7.1	33.3	54.8	1.62	0.82
14. I always try my best in science class.	62.8	18.6	11.6	7.0	3.37	0.95

*4= A lot like me, 3= Usually like me, 2= A little like me, 1= Not at all like me

In addition to analyzing by content area, subscales were also created for STEM attitude, interest, and self efficacy across the three areas. The items used to compute each subscale score are provided in Table 6.

Table 6.
Items Used to Compute Interest, Attitude, and Self Efficacy Subscores.

Interest	Attitude	Self Efficacy
I would like to learn more about math in college.	I always try my best in math class.	I am good at solving math problems.
I enjoy taking math classes.	I believe what I learn in math classes is useful in the real world.	It is easy for me to pay attention in math class.
It is easy for me to pay attention in math class.	I enjoy taking math classes.	I usually give up when solving a math problem.
When I am older, I want a job that does not use math.	I do not like going to math class.	I feel confused during math class.
I do not like going to math class.	I believe what I learn in science classes is useful in the real world.	I am not good at math.
I would like to go to college and learn more about science.	I enjoy taking science classes.	My teachers think I do not understand math very well.
I enjoy learning about a new theory in science class.	I think that learning about science is fun.	I always try my best in science class.
I wish I did not have to take science classes in school.	I do not like going to science class.	I feel confused during science classes.
I enjoy taking science classes.	I always try my best in science class.	It is difficult for me to pay attention in science class.
It is difficult for me to pay attention in science class.	I wish I did not have to take science classes in school.	I understand mostly everything in science class.
I do not like going to science class.	I enjoy computer games.	It is easy for me to answer questions in science class.
I wish I knew more about computers and technology.	I think you need to know how to use technology to get a good job.	My teachers would say that I am good at science.
I enjoy computer games.	I do not think learning about technology is useful.	I know a lot about technology and using a computer.
I wish we used computers more in my classes at school.		I can explain how to use a computer to someone who needs help.
I would like to learn more about technology in college.		I do not do well when I have to use a computer for a class assignment.
I have ideas for designing new video games.		I am good at playing video games.
I do not like to work on the computer.		I feel nervous when I have to use a computer.
		I have ideas for designing new video games.
		Technology is difficult for me to learn and use.

The negatively worded items were reverse-scored to compute the subscales. The reliability coefficients for the subscales were .77 (attitude), .77 (interest), and .77(self efficacy). Table 7 describes the ranges for the attitude, interest, and self-efficacy subscales.

Table 7.

Ratings Scales for STEM Self Efficacy, Interest, and Attitude (N=44).

Rating	Attitude Scale	Interest Scale	Self Efficacy Scale
A lot like me	40-52	32-68	58-76
Usually like me	27-39	35-51	39-57
A little like me	14-26	18-34	20-38
Not at all like me	0-13	0-17	0-19

Students scored high on each of the three subscales. The self-efficacy was particularly high: eighty-nine percent of the students scored "A lot like me," 11% scored "Usually like me," and no students had scores within the lower categories of "A little like me" or "Not at all like me." For the attitude scale, 2% of students scored "A little like me," 25% scored "usually like me," and 73% scored "A lot like me." For the interest scale, 23% scored "Usually like me" and 77% scored "A lot like me." Descriptive statistics of the subscales are presented in Table 8.

Table 8.

Mean Ratings for STEM Self Efficacy, Interest, and Attitude (N=44).

Dimension	Min	Max	Med	M	SD
Attitude	26	52	43	42.44	5.82
Interest	35	67	54.5	55.39	6.68
Self Efficacy	53	76	65	65.23	5.64

FIELD OBSERVATIONS OF CLASSROOM SESSIONS

As discussed earlier, the GDMC program explicitly teaches students to use a range of complex modeling, animation and game design software. In the first year, students spent the most time learning to use the professional level 3-D modeling and animation tool, Maya. After an initial class session where students were introduced to the concept of 3-D modeling via the simpler tool, Google sketch-up, the rest of the ten week session, students spend at least 45 minutes each Saturday working in Maya. In this analysis, we focus on our field notes and summary reports of the Maya sessions, particu larly looking at how the GDMC classes in Maya encouraged learning not only in technology, but also in math and science.

For example, using Maya involves thinking in a 3-dimensional coordinate geometry system. In every class observed, students needed to think of objects in terms of where they are located, and their relative size along the x, y, and z axes. Each class session was regularly punctuated with reminders to check the position of objects from multiple angles. For instance, when students were creating the set of balls for a pool table, they often found that balls that looked well-aligned from one perspective (Figure 2), were actually located at different heights along another axis (Figure 3).

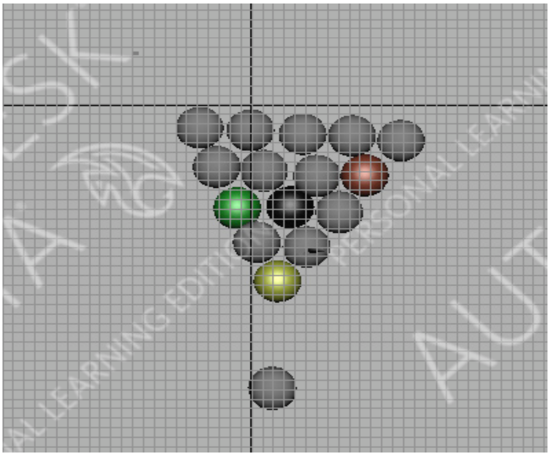

Figure 2. Sample student work of pool balls viewed top perspective showing seemingly correct alignment.

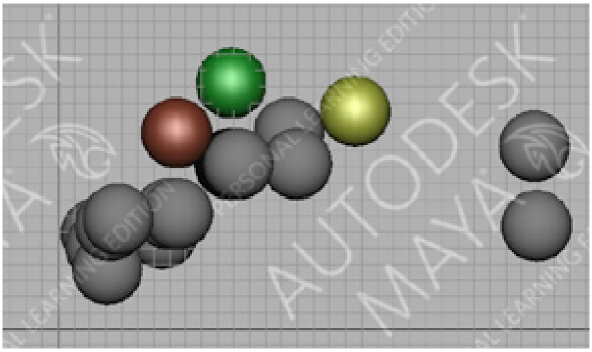

Figure 3. Same sample of student work of pool balls viewed from side perspective showing lack of alignment.

As students progressed throughout the term, they were pointed towards looking at how they could use the numerical coordinates to help them position objects. This kind of repeated clear, visible feedback on how numbers work in complex coordinate geometrical space to help them create the designs they wish likely helps students develop robust geometrical mental models.

Thus while students are motivated to learn to use the technology in order to design models for games, they are also learning key mathematical concepts.

Similarly, when students begin to animate their models, they encounter. In Sheridan, Clark & Peters (2009), we discuss how the dynamic animation mode of Maya was a powerful way for students to recognize and begin to correct misconceptions they held about scientific concepts such as how gravity affects active and passive objects, or the distinction between weight and mass.

In addition to this powerful math and science learning that emerges from basic qualities of the software, we consistently observed instructors making explicit references to math and science concepts and vocabulary. For instance, while working on a project where they create a collapsing chain of dominoes, this was a sample moment in the conversation between the instructor and a student:

> Teacher: Now, what do you think we need to get this moving? We could use keyframes, but we will use something with physics.
>
> Student: Gravity?
>
> Teacher: Yes, on earth, gravity has a value. 9.8 m/s^2. We can make calculations based on this. Select all your objects and get into dynamics mode. Choose Fields, Gravity.

Some of the additional mathematical or scientific concepts discussed during the observed classes included: Big Bang theory, weather supercomputing, artificial intelligence, electrical currents and circuitry, algebra, geometry, calculus and integrals. While these aside mentions do not constitute formal instruction in math or science, they do work to create an environment where STEM topics are seen as relevant and interesting. In addition, the instructor would frequently point out aspects of the software or project and say things like, “When you take calculus in high school or college, you’ll learn more precisely how to calculate these positions along the curve.”

There was a frequently expressed assumption that the students participating in this program would be taking advanced mathematics and science courses. In focus groups with students, students recognized the need for math and science in designing games. For instance, in one discussion students talking about the using the software said, "You use math because you put objects at different angles. You need to know math cause its one of the most important subjects." In another discussion a student stated that "You get to measure angles, and a lot of stuff comes from math, like how to shoot a basketball or how to bowl."

Discussions of how the students work in the GDMC program could connect to future careers was a frequent element of the observed classes as well. Observers noted potentially relevant careers being discussed in relation to specific activities students were doing in 7 out of the 8 class sessions observed, including architect, physicist, game designer, engineer, computer scientist, motion graphics animator, computer programmer. For instance, in the domino class mentioned above, the instructor talked about how different companies like Boeing and car manufacturers relied on people who could simulate how the airplane or car would work under different conditions.

DISCUSSION

One of the powerful aspects of the GDMC program is the social context it provides for a group of students who are traditionally underserved and represented in STEM fields. The prototypical student in the GDMC program is an 8^{th} grade African-American male who attends a Washington D.C. public school. He has regular access to a computer and reports spending hours a day on it. He is highly interested in video games and technology, and is interested in occupations related to those fields. To a lesser extent, he is interested in other STEM related occupations. He is interested in, has a positive attitude towards and believes he is competent and can achieve well in the areas of technology and math and science. He reports generally receiving A's or B's in his math and science classes. In the first year of the GDMC program we brought together 139 participants, at least 60 of whom could be considered consistent "regulars," creating a fairly sizable community of primarily African-American boys, primarily from underserved Washington DC and 35 surrounding area public schools, who range in age from 9-19, have a shared interest in technology, and STEM fields, with a majority doing reasonably well in math and science classes, all of whom have voluntarily decided to spend time on Saturdays to develop their skills in learning programming and 3D modeling to design games. This creates a powerful peer group context, where intelligence and competence in technology and other STEM areas are valued.

In addition, the program provides roles for more experienced and knowledgeable students to serve as mentors to the younger and/or beginning students in the program. These students not only support instruction and learning, they act as role models of students who have pursued more advanced learning in technology. The student mentors in the program were also primarily African-American students who attended Washington D.C. public schools, have positive attitudes towards, interest in, and self-efficacy in STEM areas and who are highly interested in learning to design video games. Zimmerman (2004) demonstrates that individuals are more likely to attend to and emulate models who they perceive as similar to themselves.

Finally, the focus of the program on game design is a strong motivator for students. An interest in gaming is ubiquitous in contemporary youth culture, and the students' survey responses also clearly show that learning to design video games is their primary motivation for participating in the program. However, as the field observations of the class sessions indicate, other aspects of math and science learning are inextricably entwined in the modeling, simulation and game design process taught in the program.

We see the key features of the GDMC program as: a large STEM-oriented collaborative peer group of traditionally underserved students, ongoing interaction with relevant and competent mentors/role models, a design studio environment that draws on the potential for technology to engage learners in exploration and experimentation and foster collaborative learning, and the use of professional level tools combined with explicit discussion of career and educational applications of these tools. All these factors in combination work in concert to make game design a powerful educational avenue for STEM learning among traditionally underserved students.

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