Possible Contributors to Evaluated Student Outcomes in a Discovery-Based Program of Game Design Learning

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Abstract: This paper explores contributors to student outcomes within a five-year pilot program of game design learning being conducted with middle school, high school, and community college students throughout the state of WV. In order to evaluate student engagement and learning in the program, researchers developed a content analysis evaluation framework to analyze the artifacts of students' project-based learning. Evaluating the extent of student learning and the underlying constructs supporting outcomes will help us better understand the ways in which this discovery-based program of learning might or might not be effective. Findings indicate that among 20 pilot locations, the highest mean game evaluation value at a school was 47 (with 61 being the highest possible value and 16 being the lowest). The lowest mean value for a school was 18.57. Variation appears present across pilot locations, which may be affirmed through future tests of relationship that will explore the variable of pilot location itself as a contributor to student outcomes. A range of other by-location descriptive statistics are examined for patterns, to further unpack some of the possible location-level variables that may contribute to student outcomes.

Introduction

This paper reports descriptive results for student outcomes within a five-year pilot program of game design learning being conducted with middle school, high school, and community college students throughout the state of WV. In order to evaluate student engagement and learning in the program, researchers developed a content analysis evaluation framework to analyze the artifacts of students' project-based learning. The coding scheme is based on a set of learning objectives for the program.

Here, we report the findings of the content analysis by location, and address these findings in relation to a range of program implementation variables. In our analysis, we look for possible patterns in the descriptive data that may indicate possible contributing factors to the variation in game design outcomes we are observing across locations. The program's curricular design, research, and evaluation frameworks, and the results highlighted and cross-referenced in this paper can inform improvements and allow us to offer more effective learning supports to participants in this discovery-based program of learning.

Further, this research is relevant to the learning sciences scholarly community in that programs of creative, project-based digital work are being implemented more and more as digital literacy, participatory culture and digital divide concerns enter the national educational agenda (e.g., Jenkins, 2009; Hobbs, 2010; Knight Commission on Information Needs of Communities in a Democracy, 2009; Mossberger, Tolbert & McNeal, 2007; National Education Technology Plan, 2010). Our research into novice students' learning processes, behaviors, and activation into participatory engagement in the game design program contributes to the larger program of research in this area, and relates to exploration of both a) naturalistic youth engagement in digital culture, and b) participation processes that result from experiences students have in programs such as this one, in which students engage in daily introductory computer programming and content creation activities across time.

Theory

The game design workshop program involved in this study is a 5-year grant-supported pilot initiative being conducted in the state of West Virginia, through grant support and involvement of the West Virginia Department of Education and Governor's Office of Technology. From Pilot Year 2 (2008/2009) to Pilot Year 3 (2009/2010), the number of schools participating in the project increased from 14 to 22. The N of students increased from 291, to 534 active students (non-drops) in Pilot Year 3.

In this program, a non-profit organization based in New York City has developed and offers school partner participants with a range of affordances and learning supports. Partner schools implemented the curriculum as an in-school game design course elective offered to students daily for credit and a grade during the regular school day. Students and teachers were provided Flash software licenses for enrolled Game Design students; an open source game design course syllabus and curriculum; a wiki-based e-learning environment containing the syllabus and formatted wiki tools for students' online collaboration, code sharing and game publishing; a suite of targeted free game design tutorials and resources; ongoing in-person student and educator trainings and virtual real-time supports such as virtual office hours with a Flash game design expert. Each syllabus topic is presented as a link on each school's network wiki, providing access into a set of activities, tutorials, and other learning supports, all posted online. Full year students typically proceed through Game Design syllabus topics in Semester One, and Game Development syllabus topics in Semester Two, uploading their files and posting their assignments on their profile and projects pages. Students engage in a significant amount of discourse, presentation and sharing of in-progress work within the courses, to elicit ongoing feedback from peers and their teachers. Teachers develop a schedule and assign deadlines for all of these assignments, based on the local needs and timeframe.

The founders have applied Constructionism, situated learning, social learning systems, and computational thinking principles to the program's design and development (Harel & Papert, 1991; Seely Brown, 2005, 2006; Lave & Wenger, 1991; Guzdial & Soloway 2003; Rich, Perry, & Guzdial 2004; Forte & Guzdial 2005). Computational game *making* activity by young learners has been investigated previously in research involving the educative "framework for action" or learning philosophy called "Constructionism" (Harel and Papert, 1991). Constructionism draws upon both Piaget's constructivist theory and Vygotsky's social constructionist theory, addressing learning as a constructive, social enterprise.

The program holds six main dimensions of student practice and expertise as learning objectives (Reynolds & Harel, 2009) presented in the following table.

Table 1. Six Contemporary Learning Abilities Framework

1. Invention of an original digital project concept (in this case, a game), and, successful development and completion of a finished computational artifact representing the concept.
2. Project-based learning and project management in wiki-based, networked environment
3. Posting, publishing and distributing digital media (*e.g., creating and uploading digital graphics, interactive designs, videos, notes, prototypes, and games*)
4. Social-based learning, participation, and exchange (*e.g., forming and sharing ideas, process notes, programming code*)
5. Information-based learning, research, purposeful search, and exploration (*e.g., researching the subject domain of a game; exploring design resources*)
6. Surfing websites and web applications (*e.g., game examples, wikis, blogs, web apps*)

In order to support these program objectives, the program incorporates a mix of both closely guided instruction and discovery-based learning strategies in its co-learning model, in which students and their educators work together using the syllabus and design resources provided. This means that students have occasion to engage in self-directed inquiry online to seek out learning supports, especially in cases in which their educator is unable to support them in a given task, due to the educator's lack of experience and his or her own ongoing learning curve.

Researchers have observed through participant observation and found support in analysis of open-ended survey response results relating to this program implementation, that some students find discovery-based learning in the program to be particularly engaging, whereas others find it somewhat frustrating (Reynolds & Harel Caperton, 2011). Kirschner, Sweller & Clark (2006) criticize "discovery-based learning" models as ineffectual, due to the frustration that can result from cognitive load, especially among novice learners who must seek out learning supports to meet design needs in the moment.

While a range of resources are provided in the online syllabus, such as links to specific video-based and written tutorials, the use of such resources appears to require a measure of reflection and self-initiative by student participants as they experience an immediate need in the game design process. The rationale for the co-learning model is the larger societal context of technological advancement in which we are educating today's youth and training educators, and the immediate need to train teachers and students on effective technology uses, to bring about a computationally-literate public now, to stem digital divide gaps at both level 1 (access) and level 2 (sophistication of use).

In order to better understand student engagement in the program, and the range of learning outcomes, this paper addresses the following research questions.

1. In what ways do student outcomes vary by location across participating middle schools, high schools, and community colleges?
2. What factors may contribute to any observed variation?
3. To what extent do the results offer support for the program's effectiveness in eliciting student achievement of the main learning objectives?

Measuring the extent of student achievement of learning objectives, and exploring the variables supporting outcomes will help us better understand the mechanisms of engagement and learning in this social learning system. To address these questions, we present content analysis results by location, in the context of other findings, and explore what patterns may be emerging.

Method

Here, we report results of content analysis for the games created at the school level. Further, we rely upon two other data sources: a student pre-survey, as well as a set of quarterly progress reports completed at four points in the year by participating educators at each location.

Participants

The total number of participants in Pilot Year 3 was 534, with 334 males and 190 females participating. Participation in the research was voluntary, and we acquired signed parent/guardian university IRB-standard permission forms for all 534 students who participated in the program, which is managed and operated by the NYC non-profit organization. Copies of the completed consents reside both with the non-profit organization and with the participating schools. Additionally, we have achieved child assents for all student program participants who are minors.

As for the survey response rate, out of 534 student participants, a total of 472 volunteered to complete the pre-survey, and 343 completed the post-survey. The administrative protocol for the survey required teachers to inform students in person that their participation was voluntary. As another measure of protection, each online survey session began with a written reminder that participation was voluntary. Skipping questions was permitted. Students were made aware that their responses to the survey would remain anonymous. We placed no time limits on the students; the time needed to complete each of the surveys ranged from fifteen to thirty minutes. The drop-off from pre-survey to post-survey is due to a range of factors, including student voluntary opt-out, student absences at the end of the school year, and student discontinuations in the program, changing of schools, etc.

Game evaluation

In order to evaluate student game quality, we conducted a content analysis of all student final games. Neuendorf defines content analysis "as the systematic, objective, quantitative analysis of message characteristics" (2002, p.1). Neuendorf explains that in order to use content analysis, "there must be communication content as a primary subject of the investigation" (p. 14). She makes references to text as the message, but further notes that "the text of a film includes its dialog, its visuals, production techniques, music, characterizations, and anything else of meaning presented in the film" (p. 15). In the case of web games created in this program, the text is the social or educational message students build into them (such as global warming, or social / cultural themes local to West Virginia). Also, the game files demonstrate student production techniques. That is, the medium itself (the game design and mechanics of the game evidenced in the SWF and FLA files) is part of the message we evaluate. Game artifact content indicates student engagement in the program, and signals CLA development of the more Constructionist CLAs 1 and 2 (while also partially indicating CLAs 3, 4 and 5).

Coding Scheme Development

Rourke and Anderson (2004) provide five steps to developing a theoretically valid scheme. The first step is to identify the purpose of the coding data; the second step is to identify behaviors that represent those constructs. They suggest that a literature review can help to identify representative behaviors. The six CLA objectives (especially the first three), and the literature that influenced them guided our work. Rourke and Anderson's (2004) second step involves studying the data in open coding. We reviewed student games and wiki interactions to refine the scheme; especially the codes addressing game genres and concept development. The third step (Rourke & Anderson, 2004) consists of reviewing the categories and indicators of the scheme, enlisting experts. Scholarly works by experts who use content analysis to study games largely focused on commercial games with the intention of understanding gender roles and levels of violence in *gameplay* (for example, Beasley and Standley 2002; Dietz 1998; Ivory 2006; Thompson and Haninger 2001). Walker and Shelton (2008) created a rubric for assessing problem-based learning outcomes and characteristics in video game play. Rice (2007) constructed an evaluative rubric to assess the amount of higher-order thinking required in video game *play*.

We applied Walker & Shelton's (2008) general coding strategy of measuring presence or absence of the variables (1=Yes, 0=No) for our evaluation of Actionscript inclusion in games. We also observed that these authors (2008) and Rice (2007) had codes that were more parsimonious than those used in a previous coding scheme draft the year before, prompting further refinement. Through review of this literature we also realized the need to explicitly define what constituted a web game in the program context. We define "game" as: a file that goes beyond a mere image, to include some level of interactivity, in which, at minimum, the file provides response to the player, based on a player action. The format of the game files students post online include both .SWF (Small Web Format / Shockwave Flash) and the .FLA project file format. To be evaluated files must reflect at least an actionable button and response screen, or an object that moves based on player actions. Distinguishing and defining a "game" at this most minimal level of interactivity allows us to code the full range of game files created by students, basic to advanced.

We also consulted with an industry expert on Flash game and simulation design. Her consulting process involved review of the online syllabus to identify main areas of focus in the game design curriculum; review of the SWF and FLA files for 5 games, and thinking about the range of student abilities reflected in the games; developing an initial set of Actionscript elements that were commonly used by developers and reasonable to be expected in a student game; and revising the previous version used in the year before, to evaluate SWF files, refining language and revising main header categories.

The result was a new draft of the coding scheme improving upon that used in the year before. Practice coding is the fourth step (Rourke and Anderson, 2004), and this was conducted by four coders (three experienced Flash designers, and one lead researcher), who all analyzed a set of five common games. The group reviewed discrepancies, and further revised the coding scheme, removing redundant categories, refining language, and establishing a 3-point scale for the design evaluation instead of 0/1. The final coding scheme allows evaluation of Actionscript programming codes that could reasonably be expected from introductory game design students (1=present, 0=absent), and, evaluation of design attributes built into the game (visual and sound design elements, game play experience, concept development, genre) (1=Not present / insufficient representation; 2=basic / introductory representation; 3=well-developed representation). The highest possible score was 61. The lowest possible score was 16.

Final Coding Scheme

The codes in the final coding scheme are presented as follows.

Table 2. Programming categories (0=not present, 1=present)

roll over/roll out		preloader	if statements* (conditional executions)
Button presses	timer *	load sound	
hit test/collision detection	drag and drop	Physics engine	
key press	dynamic text or input text	variables	
on enter frame *			

Table 3. Design categories (1=Not present/insufficient representation; 2=basic/introductory representation; 3=well-developed representation)

Visual and sound design element
The visual design of the game creatively reflects the concept of the game (e.g., the designer uses color, shapes, and patterns so that the visuals and design reinforce the ideas in the game design plan)
The visual / graphic style carries throughout the game consistently (e.g., elements of color-scheme, character design, game-play objects are held consistent throughout the game)
Sound is used to enhance game-play (e.g., no sound = 1. if certain objects have sound embedded = 2. If sound is used to enhance experience overall =3)
Non-player moving characters and animated objects in the game provide dynamism to the game play (e.g., graphic animation elements are created and included as files)
Sprites, animations and/or sounds add to the coherence of the design plan and game story; they encourage players to immerse themselves in play
Game play experience
Game instructions are clear and helpful to the viewer
Game provides helpful feedback when the player advances or fails to advance through the game (e.g., quiz game provides feedback on a response; when a character dies a life is lost or a message appears, etc.)
Game is navigable and intuitive to use
Game mechanics are simple to understand and learn, but challenging to master
Based on their game design plan on the wiki, it appears that students have a clear idea of their “audience”, and their game design has been executed to address this audience based on the plan.
Concept development
The game provides enough context up front (either in the storyline or mechanics) so that the game's objective, strategy are apparent to the player.
Game concept, storyline are coherently integrated with the mechanics and gameplay (e.g., an educational game uses effective instructional strategies; social issue games use mechanics that fit well with expressing the topic, etc.)
Any facts included are presented accurately and reflect research.
Any facts are integrated with the game concept and game mechanics, not as isolated quizzes
Game has an ending/conclusion that provides closure to the player.
The game design document on the wiki is thorough, clear, understandable.

Genre
Is the game a Social Issue game, an Educational game, or an Entertainment game? (write out which)
If the game is educational, what is its topic? Please state if it could be considered science, technology, engineering, math, or civics. If not, what is the topic?

Inter-coder reliability was conducted on 29 student games created in Pilot Year 3 (out of 216 games in total). To establish reliability, after our initial testing phase of the coding scheme, we trained a PhD student coder, discussing and establishing best process for analyzing Flash code to ensure that code on both frame layers and movie clip objects were taken into consideration. The 29 games were then coded by two people: a) the author and b) a PhD student. Inter-rater reliability analysis using the Kappa statistic was conducted to determine consistency among raters. We performed the analysis for each section of the coding scheme. Results are presented separately for each section below.

Actionscript programming evaluation

The inter-rater reliability for the raters for the Actionscript programming section of the coding scheme was found to be Kappa = 0.85 (p <.0.001), 95% CI (0.793, 0.903).

Visual and sound design evaluation

The inter-rater reliability for the raters for the Visual and Sound Design programming section of the coding scheme was found to be Kappa = 0.81 (p <.0.001), 95% CI (0.725, 0.894).

Game play experience evaluation

The inter-rater reliability for the raters for the Game Play Experience programming section of the coding scheme was found to be Kappa = 0.87 (p <.0.001), 95% CI (0.775, 0.955).

Concept development evaluation

The inter-rater reliability for the raters for the Concept Development programming section of the coding scheme was found to be Kappa = 0.75 (p <.0.001), 95% CI (0.658, 0.846).

Genre

We achieved full agreement in all 29 cases for the Genre code. For the Subject code, this category was open and will be reported as inductive results. All of these results present acceptable levels of inter-rater reliability for the coding scheme, indicating that using the scheme, independent coders have evaluated these 4 different characteristics of the game artifacts, and reached the same conclusions. (3)

Results

Descriptive data

The total number of participants in Pilot Year 3 was 534, with 334 males and 190 females participating. We arrived at this metric by cross-checking the Globaloria database (which draws from educator quarterly progress reports as the primary source), and student pre-surveys. The N of students by grade level is presented in the following table. The alternative education category refers to two pilot locations, neither of whose students created any games.

Table 4. N of students by grade level

	N	*Percent*
Middle School	64	12.00%
High School	322	60.20%
Community College	71	13.30%
Alternative Education	77	14.60%
Total	*534*	*100.00%*

Student Game Design Outcomes

Student work in Pilot Year 3 yielded 216 games. The table below reports the game genres, analyzed by a trained PhD student coder. Games that were coded as core curriculum topics include themes on traditional school subjects (English, math, science, social studies). Games that were purely entertainment and did not contain any substantive content theme were coded as Entertainment. We also have an Other category, which include games that bear for instance engineering, technology, social issues themes that were not science, and other substantive themes that do not fit the criteria above. The total additive N of games counted in these genres is 216.

We were also interested in games that could be characterized as STEM, due to our interest in the future in evaluating the extent to which game design can support STEM content learning. Thus, we calculated an additive value for the N of STEM games. The same was the case for some locations that focused on developing Civics games. Thus, we counted games in the Civics genre as well. Further, we tallied all of the games whose subjects had a global social issue theme such as climate change, pollution, poverty, etc., which commonly overlapped with Science, or Other categories. All of these games in the aggregate categories were also counted in one of the singular categories outlined above.

Table 5. Year 3 final games created

Total Game Projects Created	216
Student Games by Focus	
Math	26 (12%)
Science	79 (37%)
English	1 (0%)
Social Studies	46 (21%)
Entertainment	28 (13%)
Other (e.g., engineering, technology, manufacturing, education, poverty, etc.)	36 (17%)
Student Games with a Social Justice Issue Theme (e.g., the environment, poverty, nutrition, health care) – many are also science games, or, "other" games; all are also counted above	
Social Issue Game	72 (33%)
Student Games Focusing on STEM or Civics (all are also counted above)	
STEM Games	114 (53%)
Civics Games	36 (17%)
Individual vs Team Games	
Total Games made by an Individual	59 (27%)
Total Games made by a Team	157 (73%)

Out of the total set of student participants (N=534), 415 students either participated in teams that created games, or created games individually. A total of 119 students did not get far enough in their game design learning to achieve development of a game that fit our definition (file containing interactivity) that could be coded and analyzed. The three tables below feature the game evaluation findings for 20 Pilot Year 3 schools, excluding the two alternative education schools, segmented by grade level (MS, HS, community college).

Overall, the mean location-level game values reflect variation. The highest possible value in the coding scheme is 61. The lowest possible value is 16. The mean for the entire set of 216 games was 26.73. The standard deviation for the game evaluation outcome value was 8.10. Among all games, the highest scoring game was called "Deceptive Cadence," created by a team of 2 students at HS1, and achieving the high value of 52. The second highest scoring game had a value of 49 and was created by 3 students at MS1, called "It's Your Choice." Both of these top evaluated games reflected a large proportion of the attributes we were coding for. The lowest scoring game had a score of 16; there were a total of 8 games with this score, across 4 locations. While we separated the schools by grade levels, we see that the results are largely intermixed by grade level.

In each grade level table below, the schools are presented in rank order from highest to lowest, according to the total mean game evaluation value (which was additive of all the game categories). Additionally, the tables feature the by-location means for each category in the coding scheme (Programming, Visual and Sound Design, Game Play Experience, and Concept Development).

Proxies for Socio-Economic Status: Parent Education, Prior Computer Use (Home/School)

Further, adjacent to the game evaluation results grouped by grade level, we present results for some student survey variables (including the N of students who did not complete a game). We include these results for the schools in the rank order of their game evaluation performance. While we did not conduct statistical tests of difference or correlations in this study, based on the school game evaluation means and schools' rank order, we may be able to note some initial patterns in the descriptive results that can then be tested statistically.

A total of 472 out of 534 completed the pre-survey. We present by-location mean results for the variables parent education, and prior frequency of computer use at home and at school in the pre-survey. These variables may be seen as proxies for student socio-economic status (1,2).

Middle School Students

Among the three middle schools, the high mean game evaluation value for a school was 35.73 and the low was 27.40. The lowest middle school value appears higher than the mean value for the entire set of 216 aggregate games (26.73). We see that MS 3 (the middle school with the lowest mean game evaluation value) began the program in Semester 2 and thus had a lower average N of participation months whereas MS1 and 2 were full-year locations. Further, it was MS3's first year in the program whereas it was the second year for both MS1 and 2. For students at all schools, it appears on average that they use computers more often at home than at school. For the proxy measures for socio-economic status (SES), MS1 appears lowest in two of the three SES proxy variables while they are highest in game evaluation. It appears that the game design category with the greatest amount of variation is that of programming.

Table 6. MIDDLE SCHOOL Game Evaluation Results for Middle Schools

Middle Schools	*N of Games Created*	*Total Mean Game Evaluation Value*	*SD, Total Game Evaluation*	*Programming*	*Visual and Sound Design*	*Game Play Experience*	*Concept Development*
MS1	11	35.73	9.08	7.09	8.64	9.27	10.73
MS2	17	29.53	6.40	3.94	7.35	8.53	9.71
MS3	5	27.40	4.28	2.60	7.60	7.80	9.40

Table 7. MIDDLE SCHOOL N of students by location, for the following variables: Gender, semester start, pre-/post-survey; and, average participation months

School	*N of Students*	*N Students Not Completing Game*	*Female*	*Male*	*Semester 1 Start N*	*Semester 2 Start N*	*N of Years in Program*	*Pre-Survey N*	*Post-Survey N*	*Avg. Partic. Months*
MS1	26	0	14	12	26	0	Second	25	25	9
MS2	20	2	4	16	20	0	Second	19	18	9
MS3	16	0	7	9	0	16	First	16	15	4

Table 8. MIDDLE SCHOOL Means and standard deviation for parent education, and *Pre-Survey* frequency of computer use at home and at school

School	*Parent Education*	*SD*	*Pre-Survey Freq. Comp. Use at Home*	*SD*	*Pre-Survey Freq. Comp. Use at School*	*SD*
MS1	2.43	1.04	4.54	1.86	4	1.02
MS2	3.38	1.41	4.84	1.07	4.37	1.12
MS3	4	0.95	5.06	1.29	3.75	1.07

High School Students

The tables below present the results for high schools. The highest mean game evaluation value for a high school was 47.00 and the low was 18.57. Among the thirteen high schools, at HS7 the N of students who did not create games was highest (12). This location had 43 total students (the second largest group). We must inquire into further into HS7 to identify why this is the case, as it is another measure of student and location performance, aside from game evaluation values. It may be the student/teacher ratio played a role.

While we might expect that newcomer status (first year in the program) might appear related to outcomes, it does not appear that there are any discernable patterns in this regard for the high schools. It appears that students at HS1 also reflect lower apparent parent education means when compared with most other schools, similar to the highest ranking middle school. While among the general youth population, content creation and more productive technology uses have been found as positively correlated with socio-economic status (Hargittai & Walejko, 2008), it may be that once an intervention such as Globaloria is offered, this relationship no longer holds, or that motivational differences are present in the educators and/or students, given this opportunity.

HS9 appears to have a higher score in Concept Development, in comparison with their students' performance within the other game evaluation categories. We have noted in retrospective participant observation that students at HS9 created files that were more reflective of simulations than final games. The final files at HS9 actually do not fit with our stated definition of a game bearing interactivity. However, these students created very thorough game design plans that were organized well on the class wiki, and the content themes were relatively complex; thus our coder evaluated them anyway. Interestingly, largely due to the high evaluation scores for Concept Development, several of the HS9 simulation files achieved higher scores than students' files at other locations in the combined additive mean.

Table 9. HIGH SCHOOL Game Evaluation Results

High Schools	*N of Games Created*	*Total Mean Game Evaluation Value*	*SD, Total Game Evaluation*	*Programming*	*Visual and Sound Design*	*Game Play Experience*	*Concept Development*
HS1	4	47.00	4.08	7.75	14.50	10.25	14.50
HS2	13	32.08	6.24	4.77	8.38	8.62	10.31
HS3	12	29.83	7.66	4.92	8.08	8.25	8.58
HS4	7	28.71	5.99	5.14	7.00	7.71	8.86
HS5	5	27.80	3.27	3.20	7.20	8.00	9.40
HS6	4	27.25	10.34	5.50	7.25	6.25	8.25
HS7	18	26.22	5.47	4.56	6.44	7.33	7.89
HS8	16	25.13	5.76	2.94	6.63	7.56	8.00
HS9	14	23.36	2.56	2.50	5.93	5.79	9.14
HS10	5	22.20	2.95	1.60	6.80	6.80	7.00
HS11	2	22.00	7.07	4.00	5.50	6.00	6.50
HS12	36	19.08	2.70	0.44	5.64	6.03	6.97
HS13	7	18.57	1.51	0.86	5.14	6.00	6.57

Table 10. HIGH SCHOOL N of students by location, for the following variables: Gender, semester start, pre-/post-survey; and, average participation months

School	*N of Students*	*N Students Not Completing Game*	*Female*	*Male*	*Semester 1 Start N*	*Semester 2 Start N*	*N school Years in Program*	*Pre-Survey N*	*Post-Survey N*	*Avg. Partic. Months*
HS1	15	3	2	13	15	0	first	15	12	9
HS2	28	1	8	20	18	9	third	25	18	4.2
HS3	13	0	4	9	0	13	first	12	6	4
HS4	15	1	2	13	14	1	first	14	12	9
HS5	14	0	8	6	0	14	first	13	10	4
HS6	9	0	5	4	9	0	second	9	5	9
HS7	43	12	8	35	43	0	second	42	28	9
HS8	36	1	16	20	0	36	first	34	28	4
HS9	33	5	13	20	33	0	third	31	22	9
HS10	12	1	6	6	1	11	third	10	8	4.5
HS11	10	0	2	8	10	0	first	10	9	9
HS12	76	6	8	68	76	0	third	73	48	8.5
HS13	20	3	10	10	0	20	first	20	13	4

Table 11. HIGH SCHOOL Means and standard deviation for parent education, frequency of computer use at home and at school

School	*Parent Education*	*SD*	*Pre-Survey Freq. Comp. Use at Home*	*SD*	*Pre-Survey Freq. Comp. Use at School*	*SD*
HS1	2.86	0.86	5.27	1.44	4.33	1.35
HS2	3.29	1.27	5.64	0.57	4.4	1.23
HS3	3.55	1.29	5	1.71	4.25	1.42
HS4	3.21	0.8	4.93	1.44	5.57	0.51
HS5	3.09	1.22	5	1.6	5.67	0.49
HS6	2.44	1.13	4.89	0.93	5	1.23
HS7	3.31	1.03	4.76	1.59	4.17	1.08
HS8	2.59	0.87	5.18	1.29	4	1.32
HS9	3.29	1.56	4.71	1.42	3.9	1.17

HS10	3	1.12	5.6	0.7	4.67	1
HS11	3	1.53	5.8	0.42	5.5	0.53
HS12	3.5	1.27	5.34	0.82	4.44	1.26
HS13	3.15	1.39	4.95	1.54	4.45	1.57

The highest mean game evaluation value for a community college was 28.00 and the low was 26.89. Among the community college locations, the finding that stands out most is the extent to which mean game evaluation results hover within a few points, close to the overall mean of all 216 games taken together, and the middle set of four high schools out of thirteen. There is less variation across schools in outcomes. Among these older college students who participate in a somewhat different modality (a typical college course that is not conducted daily but rather twice a week with daily optional lab time), they did not appear to achieve the same level of success seen by higher scoring younger counterparts in one middle and several high schools. Importantly, the average participation months for the college students is lower, which may contribute to the outcomes. Also interesting is the larger proportion of self-selected male participants at the community colleges, which may have to do with the technical nature of the academic departments in which the program is offered, which focus on web development training and IT network administration.

Table 12. COMMUNITY COLLEGE Game Evaluation Results

Community College	*N of Games Created*	*Total Mean Game Evaluation Value*	*SD Total Game Evaluation*	*Programming*	*Visual and Sound Design*	*Game Play Experience*	*Concept Development*
CC1	11	28.00	8.45	5.09	7.55	7.27	8.09
CC2	7	27.86	7.38	4.57	7.43	7.86	8.00
CC3	15	27.47	8.77	4.60	8.00	7.07	7.80
CC4	9	26.89	8.05	4.00	8.22	6.56	8.11

Table 13. COMMUNITY COLLEGE N of students by location, for the following variables: Gender, semester start, pre-/post-survey; and, average participation months

School	*N of Students*	*N Students Not Completing Game*	*Female*	*Male*	*Semester 1 Start*	*Semester 2 Start*	*N of Years in Program*	*Pre-Survey N*	*Post-Survey N*	*Avg. Partic. Months*
CC1	24	1	11	13	12	9	first	24	11	3.5
CC2	10	0	0	10	0	10	first	8	8	3.5
CC3	27	5	0	27	14	13	third	23	23	3.8
CC4	10	1	3	7	10	0	first	1	5	4

Table 14. COMMUNITY COLLEGE Means and standard deviation for parent education, frequency of computer use at home and at school

School	*Parent Education*	*SD*	*Freq. Comp Use at Home*	*SD*	*Freq. Comp. Use at School*	*SD*
CC1	3.67	1.4	6	0	5.5	0.93
CC2	4	1.26	5.38	1.41	5.25	0.89
CC3	3.36	1.5	5.7	0.56	5.59	0.73
CC4	3.8	1.23	5.9	0.32	5.6	0.84

Discussion

It has been found that individuals' working memory is challenged by the presence of novel stimuli unrelated to the exact material to be learned – distractions such as the need to seek out resources to learn the core intended material present in this program – leading to frustration in the learner (Kirschner, Sweller & Clark, 2006). These authors (2006) advocate for supporting student learning of the material of focus with minimal distractions, using scaffolds offered front and center in the immediate moment, such as a teacher's or intelligent tutor system's diagnosis, knowledge and immediate help.

In this game design program implementation, while teachers are still novices, students must engage in some level of discovery-based learning through access and use of an array of learning supports that are aggregated in the context of the online wiki syllabus. This study begins to map the terrain of the program implementation and outcomes using data analytics, in order to better understand what factors may be contributing to more or less positive results, under the present conditions.

When segmenting the data by location, it appears that there is variation in game evaluation outcomes based on location, which we see from the distribution of grouped means. Thus, it appears that the location itself may be a variable contributing to student outcomes in the overall dataset. One of the location-level variables by which we further sub-grouped the data was grade level. We did not discern particular patterns of this variable as a contributor to outcomes, but we will continue to explore grade level as a factor. At the location level we also noted the number of years the school has been participating in the project as a possible contributor; we will continue to consider this.

There are many other school-level factors that vary in the 22 pilot locations that were not measured here, including the following:

- Number of hours the students worked (more granular tracking of time on task)
- Game topic modality (school subjects, versus social issues, versus open choice)
- Team versus individual game design contexts
- Hardware, software and networking technologies present in the schools
- Proportion of students to teachers
- Educator's number of participation months, level of game design expertise and motivation
- Teaching styles of the educator

These variables should be investigated further. Also, based on the findings in this exploratory analysis, we will continue to investigate the following individual student level variables:

- Grade level (individual student grade)
- N of participation months
- Socio-economic status (interesting for the possible non-relationship)

Other student individual-level variables that we might explore as contributors to student outcomes include:

- Prior school performance in traditional subjects (e.g., grades, standardized test scores)
- Prior home technology access and experience
- Prior game playing experience
- Subsequent home technology access and use once enrolled
- Age
- Gender
- Interest, effort and productivity in the class
- Motivation for learning in general, and, toward program activities
- Learning styles
- Self-efficacy
- Self-regulation styles

On the whole, it appears that the program's co-learning model, in which educators and students learn a new set of technology, design, and productivity skills and practices together, using expert mentorship and resources provided by the non-profit organization, has mixed results. The varying levels of success we are observing at the pilot locations are likely due to a mix of factors, including the number of participation months and years of schools' participation, and teachers' varying learning curves. It may be that the less experienced and supportive the educator is, the lower the student outcomes are. It may also however be the case that the less experienced and supportive the educator is, the more students must rely autonomously on the online tutorials and supports provided in the online game design syllabus and curriculum. Some students may find this autonomy motivating, and others may find it challenging and frustrating. It may be that not all types of learners are fully supported in the program. However, given the higher evaluation means at some locations (47 out of 61), some students are succeeding in the goal of creating a final game and learning Constructionist technology and design practices in accordance with the learning objectives.

Given this is a pilot, the program leaders implement improvements and changes every summer prior to the subsequent year's launch. Many such changes were implemented for Pilot Year 4 currently underway. Thus, as the program implementation evolves, results across locations will also continue to evolve. The basic data collection and evaluation procedure outlined here begins to provide a framework that can contribute to the development of a logic model for the system of learning that is occurring in the program, and the relationship among variables and factors in the learning context.

The measurement of student game design outcomes is an important step in evaluating the effectiveness of this program in meeting its stated goals and objectives. The coding scheme measures teams' project-based work by evaluating the product of student design team activity. If the teams are able to program the games to include the given parameters, this indicates that students in the team collectively have a certain threshold of expertise, as they have learned the skills needed to do so. Our coding scheme does not however capture individual-level activity; thus, when conducting statistical tests of relationship and difference, care will be needed to choose analytic techniques that appropriately address the given group work context.

Being able to rank schools based on their mean game evaluation value outcomes allows us to compare performance at the different locations. From a programmatic standpoint, this is helpful to the non-profit staff who manage the program as it allows them to intervene if necessary for struggling locations. In addition to school rankings, knowing more about the underlying factors that contribute to the variation in student outcomes will help us even further. If we don't know **why** some students at some schools are struggling, it is difficult to know how to help and support them. Therefore, in this exploratory study we have investigated some possible contributing variables, using available descriptive data, and observing apparent differences that might be explored statistically in the future. If we are able to learn what some of the contributors are to student outcomes in this unique workshop-based educational context, we can use what we learn about the contributors to better support students.

Supports and improvements might include direct human interventions from non-profit staff to students and educators in the moment when they are challenged; improved ongoing teacher training and professional development that addresses their own learning, and, their support of students' work (such as anticipating student challenges given individual differences / learning styles that we might discover effect outcomes); improved curricular development such as sequencing of syllabus topics; and the development of more customized digital tutorial resource supports. For instance, the program staff is currently piloting a digital online cognitive tutor developed in Flash by the author and a colleague, that will help students better understand how to generate the Actionscript code needed to complete the Mini-Game assignment, which is a pivotal assignment in their Flash learning when they are first introduced to programming of interactivity into their game.

One limitation of the approach outlined in this study is that it does not capture time as a variable of student learning. While many common supports were provided to students and educators across locations (such as wiki platform provided to each pilot location, Flash and CS2 as game design software, sequential game design and game development curriculum, non-profit training of the educators twice-annually and direct support to students through live expert resources such as office hours, virtual trainings), *the ways in which students and educators used these resources and engaged in the program* also varied. That is, it may be that the sequence of student activities and their learning pathways play a role in their outcomes. More research is needed to define and understand possible variations in student pathways. In particular, research in our program is sorely needed to understand teamwork and student learning dynamics in game design teams. Further, to what extent do educators offer flexibility in how students approach their projects? Do they require all students to go through the same steps as a class? Or, are students given autonomy in their design process, to complete syllabus topics out of sequence for instance, driven by the students' perceived design needs? We continue to explore such questions in parallel case study research. Best practices and continuing program improvement can result from such continued investigation, when coupled with the more structured framework for data analysis and student evaluation mapped and presented here.

Exploring the extent to which variables such as these play roles in student game design outcomes can allow us to better understand project- and discovery-based learning and development of digital and participatory skills in Constructionist environments. A larger key question that we seek to address moving forward is the extent to which student experience in a workshop-oriented program such as this one mitigates the participation gap discussed by scholars such as Jenkins (2009) and Hargittai & Walejko (2008). These scholars have found that productive, constructive digital activities and participation such as content creation is correlated to socio-economic status. If participation in this game design program among students from low socio-economic backgrounds results in an equal or greater sustained extent of productive and constructive digital participatory activity as compared to comparable individuals in higher socio-economic brackets, it would give us indication that indeed this program can help mitigate digital divide effects. We expect that practicing these activities in a supportive setting may provide students with the experience and expertise that is needed to spark ongoing engagement, participation, and future opportunity. Ongoing research with a mind toward longitudinal effects will help us to determine whether this hypothesis is supported.

Endnotes

(1) For parent education, we asked students to identify the level of education for each parent separately using the scale, 0= Don't Know/ missing; 1= Did not complete HS; 2= Completed HS; 3= Completed HS, attended some college; 4= Completed college (at least 4 years); 5= Completed college, attended some GS; 6= Completed GS. The final parent education value used was the level of education for the parent with the highest education level (since many students only responded for one parent). Frequency of computer use was measured with 2 survey items asking "*How Often Do You Use a Computer at Home/School*" and a 6-point scale: 1 = Never; 2 = A few times a month; 3 = About once a week; 4 = A few times a week; 5 = About once a day, and 6 = Several times a day.

(2) The relationship between adolescents' self reports and parents' actual reports of parental education has been found in a previous study to be in fair agreement; kappa statistics were 0.30 and 0.38 for fathers' and mothers' education, respectively (Lien, Friestad, Klepp 2001). This finding supports the validity of using student self-reports of parent education.

(3) In Pilot Year 3, we lacked an individual-level knowledge outcome variable. No knowledge tests in the program have been given. Thus, in our study we evaluated students' *team* games as our knowledge construct. In most cases, students worked in teams of 2, 3, or 4. Thus, in the creation of our dataset, we spread the grouped team-level evaluation values to each unique team member of a given small group in our individual student dataset case rows. We were fortunate to have mapped which team member was in what team, at each location, through the teams' pages on the wiki, very specifically. The individual game evaluation value for each small group member thus reflects the outcome of the small teams' collective group cognition. Thus, the individual game evaluation values reflect the *maximum* amount of learning for an individual in each team as evidenced by their team final games.

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