https://doi.org/10.28990/jaid2018.071003

From Passive Players to Active Developers: Undergraduate Biology Students Developing Their Own Digital Learning Game with Twine

Jordan Clark, Sam Houston State University
Rachel Baxter, Sam Houston State University

Abstract: Undergraduate microbiology students were tasked with creating a digital learning game. The purpose of this project was to change the student role from passive player of educational games to active developers. The microbiology course curriculum does not require programming knowledge nor dedicate instructional blocks to computer skills. Students were instructed to apply microbiology concepts and clinical case studies to create an interactive text-based digital game using the open source program Twine. A pre-project survey showed concerning attitudes towards gaming. The course students reported spending fewer than two hours per week engaged in casual game play and preferred a mixed approach to learning through traditional formats. Over 50 percent of the class expressed uncertainty in the skills required for this project. Despite the initial uncertainties, projects grades were above 90%. Rubric assessment, compared from the course instructor to an independent grader, showed high marks for science application, creative play, and instructional intent. Over 50 percent of the students reported a positive experience with many reporting increased confidence in their abilities to create a digital learning game. This study shows that students can create their own digital learning game with minimal programming knowledge and instructions.

Keywords: Digital learning game, game development, undergraduate science course, microbiology, student project

The popularity of digital games in America has provided a potential new medium for educational tools. Several structural elements of games are attractive to players. These include, but not limited to, structured rules, defined objectives, conflict, and interaction (Garris & Ahlers 2002; Wilson et al. 2009). Educators can motivate students to learn by applying these game characteristics (Butler et al. 2014). Digital games as educational tools, or serious digital games have become popular in STEM courses (Breuer & Bente 2010; Halpern et al. 2012). Research suggest that digital games can enhance learning of scientific concepts and promote scientific thinking (Ravenscroft 2007; Halpern et al. 2012; Morris et al. 2013) Student learning motivation and engagement may increase when incorporating digital gaming compared to non-gaming methods (Miller et al. 2011). However, the complex stimuli and cognitive demand of some digital game interfaces may overwhelm students (Zaphiris et al. 2007; Chen & Huang 2013). Prior experience and knowledge of digital games may also influence a student's attitude when incorporating such media into a learning protocol (Blumberg et al. 2008; Orvis et al. 2008).

Individual learning styles may bias a student's attitude towards digital game learning. Though the taxonomy and measurement of learning styles remains controversial (Curry 1990; Coffield et al. 2004; Liu 2007), research has shown some benefits in educational strategies that address unique learning styles (McParland et al. 2004; Kolb & Kolb 2005; Wang et al. 2013). However, style-specific teaching strategies like digital game learning may alienate those who prefer different or traditional methods of instruction. These discrepancies in attitudes and learning styles represent a critical obstacle in realizing the full potential of digital games in the education.

Recently, educators have addressed these concerns through student-created games. Changing the student's role from a passive learner, as the case when playing educational games, to an active designer can foster empowerment through ownership (Yang & Chang 2013). This new role for the student helped create the theory of Digital Game Authorship (DGA) (Yang & Chang, 2013). Some of theoretical basis for DGA describes the creation of knowledge through application of experience and increased attention to tasks (Yang & Chang,

2013). An important aspect of DGA is the opportunity for collaboration, planning and socialization that may encourage critical thinking skills (Triantafyllakos et al. 2011; Carolyn Yang and Chang 2013).

Given the academic potential for DGA and game-based learning, we wanted to assess the ability of undergraduate microbiology students to develop their own digital learning game (DLG). The immediate challenge of this project is integrating computer-programming skills into an already demanding course curriculum. The priority of the microbiology course is learning of basic microbial features, application to human illnesses, and analytical lab experiments. Requiring students to develop a digital game may distract from the course objectives. Some may deem game development as an unnecessary learning component and jeopardize class performance. Optimally students would need software that requires little programming knowledge. This would also benefit teachers unfamiliar with digital games, allowing them to spend minimal instructional time on software use. Twine is open source software that allows users to develop digital text-based games (Chris Klimas, 2009). Twine requires minimal programming skills and is free to use on a browser or downloaded to a desktop. Game play is structured in a nonlinear format allowing players to choose multiple story lines that may result in different outcomes. The simple design of Twine software and user-friendly tools allows students to focus primarily on accurately integrating science concepts and creative storytelling without the complexity of programming language. By using Twine, we hypothesize that students can create a digital learning game with minimal programming experience. Additionally, we hypothesize that challenging students to create a digital game will positively change their attitude towards knowledge application, computer and problem-solving skills.

Methods

Participants

The Twine DLG project was assigned to an undergraduate class of approximately 80 students enrolled in Introduction to Applied Microbiology at Sam Houston State University. All the students in the course were pre -nursing majors.

Introductory Block

Students were advised to form groups of two to four people, though single student projects were permitted. The class received an in-class tutorial about the website Twinery.org with instructions on navigating the website's tools(Chris Klimas, 2009). Next, the instructor demonstrated how to make a Twine DLG using a simple campus navigational story (see Figure 1). The demonstration game was shown in editing mode emphasizing how placing of double brackets at the beginning and end of words create clickable links leading to different story passages (see Figure 1). Next, the Twine demonstration DLG was shown in game-play mode. The double brackets inserted around text in the editing mode appear as hyperlinks that take the player to different panels (see Figure 2). Students were provided links to a series of basic video tutorials on Twine and archives of twine stories with themes of science fiction, mystery, and comedy. Students were advised to spend one week exploring the various twine stories while creating a demonstration game to become familiar with the programming requirements.

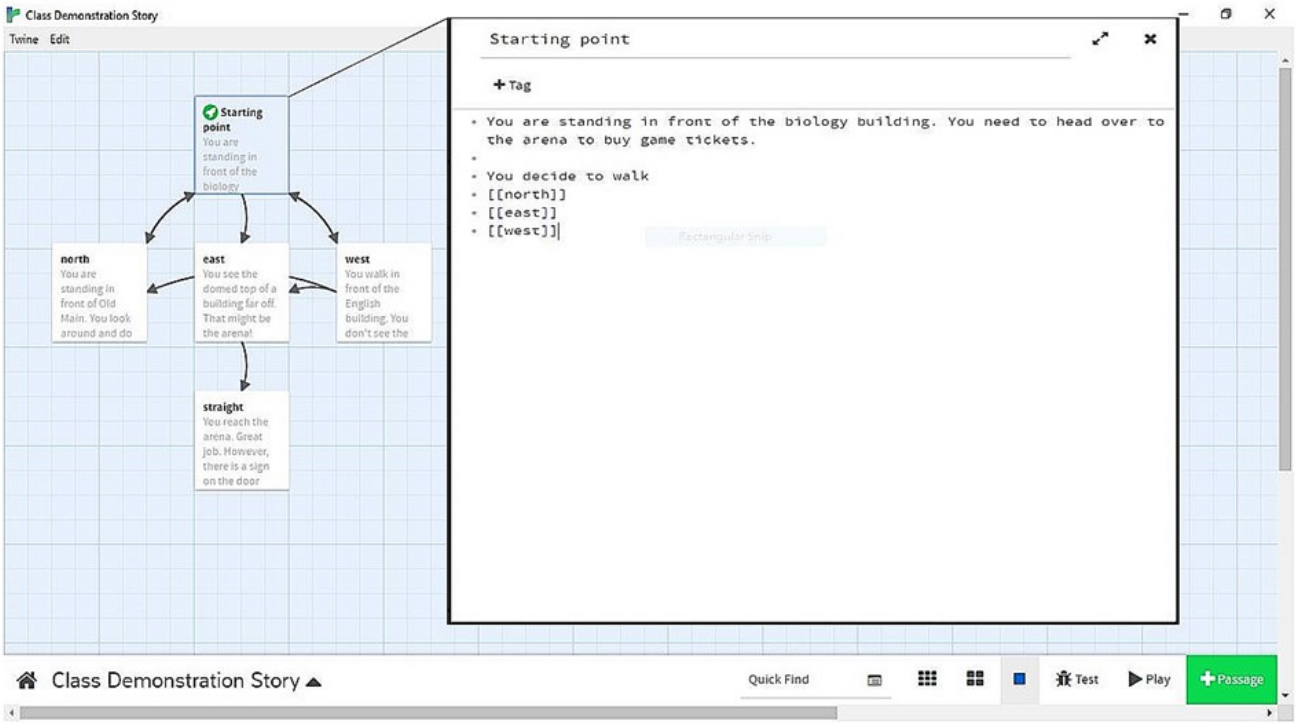

Figure 1. Instructor demonstration of Twine story in editing mode.

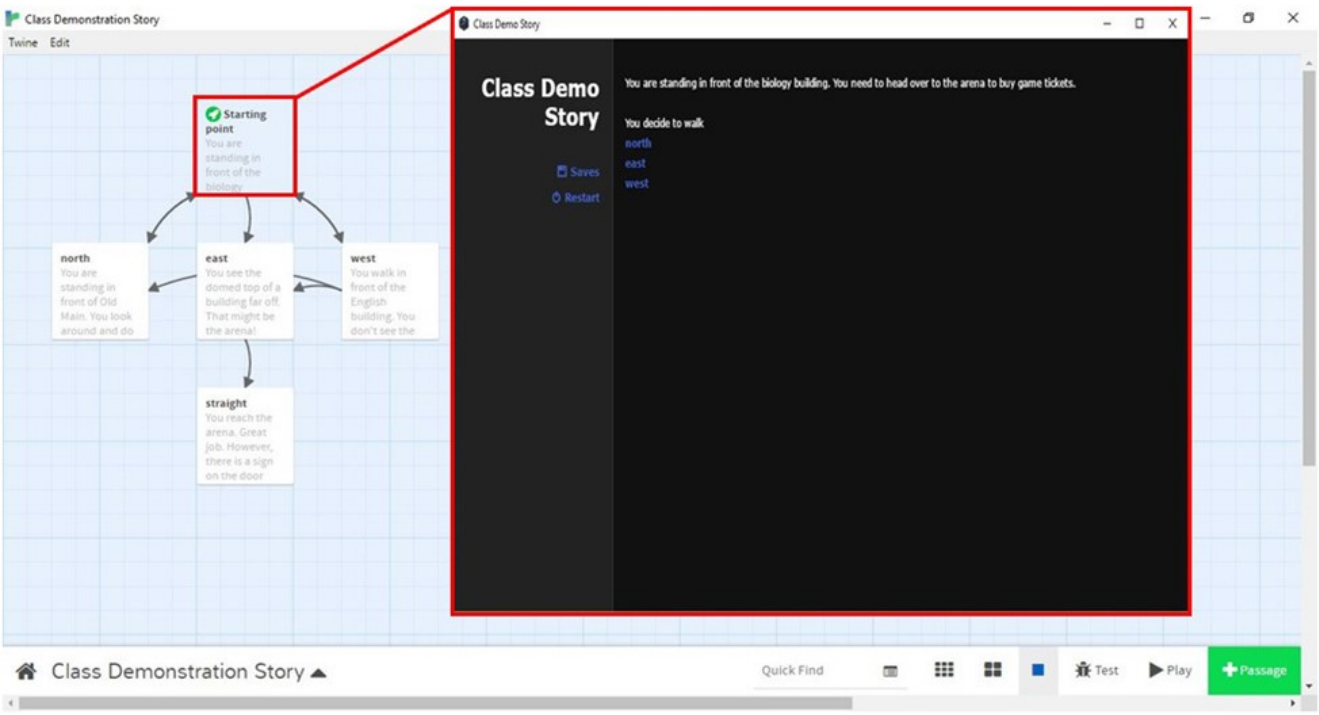

Figure 2. Instructor demonstration of Twine story with game-play mode panel.

Development Block

Following the two-week introductory block, students were instructed to select a topic in microbiology. Microbiology clinical case studies were recommended as a template for their DLG. Students were given the following guidelines on how to make a thorough DLG with Twine.

1. Create a case study or fictional story about a character or characters who contract a microbial disease
2. Give the player options that may be correct or incorrect.
4. Make the incorrect options logical and plausible.
5. Make sure the science is accurate.
6. The length of the game should require a minimum of 5 minutes playtime.
7. Be creative. Your story can take place anywhere and anytime you chose.

After completion of a rough draft, students were introduced to some advanced programming techniques, such as adding images, formatting text, variable and hook markups. These advanced programming techniques were not mandatory for inclusion in their game.

Evaluation

All students in the study were required to read and sign given privacy notices as proof to participate, as per the IRB requirements of the Sam Houston State University. Students were given time during and out of class time to complete the survey, and it is 100% volunteer at the time of this paper. Student Twine DLGs were graded using a 16-point rubric (see appendix A). The course instructor and a blinded independent grader scored the student Twine games.

Pre-and post-surveys were administered to students to assess background and attitudes towards gaming and the DLG project (see Table 1 and Table 2). Surveymonkey.com was used for administration and collection of survey data. This survey received face validation from an expert in the field of Learning Technology at the University of North Texas Dr. Tandra-Wood for the Analysis of Research in Learning Technology PhD course work completed in the summer of 2017. Analysis of all survey questions included

- Correlation/comparison between pre-and post
- Correlation/comparison within post survey: max of 2 comparisons

Twine submissions were graded using a 16-point rubric (see appendix). Twine project grades were averaged into the student's overall course grade.

Results

Final DLG Project Grades

All DLG projects were submitted as an HTML file to the instructor. Projects were scored using a 16-point rubric by the course instructor. An independent blinded grader scored the projects and compared the averages to the instructor's scores. A 2-sample T-test showed no significant difference between the instructor's project averages (μ=15.48, SD=.508) and the blinded grader (μ =15.10, SD=1.45);t=-1.41; p=.168. An example of a high scoring student DLG project, titled "Mrs. Johnson (see Figure 4), was modeled in the story format on traditional microbiology case studies (see Figure 2). The story proceeds briefly in a linear fashion allowing the player to preview Mrs. Johnson's medical records. In the advance story sequences of "Mrs. Johnson" (see Figure 5) the player is given the option of a selected a biopsy and provided the results of a possible infectious

Table 1. *Pre-Survey on Student Background and Attitude Towards Games*

Pre-Project Survey						
1. Age Range						
18-22	23-26	27-30	31-35	36-40	40-45	50+
2. Male or Female						
3. When it comes to learning things I prefer:						
Paper or traditional text	*Digital or online*	*Both*				
4. I play games in such formats as digital, home console, and/or computer games on average per week:						
Never(0 hrs)	*Rarely(1 hr)*	*Sometimes(2-3 hrs)*	*Often(4-5 hrs)*	*Frequently(6+hrs)*		
5. I am confident that I have the problem solving and/or computer skills needed to create a storytelling digital media, to be used to create an online game and/or teaching tool.						
Strongly Disagree	*Disagree*	*Uncertain*	*Agree*	*Strongly Agree*		
6. My learning style(s) percentages are						
Visual	*0-20*	*21-40*	*41-60*	*61-80*	*81+*	
Aural	*0-20*	*21-40*	*41-60*	*61-80*	*81+*	
Verbal	*0-20*	*21-40*	*41-60*	*61-80*	*81+*	
Physical	*0-20*	*21-40*	*41-60*	*61-80*	*81+*	
Logical	*0-20*	*21-40*	*41-60*	*61-80*	*81+*	
Social	*0-20*	*21-40*	*41-60*	*61-80*	*81+*	
Solitary	*0-20*	*21-40*	*41-60*	*61-80*	*81+*	

microbe. The player must decide the morphology of the presented microbe. The student developers used a gaming technique that presents the player with identical story paths regardless of the option selected. This technique allows the player to proceed for some time despite selecting a wrong answer. The player will eventually come to an erroneous conclusion and must backtrack through their options.

Pre-survey Assessment

Students' experience and attitudes of gaming and class instructions were assessed using a pre-project survey (n=36). Responses for Like/Strongly like and Disagree/Strongly disagree were collapsed due to low n. A decision was made to remove two of the questions asked in the survey. The question asking age was removed because only 1 of the 36 respondents was not in the 18-24 age range. Question number two for male or female variable was removed because only 3 of the 36 respondents were male. A factor analysis was run on the 36 pre-survey responses, even though n is below the ideal of 108 responses or 12 responses for the 9 possible variances that remained. The variables used in the factor analysis were 1) Preference on learning; 2) Confidence in problem solving skills to create the Twine; 3) Time spent playing digital games; and 4) Learning styles. For variable 4, the individual learning styles assessed were visual, aural, verbal, physical, logical, social, and solitary. The Oblimin factor analysis reported with a determinant of 0.089. Review of the correlations (see Table 3) show no factors with as correlation of 0.8 or higher, thus no multi collinearities or variables were combined.

A Keiser-Meyer-Olkin measure showed that the relationship strength among the variables was high making the analysis acceptable (KMO=.56). The Bartlett's test of sphericity was significant for correlations in the matrix (χ^2 (74.734), p=.004). Review of the Scree Plot show only the first four (4) components are above the Eigenvalue cutoff value of 1.0 (see Figure 3). To ensure using the most accurate data a Monte Carlo PCA for Parallel Analysis was employed (see Table 4). Results

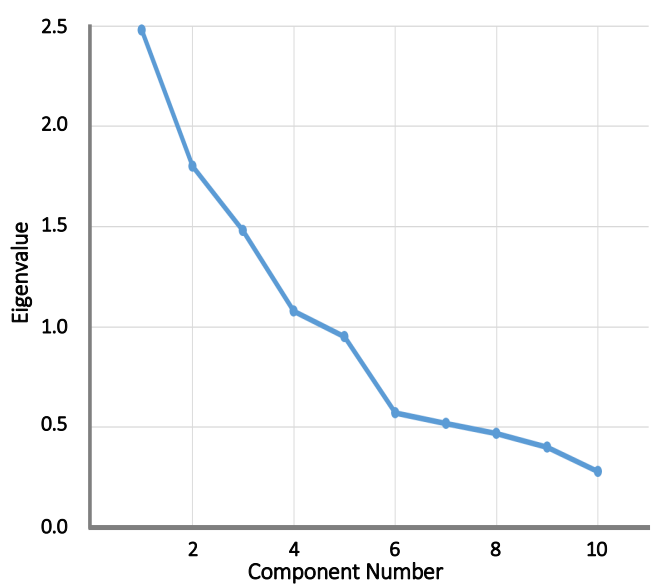

Figure 3. Twine pre-survey scree plot.

Table 2. *Post-Survey on Student Attitudes Towards Games*

Post-Project Survey
I am rating my overall experience using Twine as:
Horrible *I barely survived* *Neutral* *This was fun* *I loved doing it*
I am confident now that I have the problem solving and/or computer skills needed to create a storytelling digital media, to be used to create an online game and/or teaching tool.
Strongly Disagree *Disagree* *Uncertain* *Agree* *Strongly Agree*
My learning style(s) may have an effect on how you did on the Twine project.
Strongly Disagree *Disagree* *Uncertain* *Agree* *Strongly Agree*
5. I am confident that I have the problem solving and/or computer skills needed to create a storytelling digital media, to be used to create an online game and/or teaching tool.
Strongly Disagree *Disagree* *Uncertain* *Agree* *Strongly Agree*
By completing the Twine project, I feel that I have learned more about microbiology (or subject) than I would have if I was doing traditional readings and "pen and paper" assessments like a test or paper.
Strongly Disagree *Disagree* *Uncertain* *Agree* *Strongly Agree*
Teachers using more storytelling digital media like Twine would be more engaging for students and thus learn more.
Strongly Disagree *Disagree* *Uncertain* *Agree* *Strongly Agree*
Suggestion on how to improve the Twine project.

showed that *preference* that they had the problem solving or skills to create the Twine had the greatest effect, followed by item 3- How often in a week do they play games and the learning styles of and item 2- Preference on how they like to learn.

Post survey assessment

An Oblimin factor analysis was run on the post-survey responses (n=48), but the solution could not be rotated. A qualitative approach was used to further extract results. Post survey results showed that 52%(n=25) students had a positive experience using Twine while 12.5% (n=6) students reported a negative experience using Twine. 35.42%(n =17) reported a neutral response to using Twine. For post-project confidence levels 68.75% of students agreed they now have the skills necessary for creating a DLG (n=33) while 10.42% disagreed(n=5). The remaining 10 student respondents were uncertain. 66.67%(n =32) of the respondents agreed they learned more by completing the Twine project than if they had just focused on traditional pen/paper exercises. DLG while 18.75% disagreed(n=9). 60.42%(n =29) of students agreed that they would be more engaged in course material using projects like the Twine while 16.67% disagreed (n =8).

Discussion and Conclusion

The academic potential for digital learning games (DLG) is promising (Miller et al. 2011) . However, when using DLGs in a classroom, students typically assume a passive role of participants. A unique approach to this learning setting by allowing students to become the creator, taking ownership of learning content (Yang & Chang 2013). Students developed their text-based game using Twine, an open source programming software. This study showed that students could successfully create a DLG with minimal programming knowledge. In addition, students responded positively to the experience and challenges of the developing process.

There are many measurable components when introducing a game development project. However, the primary focus of this project was on the creation of the game. This presented a challenge, as the core content of a microbiology class is rigorous. Expecting students to develop computer games in addition to learning science concepts may be overwhelming. Thus, before assessing

Table 4. *SPSS Total Variance Compared to Monte Carlo Analysis*

Component	SPSS Total Variance Explained	Monte Carlo PCA Parallel Analysis
Preference	2.466	1.7913
Confidence	1.824	1.4961
Time Play	1.475	1.3279
Learning styles	1.106	1.165

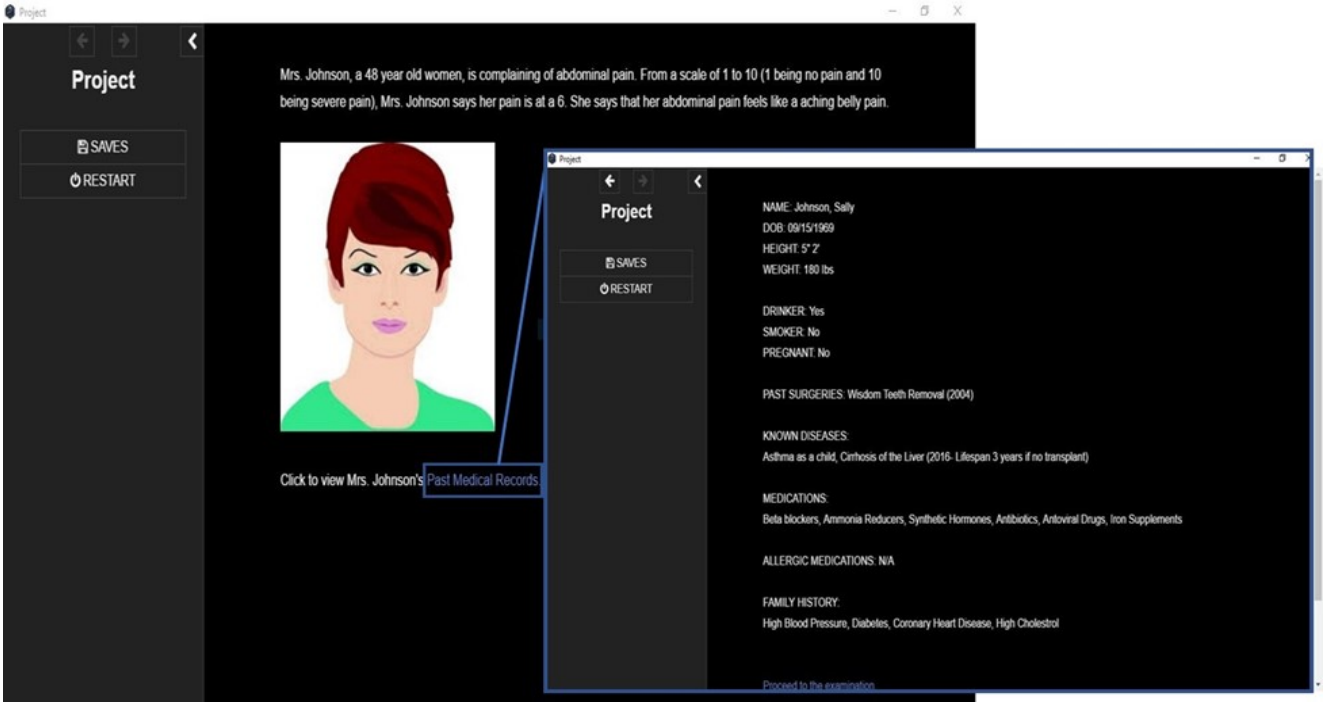

Figure 4. Student DLG project "Mrs. Johnson" opening scene in game-play mode panel.

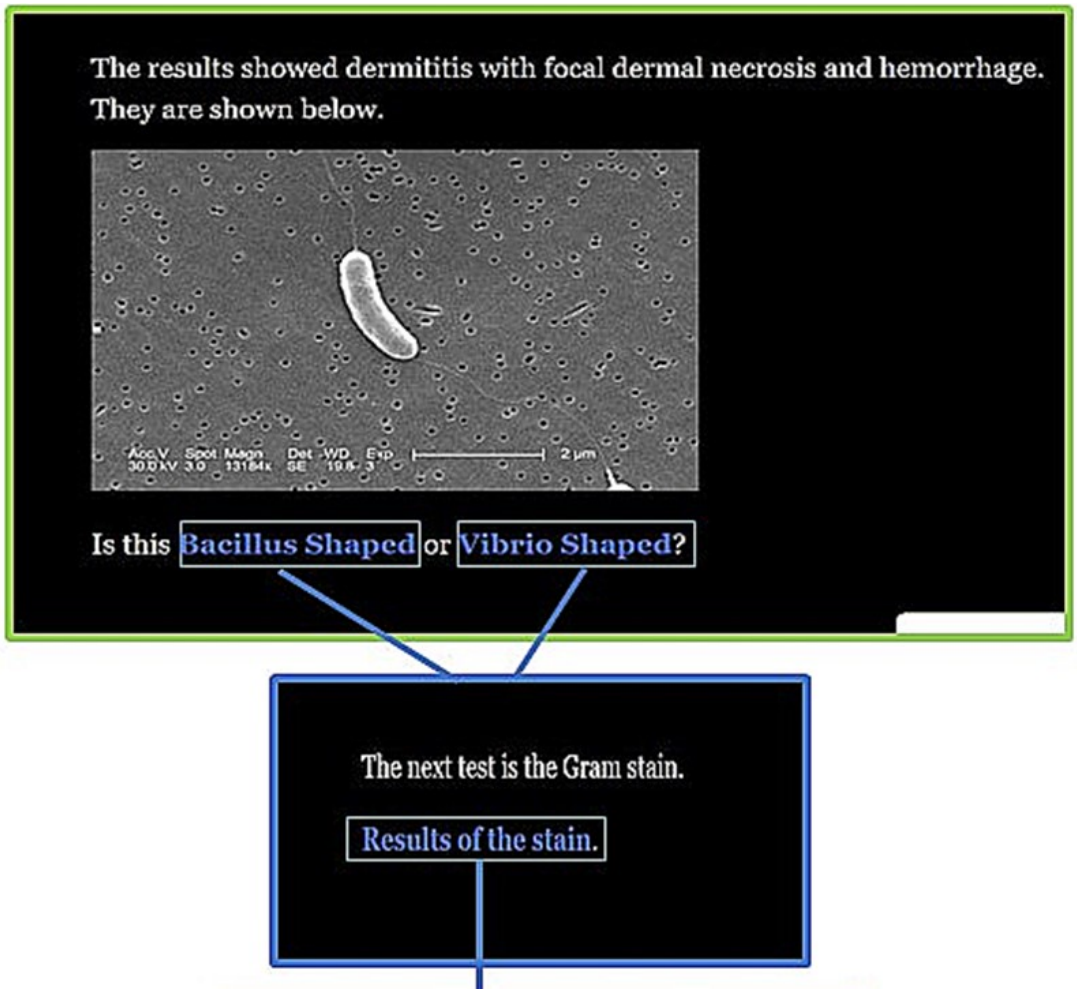

Figure 5. Advance story sequence of student DLG project "Mrs. Johnson." Photomicrograph courtesy of Janice Haney Carr, CDC, Public Image Health Library, 2005.

Table 3 *Oblimin Factor Analysis Results-Pre-Survey Correlation Matrix*

		Prefer to learn	*Confi-dent they can problem solve & make a Twine*	*How often play games per week*	*Visual*	*Aural*	*Verbal*	*Physical*	*Logical*	*Social*
Correlation	*Prefer to learn*	*1.000*	*.205*	*.151*	*.151*	*.041*	*.104*	*-.087*	*.032*	*-.014*
	Confident they can problem solve & make a Twine	*.205*	*1.000*	*-.024*	*-.024*	*-.312*	*.074*	*-.032*	*.255*	*.097*
	How often play games per week	*.028*	*.064*	*1.000*	*.189*	*.035*	*-.125*	*-.156*	*-.081*	*.300*
	Visual	*.151*	*-.024*	*.189*	*1.000*	*.465*	*.009*	*.441*	*.280*	*.335*
	Aural	*.041*	*-.312*	*.465*	*.465*	*1.000*	*-.078*	*.349*	*.070*	*.263*
	Verbal	*.104*	*.074*	*.009*	*.009*	*-.078*	*1.000*	*-.096*	*.190*	*-.209*
	Physical	*-.087*	*-.032*	*.441*	*.441*	*.349*	*-.096*	*1.000*	*.460*	*.162*
	Logical	*.032*	*.255*	*.280*	*.280*	*.070*	*.190*	*.460*	*1.000*	*.216*
	Social	*-.014*	*.097*	*.335*	*.335*	*.263*	*-.209*	*.162*	*.216*	*1.000*
	Solitary	*-.079*	*-.137*	*.288*	*.288*	*.214*	*.396*	*.322*	*.486*	*-.199*

improvements in content learning and critical thinking, it is important to show that students could successfully create a DLG. Success was defined as accurately applying learned science concepts in an instructional and creative context. The class average for the projects were above 90%. This average was consistent in comparison to a blind grader independent from the course.

Preconceived student attitudes of technology may affect their motivation and experience in the project (McParland et al. 2004; Liu 2007). Pre-survey results showed that learning preferences had the greatest effect on project attitudes and abilities. Interestingly, students did not favor a specific style of learning in comparison to other styles. A majority preferred a mixture of traditional and digital strategies. This response illustrates the problems of exclusive incorporation of a learning strategy. Relying solely on digital or traditional means may discourage student motivation and participation (McParland et al. 2004; Liu 2007). The final component affecting attitudes was time engaged in digital games. Students reported spending less than two hour a week with digital games. We expected a higher response of engagement factoring in the popularity of digital games. This may explain the challenges we experienced when promoting the dynamics of DGL to the students.

Another component affecting project attitude and ability was confidence levels. This was expected as creating a digital game might require unique problem-solving strategies. Composing non-linear stories may be a unique skill unfamiliar to many. Students were asked how confident they were in problem solving and computer skills. Over 50% of the students were uncertain or disagreed that they had the skills necessary to create a digital game in the pre-survey. These responses further emphasize the importance of selecting game software with minimal programming knowledge.

Following completion of the project students were administered a survey to reflect on any changes in attitude and perception toward creating a digital learning

game. Over 50% of the students responded having a positive experience developing their game. No specific variable, such as confidence or game exposure, as being a major factor in their positive response. Students previously reported confidence concerns in creating a DLG. Upon completion of the project, approximately 68% reported an increase in confidence. Despite such a high response, this was not a significant change compared to pre-project confidence levels. One possible reason is that approximately 40% of students reported some confidence in in their abilities before the start of the project. A larger and more consistent survey response may support a significant increase in confidence.

A project requiring students to create a digital learning game can be a daunting proposal. There is risk in compromising the core intent of the class for demonstrations in game development. Twine is attractive for its ease of programming and self-directed tutorials. This benefits not only student, but also instructors who may have little experience in game development. For this unique project, students assumed an active role in development of educational media, applying learned material and claiming authorship of a digital game. The next phase of this project will examine changes in students' problem skills following development of a Twine DLG. These skills are critical for experimental design, as multiple outcomes must be accounted for. Incorrect conclusions or design flaws must be linked back to the source of error with selection of correct procedures. Twine DLG may provide a unique platform for developing the skills needed for laboratory experimental design.

References

Blumberg FC, Rosenthal SF, Randall JD. (2008). Impasse-driven learning in the context of video games. *Computers in Human Behavior*, 24(4), 1530-1541. . doi:10.1016/j.chb.2007.05.010.

Breuer JJ, Bente G. (2010). Why so serious? On the relation of serious games and learning. *Eludamos Journal for Computer Game Culture, 4*,7–24. doi:10.1177/1461444812450426.

Butler YG, Someya Y, Fukuhara E. 2014. Online games for young learners' foreign language learning. *ELT Journal, 68,* 265–275. doi:10.1093/elt/ccu008.

Carolyn Yang YT, Chang CH. 2013. Empowering students through digital game authorship: Enhancing concentration, critical thinking, and academic achievement. *Computers & Education, 68,* 334–344. doi:10.1016/j.compedu.2013.05.023.

Chen SY, Huang PR. 2013. The comparisons of the influences of prior knowledge on two game-based learning systems. *Computers & Education,68*, 177–186. doi:10.1016/j.compedu.2013.05.005.

Coffield F, Moseley D, Hall E, Ecclestone K. 2004. Should we be using learning styles?: what research has to say to practice/Frank Coffield...[et al.]. voced.edu.au.

Curry L. (1990). A Critique of the Research on Learning Styles. *Educational Leadership*. 48(2),50-56.

Garris R, Ahlers R., Driskell, J. (2002). Games, motivation, and learning: A research and practice model. *Simulation & Gaming, 33*(4) ,441-467.

Halpern DF, Millis K, Graesser AC, Butler H, Forsyth C, Cai Z. (2012). Operation ARA: A computerized learning game that teaches critical thinking and scientific reasoning. *Think. Ski. Creat. 7,*93–100. doi:10.1016/j.tsc.2012.03.006. [accessed 2015 Aug 21]. http://www.sciencedirect.com/science/article/pii/S1871187112000235.

Klimas C. (2009). https://www.twinery.org

Kolb AY, Kolb D a. (2005). Learning Styles and Learning Spaces : Enhancing Experiential Learning in Higher Education. *Academy of Management Learnng & Education, 4*,193–212. doi:10.5465/AMLE.2005.17268566.

Liu Y. (2007). A Comparative Study of Learning Styles between Online and Traditional Students. *Journal of Educational Computing Research, 37*,41–63. doi:10.2190/TJ34-6U66-8L72-2825.

McParland M, Noble LM, Livingston G. (2004). The effectiveness of problem-based learning compared to traditional teaching in undergraduate psychiatry. *Medical Educator*. *38*,859–867. doi:10.1111/j.1365-2929.2004.01818.x.

Miller LM, Chang CI, Wang S, Beier ME, Klisch Y. (2011). Learning and motivational impacts of a multimedia science game. *Computers & Education, 57*,1425–1433. doi:10.1016/j.compedu.2011.01.016.

Morris BJ, Croker S, Zimmerman C, Gill D, Romig C. (2013). Gaming science: the "Gamification" of scientific thinking. *Frontiers in Psychology*,*4*,607. doi:10.3389/fpsyg.2013.00607. [accessed 2015 May 24]. http://www.pubmedcentral.nih.gov/articlerender.fcgi?ar-tid=3766824&tool=pmcentrez&rendertype=abstract.

Orvis KA, Horn DB, Belanich J. (2008). The roles of task difficulty and prior videogame experience on performance and motivation in instructional videogames. *Computers in Human Behavior, 24*,2415–2433. doi:10.1016/j.chb.2008.02.016.

Ravenscroft A. (2007). Promoting thinking and conceptual change with digital dialogue games. *Journal of Computer-Assisted Learning23*,453–465. doi:10.1111/j.1365-2729.2007.00232.x.

Triantafyllakos G, Palaigeorgiou G, Tsoukalas IA. (2011). Designing educational software with students through collaborative design games: The We! Design&Play framework. *Computers & Education, 56,*227–242. doi:10.1016/j.compedu.2010.08.002.

Wang M, Wu B, Kinshuk, Chen NS, Spector JM. (2013). Connecting problem-solving and knowledge -construction processes in a visualization-based learning environment. *Computers & Education*, *68*,293–306. doi:10.1016/j.compedu.2013.05.004.

Wilson KA, Bedwell WL, Lazzara EH, Salas E, Burke CS, Estock JL, Orvis KL, Conkey C. (2009). Reltionships Between Game Attributes and Learning Outcomes. *Simulation & Gaming 40,*217–266. doi:10.1177/1046878108321866.

Zaphiris P, Ang CS, Law D. (2007). Individualistic versus competitive game-based e-learning. *Adv. Technol. Learn. 4:*206–211. doi:10.2316/Journal.208.2007.4.208-0921.

Appendix

DLG Project Rubric

	1	2	3	4	*Total*
Accuracy	The science was not accurate. Explanation and use of concepts were full of errors.	The science was somewhat accurate with some concepts used or explained with error.	The science was mostly accurate with few concepts used or explained with error.	The science was accurate with no concepts used or explained with error.	
Originality	The story lacked any originality. The story did not follow the nonlinear format in a creative manner.	The story was somewhat original. The story somewhat followed the nonlinear format in a creative manner	The story was mostly original. The story mostly followed the nonlinear format in a creative manner	The story was very original. The story completely followed the nonlinear format in a creative manner	
Instructive	The story did not instruct nor educate the reader.	The story somewhat instructed or educated the reader.	The story mostly instructed or educated the reader.	The story was very educational and instructional for the reader.	
Grammar	The contained too many grammatical errors.	The story contained some grammatical errors.	The story contained few grammatical errors.	The story contained no grammatical errors.	