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A Game-Based Approach to Information Literacy and Engineering in Context

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***Abstract*— Engineering students need complex skills to be effective in college and post-graduate employment. Beyond technical skills, the ability to integrate varied types of information is essential for competence in applying engineered solutions to real-life situations. While research shows that project-based learning favorably affects engineering student success and retention as well as recruitment of diverse populations to STEM, it is challenging to find ways to incorporate projects during the first two years, where in the U.S. general education requirements typically precede major course work. As a work in progress, we report on the first phase of an experiment at Worcester Polytechnic Institute (WPI) using a sophomore-level humanities course to teach information literacy. Students develop a pedagogical role-play game to explore a historical situation simulating engineered solutions. The game offers the advantages of project-based learning within a traditionally framed classroom environment, and before students address complex engineering problems within their major areas of study. To assess the effectiveness of our educational approach we reviewed the quality and type of sources located by students and completed a textual analysis of students' reflective essays. Through game development, students effectively located information, and saw value in the research skills they gained.**

Keywords*— *pedagogical games, project-based learning, professional skills, information literacy, role-playing, simulations

I. INTRODUCTION

At Worcester Polytechnic Institute (WPI) in Worcester Massachusetts, U.S.A., which operates on a quarter system, all students must complete a 7-week humanities and arts project regardless of their intended major. Since the majority of students at our institution major in engineering or applied science disciplines, many humanities faculty offer courses in which students can critically reflect on the culture of science and engineering and its various impacts. In an effort to engage engineering and applied science students with historical content relevant to their fields of study, we developed a capstone humanities course entitled "Worcester, 1899." Within the course 12 students worked as a team to create a classroom-based role-play game in which future players (at WPI or other institutions, including high schools) would engage with a deeply contextualized engineering problem. We were inspired to design this game for two reasons: first, we wanted to see how centrally we could involve humanistic approaches in a pedagogical game that was thematically about solving an engineering problem; and second, because research suggests that in the first two years of college, engineering students are at high risk of attrition to other majors since they are not typically allowed to "get their hands dirty" playing with the tools necessary for engineering career success. We thought a classroom simulation might be able to address both concerns. Fundamental to a student's success in development of this role-playing game are the skills we call information literacy: the ability to find an appropriate variety of sources, evaluate them, and incorporate them into a project, report, or other assignment [1]. Unlike many other role-playing pedagogical games, which provide materials and make students responsible for reading, interpreting, and making decisions and arguments based on these materials, our game is designed to leave much of the responsibility for finding and assessing information to the students playing the game, and to motivate their research with questions that must be answered satisfactorily in order to win the game. Information literacy pertains to several ABET student outcomes (ability to "analyze and interpret data," "engage in lifelong learning") and is acknowledged as important to successful college-level academic project work. Recent research has shown the value of research skills for engineering students in particular [2]. While there are a number of challenges to teaching information literacy as part of the college curriculum, research suggests that faculty-librarian collaboration can be effective in creating assignments and class plans to teach these skills [3,4].

II. BACKGROUND

To graduate from WPI, all undergraduates, regardless of major, must complete a Humanities and Arts (HUA) requirement consisting of 5 courses in the humanities and arts and clustered around a particular discipline or thematic focus of the students' choosing, followed by a project relating to that focus. WPI's academic schedule consists of four 7-week terms per year. In the fall of 2013, we advised an HUA project team developing the basic structure for a role-playing game based on Worcester in the year 1899. Students were charged with identifying a particular thematic focus for their game, as well as game components and character roles. The students who

enrolled had completed courses within a variety of humanities disciplines and sub-disciplines: 19th-century history, labor history, history of science and technology, writing, creative writing, and philosophy. Their majors included computer science, civil engineering, electrical engineering, mathematics, mechanical engineering, and biology. They were asked to identify a historically authentic, complex problem that combined technological and cultural concerns. They chose Worcester's decision late in the 19th century to implement one of the country's first separated sewerage systems. The student project team developed the basic game structure, rules of play, historical context, and some provisional character roles.

The game they designed, titled "Worcester, 1899: The Sanitary Engineering Challenge," calls for players to assume the roles of various historical or fictional characters associated with Worcester's decision to build this separated sewerage system. As they debate how best to solve Worcester's sewage crisis and the pollution of the Blackstone River, students also must consider the probable economic disruption of a massive engineering project and labor concerns in an industrial city. To play their roles well, they not only read source materials supplied by game developers, but they must also seek additional information via historical records and online databases.

When we began the student project that initiated the development of this game, we imagined that the final product would resemble many other role-playing pedagogical games in that student players would be provided with historical and technical information discovered by the game developers. In this way, there would be no explicit information literacy component to the final game. However, as we watched our students develop and test-play their game, it struck us that they were engaging in meaningful and unconventional research: framing their own research questions, seeking a variety of primary and secondary sources including those written for technical as well as popular audiences, even consulting area archives, analyzing their sources, and discriminating among them. Most startling of all, they were enjoying the process. Knowing the challenges of teaching information literacy in the context of engineering classes, we thought we had stumbled upon something valuable. The experience and the data we collected and reviewed made us rethink the design of the game and seek to preserve the information literacy component at all costs.

Although we are working with our students toward developing a final role playing game (the *product*), our discussion here concerns the *process* of game development we observed during this first phase.

III. Literature Review

As Bower et al. explain, the effectiveness of games and simulations in educational contexts is well documented and includes enhanced student engagement, effective replacement for projects that extend beyond classroom walls, effectiveness in representing complex subjects, application to authentic situations, and packaging of complex ideas into a consistent narrative [5]. Bower's Brownfield Action simulation successfully teaches diverse problem-solving skills from a variety of disciplines, putting "content into motion as it is actually used in the real world."

The inspiration for the role-playing feature of this game is the "Reacting to the Past" (RTTP) series pioneered by Mark Carnes, a Barnard College historian, and now expanded into a consortium and taught in many colleges and universities. The RTTP website describes RTTP as consisting of "elaborate games, set in the past, in which students are assigned roles informed by classic texts in the history of ideas. Class sessions are run entirely by students; instructors advise and guide students and grade their oral and written work. It seeks to draw students into the past, promote engagement with big ideas, and improve intellectual and academic skills."

Although these games are becoming popular in liberal arts classrooms, their applicability to the fields of science and engineering has yet to be fully explored. Two full-length RTTP STEM games have been published as books [6]. Two other full-length games are in development: Acid Rain in Europe, 1979-1989; and Kansas 1999. In addition, ten chapter-length RTTP STEM games are in development. Museums have also pioneered interactive exhibits for teaching STEM in context [7]. Although it may seem pointless to take prospective engineers back in time to consider historical engineering decisions, this approach underscores for students the importance of social factors in shaping technical outcomes. Often the historical forces of our own age are invisible to us; young people in particular can regard these circumstances —if they think of them at all— as inevitable, timeless, and therefore irrelevant to technical matters. If one of the challenges in engineering education is this tendency to see the technical disciplines as detached from social and political influences, then by handing students an engineering problem from an unfamiliar historical era, we foreground exactly these influences.

IV. Methods of Research Instruction

To introduce students to archival and online research, we set up early library and archive learning sessions. Our class had its second meeting at the American Antiquarian Society (AAS) in Worcester, which houses a massive collection of printed and manuscript materials from Worcester's colonial, early republican, and industrial ages. In preparation for this session, students read the "Retrospective of the Year 1899" from *Scientific American* (1900) and conducted an interview with an engineering or science professor to learn as much as they could about the state of that person's discipline in 1899, then outlined possible historical events or characters that could be linked to that discipline. Finally, they each signed up for an online account at the AAS, browsed the collection, and requested at least one source from the AAS, to be picked up on the day of our class session. A tour of the archives by an expert archivist familiar with our class project ended in the reading room, where students were able to browse the materials they had requested.

The next class session was held at WPI's library. In preparation for a research librarian-led orientation to the

library, students were asked to identify and read at least one article from a professional journal of 1899, one other primary source, and one secondary source. The initial research instruction session lasted 50 minutes and was held in a computer lab where hands-on searching was possible. Our objectives for this session were for students to

- understand how historians do research;
- understand the importance of finding a variety of information sources, including but not limited to newspapers and magazines, technical reports, and government documents; and,
- know how to find and effectively search specialized research databases, such as Engineering Village and JSTOR, to find historical technical documents and records.

We set up an online research guide for the students that can be accessed at http://libguides.wpi.edu/Worcester1899. This guide contains links to research databases as well as information about primary and secondary sources within the discipline of history. Over the course of the 7-week term, the twelve students viewed the guide 323 times, and clicked through 27 resources a total count of 186 times.

V. Assessment Methods

In addition to identifying a historical controversy from 1899 that included technical and social components, and developing a game design to foster competition and compromise, students were required to identify two common readings for all game players. Each student also developed two distinct character roles, providing one or two individual readings for each. We reviewed the information sources they chose for the 24 character roles and analyzed the citations for quality and variety. We based our citation assessment loosely on methods reported in a number of studies completed in recent years that have focused on ways to authentically assess information literacy skills outcomes of undergraduates [8-11].

In addition, we qualitatively assessed information literacy skills by reviewing self-reflective student essays. This assessment was inspired by the work of researchers investigating professional competencies in engineering education through assessment of student portfolios and reflective writing [12]. At the end of our 7-week course each student submitted an essay describing the specific tasks involved in developing a game, then interpreting his or her work and describing its outcomes. Students were asked to reflect on the most important or useful features of their work designing a game, explain their rationale for choosing the subject and characters they did, describing and explaining an interpretive decision they made in the process, and reflecting on the process of collaboration and compromise as they worked on a team. They were also asked to reflect on their own learning as developers of the game: what they learned in the process, which abilities they developed particularly well, which they did not develop to their satisfaction, and how the final game represents particular competencies they learned or strengthened as they designed the game.

VI. Results

The results of our two-tier assessment suggest that students were able to locate a variety of high quality primary and secondary source materials, and that they felt the research skills they gained were an important outcome of their learning. For our citation analysis we reviewed the sources students chose as part of the 24 character profiles they created for game play. Table I provides a breakdown of the types of sources located and the number of each type across the 24 character profiles. For the purpose of this assessment, primary literature is being defined as information sources produced at or around 1899. Secondary literature refers to works completed 25 or more years after that date. Students identified a total of 42 unique sources, with each character role sheet containing between 2 and 5 recommended readings for future players, not all of which were unique between characters. Possible future work would be to require that students categorize their own sources, provide more complete citation information, and briefly describe how they found their sources (e.g. library databases, visits to archives, web searches, etc.)

TABLE I.

Distribution of Source Types	
Primary: scholarship, non-technical	10
Primary:scholarship, technical	8
Primary:government publications	4
Primary:popular magazines and newspapers	4
Primary: other (popular books, letters, ephemera, etc.)	9
Secondary: Scholarship, non-technical	3
Secondary: non scholarly	4
TOTAL Sources	42

After examining sources that students recommended, we reviewed the 12 reflective essays to better understand what they learned and how they valued it. In particular, our review focused on information-seeking competencies; what is notable is that students were not asked explicitly to reflect on their information seeking, and yet many provided rich narratives discussing how they sought information and the value they saw in the process. Their comments gave us a window into their thought process as they chose readings for their characters. Several themes related to information literacy emerged. In addition to 4 students noting that the information seeking process was the most important aspect of the project and game development, the following were the most significant indications that students found the research process critical to their work

- 7 students provided specific reflections indicating their ability to critically evaluate and use information sources to make decisions.
- 10 students described the process of finding information and its importance to the process of game development.

- Perhaps most significantly for potential impact on lifelong learning, 4 students, unprompted, explicitly indicated that they are using or plan to use these research skills in applications beyond this class.

VII. Discussion

Unsurprisingly, we were reminded that student engagement in class activities results in more successful learning outcomes; in this case, the novelty of inhabiting a role (even for students who described themselves as shy), the recognition that they could win or lose according to how well they conducted and evaluated research, and the general interest of the historical debates over pollution and its mitigation contributed to an engaging learning environment where students were motivated intrinsically rather than by course grades. The controversy over clean water, which had in fact absorbed the people of Worcester County for decades, was an authentic and meaningful topic for our students.

This meaning endured even across several discontinuities. The context of the game, and the timeframe of the sources students consulted, was the late 19th century. Thus, the technical reports and scientific data were all out of date relative to the other preparations these students were making for their careers. And this was a history course, the capstone course in WPI's HUA requirement; thus, students were unlikely ever to take another humanities course. Nevertheless, they regarded the skills they learned as transferable to situations outside this course and the discipline of history. One student noted that he was already using his newly developed research skills to complete work for the senior level civil engineering team project required for graduation. Three of several noteworthy student comments referring to skills gained through game development are:

- I hope I am able to use the research skills I developed […] in future studies, whether they be historical or in another discipline.
- […] the skills I have developed throughout the past 7 weeks have better prepared me to enter the professional world.
- I was particularly pleased with what I've learned about scholarly research in general.

In addition to research skills gained, students also mentioned development of critical thinking and communications skills that we might investigate in future work.

VIII. Future Work

We plan to spend the next year developing additional roles and assignments and refining the game system to better incorporate learning, competition, and play. In particular, we plan to give students more explicit instructions about the variety and number of sources they must find; then we will more systematically evaluate their work, using blind reviewers to categorize and count their sources. At the end of the year we will prepare the game for beta-testing in one first-year class at WPI and one local high school. We will perform a citation analysis at the end of each class to determine how well students have learned information literacy skills.

Finally, we are also developing other course modules (ethics and computational literacy) for use within this same game. Our goal is for teachers from different disciplines to be able to adapt the game for their various curricular uses.

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[7] In our city of Worcester, for instance, an NSF-funded project at the Ecotarium, *From the Lab to the Neighborhood: An Interactive Living Exhibit for Advancing STEM Engagement with Urban Systems in Science Museums* integrates urban ecological research into the museum exhibit, City Science.

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