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ORIGINAL RESEARCH

Supporting Project-Based Learning Through the Virtual Internship Author (VIA)

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Abstract

Researchers suggest that solving ill-structured problems using project-based learning approaches is one way to engender STEM learning outcomes. However, project based learning poses unique challenges in practice, including the translation of technical information, design of scenarios, facilitation of instruction, and management of student collaborations. This process is often time-consuming and inefficient for teachers. To address this issue, virtual internship author is a learning environment designed to support the design, development, and facilitation of STEM based project-based implementations. Specifically, the software is designed to scaffold (a) the instructional design process and (b) the facilitation of project-based learning. The software thus supports multiple stakeholders required for a successful project-based learning initiative, such as subject-matter experts, teachers, and students. Furthermore, the software employs unique strategies, including pre-scripted feedback, conversational agents, and latent semantic analysis to scaffold open-ended discourse during collaborative problem solving. Implications for practice are also discussed.

Keywords Project-based learning · STEM · Internship · Latent semantic analysis

1 Introduction and Description of the Emerging Technology

1.1 Project-Based Learning and Next Generation Science Standards

Educators increasingly implement project-based learning as a way to support higher learning (Herrington and Reeves 2017) and provide learners an opportunity to solve

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contextualized problems that are representative of the types of problems that practitioners solve (Chu et al. 2017; Wijnia et al. 2014). This project-based approach aligns well with the push towards Next Generation Science Standards (NGSS), which emphasize disciplinary core ideas; application of science, technology, engineering, and mathematics (STEM) practices; and an emphasis on interdisciplinary learning. Specifically, the approach calls educators to utilize problem-solving opportunities and "behaviors that scientists engage in as they investigate and build models and theories about the natural world and the key set of engineering practices that engineers use as they design and build models and systems" (NGSS Lead States, 2013, para 2). In many instances, learners are tasked with collaborative inquiry of the problem and conceptual space as they proffer hypotheses, ask meaningful questions, engage in causal reasoning, among others (Hmelo-Silver 2013; Lazonder and Harmsen 2016). Indeed, the three core dimensions of the NGSS (practices, crosscutting concepts, and disciplinary core ideas) align with both well-structured and ill-structured problems posed in inquiry-based learning.

Despite the benefits of NGSS and project-based learning, research findings suggest these instructional strategies pose unique challenges within classroom settings. Specifically, educators often need to design their curriculum for inquiry-based learning by (a) retrofitting existing materials that may or may not align with the problem or (b) develop new materials. There is a persistent concern that the new resources do not align with existing materials, which is problematic for scaffolding alignment and curriculum planning (deChambeau and Ramlo 2017; Tamim and Grant 2013). Furthermore, the process of creating materials from scratch requires a significant time investment as educators outline objectives, identify gaps in prior knowledge, design the problem, and gather information resources from various venues (Wijnen et al. 2017). As such, this initial time investment serves as a barrier for effective project-based learning implementation (Ertmer and Ottenbreit-Leftwich 2013; Park and Ertmer 2007).

1.2 Virtual Internships as Apprenticeship Models

In addition to the need to modify and develop new materials, the students who participate in project-based learning and problem solving are often novices. Indeed, turnover of participants in a team or organization is ubiquitous in the real world. When a new person joins a team or organization, the person normally goes on an internship that is guided by one or more mentors and that exposes them to the diverse stakeholders and activities of the team(s). This takes substantial training and normally follows a one-on-one apprenticeship model (Brown et al. 1989) or a more structured internship plan with a sequence of pedagogical activities. Unfortunately, bringing in a new member to a team can substantially tax the team members who are busy making progress on completing their tasks. The question therefore arises how technology can play a role in internship training.

Shaffer and his colleagues have conceptualized "virtual internships" as one approach to providing internship training to small groups of 3–5 new members (Bagley and Shaffer 2015; Shaffer 2017). One example of this is their *Land Science* educational simulation, where students role-play as interns in a hypothetical company, an urban and regional planning firm called Regional Design Associates. The students work on using a land use plan for the city of Lowell, Massachusetts, in response to a fictitious request from the mayor. They spend 10–12 hours working in teams through a web-based on-line platform. Email and chat are used to communicate with each other and with characters in the simulation, mentors, supervisors, and stakeholders in the city. Coming up with a plan to resolve the ill-structured problem requires them to consider ecological and social issues, such as housing, jobs, air pollution, and chemicals in a river. The construction of a plan also requires them to balance the needs of different stakeholder groups with very different points of view. The interns justify their proposals by reading digital information resources and examining a digital map with zones of Lowell. During the course of these internship activities, the interns learn about urban planning, different stakeholders, collaboration, and details about Lowell.

The virtual internship developed by Shaffer is a novel technological advance in project-based learning and problem solving because it does not take up valuable time of team members who need to perform bona fide work. Moreover, a single mentor can monitor and influence 3–4 teams of 3–5 interns at a time; the mentor inspects the chat and products of each team and team member and intervenes with chat contributions to help them when they are off track or stuck. This is an efficient use of mentor time and minimizes costs of expensive mentors.

It took a long time, measured in years, to build Land Science and other similar virtual internships developed by Shaffer and his colleagues. Meanwhile, changes to Lowell have required modification to Land Science. That requires changes to the materials, so authoring tools are increasingly needed to accommodate those changes. Moreover, a significant number of colleagues have wanted to build a Land Science for their own region or town. One way to support scale and adoption is to modify Land Science and substitute digital resources about their own home town. Another approach is to create their own virtual internship from scratch. All of these activities require authoring tools that are sufficiently well designed so that a person can use the tools with a modest knowledge of computer programming and software engineering (Graesser et al. 2018b).

1.3 Virtual Internship Author Overview

Technology is often used to support project-based learning, but these are often implemented in a piecemeal approach. That is, educators design the problem and leverage resources such as commercial wikis (Chu et al. 2017; Ioannou et al. 2015), existing online videos (Lajoie et al. 2014), and integrate them within their existing learning management systems. When the technology is not designed to support project-based learning, this piecemeal approach is problematic because the assembly from different mediums may not align with the instructional strategies needed to successfully support effective instruction. To address this issue, Virtual Internship Author (VIA) was design as an as an online platform for (a) subject matter experts to author project-based learning lessons (b) mentors or teachers to facilitate problem-solving and (c) students to engage in learner–learner interaction (Bagley and Shaffer 2015; Graesser et al. 2018a, b). Specifically, the system employs an internship and mentor strategy, while also providing the necessary authorware for subject matter experts to design problems (see Fig. 1).

In one designed STEM lesson (LandScience) in VIA, learners are tasked with taking on the role of interns within a regional planning firm (see Fig. 2). The module requires learners to rezone an area given the concerns of stakeholders in the business, environment, and housing sectors. As with any ill-structured problem, learners must navigate the perspectives and concerns as they engage problem representation and solution generation (Ge et al. 2016; Reed 2016). In terms of instructional design, various supports are embedded in VIA for subject matter experts to upload their materials and scaffold student learning. For the LandScience lesson, interactive interface tools such as map creation and adaptive

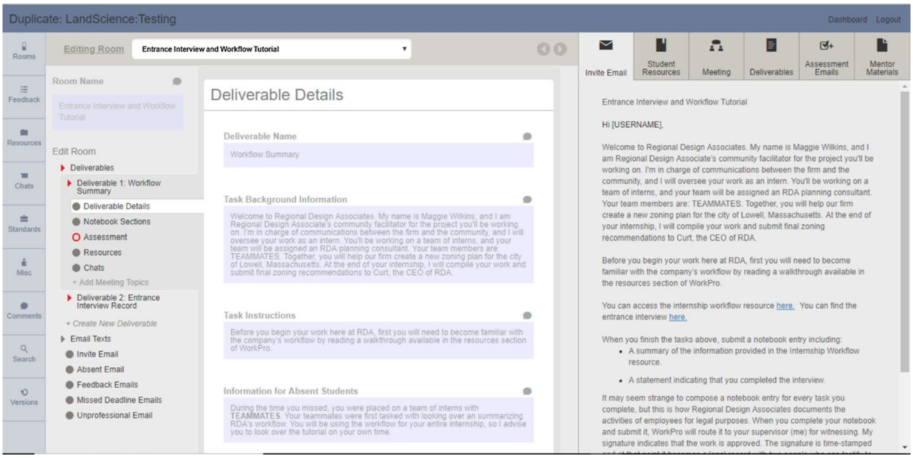

Fig. 1 Subject-matter expert input of materials

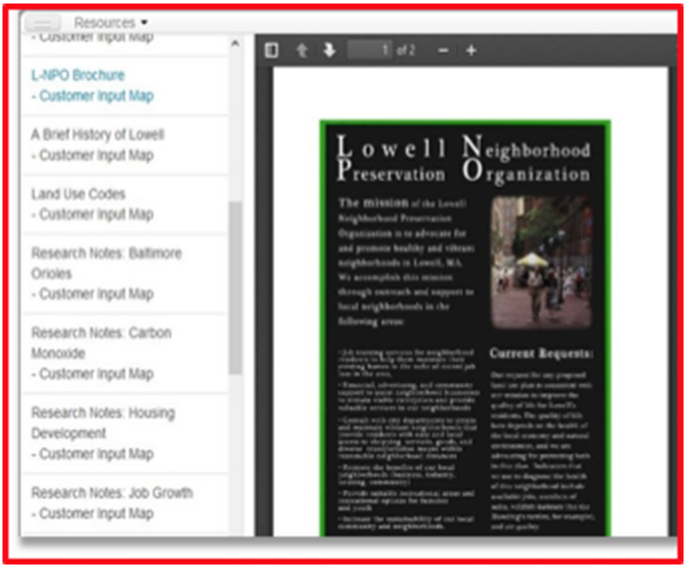

Fig. 2 LandScience scenario presented in VIA

adjustable scales are available to model acquired knowledge ideas for problem solving (see Fig. 3). Learners are also provided stakeholder preference surveys, which allow them to engage in data collection and analysis.

VIA works well with project based learning techniques and has additional features that support enhancing student's collaborative problem solving and communication skills (Graesser et al. 2018a, b). Specifically, the VIA tool allows the instructor to develop separate chat rooms, with each having its unique goals and objectives. In doing so, learners progress through the curriculum and problem-solving processes with their peers in these

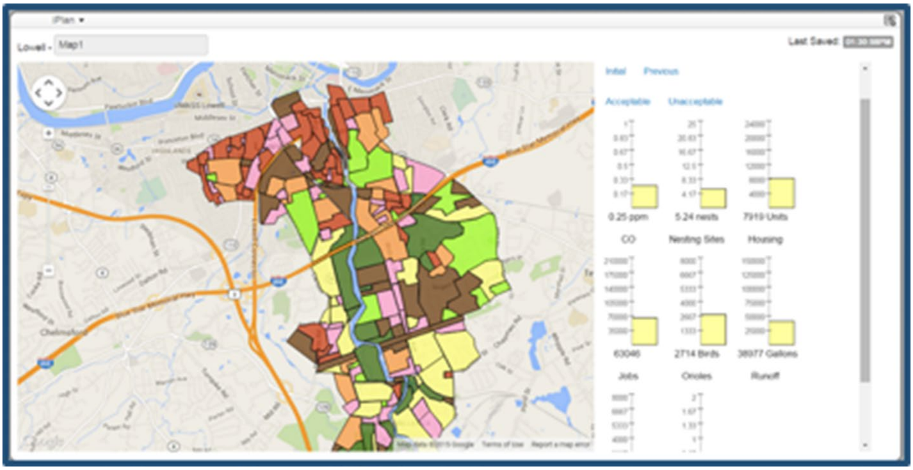

Fig. 3 Interactive map tool

partitioned rooms within the learning environment. Using synchronous communication allows for easy sharing of information and questions, which further help students to establish their collective understanding of the problem space. Finally, students are also given individual attention with private instructor chat forums, which streamlines question-asking. Chat forums can have different sources and recipients of the communication student-student, student-group, student-instructor, instructor-group, and instructor-class (see Fig. 3).

2 Relevance for Learning, Instruction, and Assessment

2.1 STEM Learning and Internships

VIA addresses the need for increased learning outcomes for STEM disciplines in multiple ways. While educators stress the importance of STEM and problem-solving, researchers have identified a number of challenges with its implementation (Hung 2015). For example, studies have shown low interest in the subject matter (Metcalf 2010). This is problematic given that additional research finds that students in the United States are not prepared for the technological future of the twenty-first century (Greiff et al. 2017; Levy and Murnane 2004). Given this need, many argue that proficiency in STEM-based activities is important for the long-term economic health of a country (Cannady et al. 2014). In parallel with the increased emphasis on STEM, schools are increasingly exploring ways to effectively integrate STEM within the classroom (Belland et al. 2017; deChambeau and Ramlo 2017). Technologies afford additional opportunities for collaborative problem-solving, which allows learners and their peers to share ideas, encounter new perspectives, and negotiate new knowledge as they solve STEM problem (Graesser et al. 2018a, b; Lucas et al. 2014).

There are two unique aspects that make the VIA project unique in terms of learning: (a) scaffolding instructional design and (b) utilization of internships as instructional strategies. As noted earlier, the latter (internships) is based on research that finds learners who participate in internships are more likely to attain full-time employment upon graduation

(Gault et al. 2010). This also aligns well with the situated learning theory perspective that is often cited in project-based instructional strategies (Brown et al. 1989; Jonassen 1997). In that vein, VIA espouses many different elements that are thought to be beneficial for internships. First, learning is situated and learners should be afforded opportunities to solve problems with authentic contexts. When considering STEM learning, students in VIA are given authentic tasks, such as the zoning example, that those involved in urban planning are tasked with solving. VIA also seeks to address the challenge of STEM learning by applying the theoretical tenets of internship (interns, mentors) and designing for effective facilitation. After the subject matter expert has developed the learning materials in VIA, the mentors use the software to provide specific expert guidance to interns (students) as they progress through the different zoning tasks. Moreover, the software is structured so that the mentor can serve as a project consultant, which provides a high level overview for students. In other instances, the mentor can serve as a fellow intern role or serve as a peer collaborator. By allowing a cooperative versus authoritative role, the software affords flexibility to better meet students in situ needs.

2.2 Supporting Instructional Design of Project-Based Learning

An additional unique element lies in the scaffolding of the instructional design process for the subject matter expert. Often, many project-based learning environments are designed to support student learning rather than the design of learning resources. Indeed, the design of adequate authoring tools is one of the serious barriers in this effort (Bagley and Shaffer 2015). As noted earlier, one of the goals of the VIA tool is to mitigate some of the initial curricular development investment for educators. The performance-support system approach in VIA allows experts to generate their own internships with little or no programming knowledge. To scaffold the design process, VIA divides the materials into a series of modules (‘rooms’) as a way to segment the content. In each room, subject matters include a single topic and task that will be evaluated. The mentors and interns use these rooms to discuss how to solve the problems. The system also includes space that helps the subject matter expert to upload materials given the topic and task. As such, the onus is not just on the instructor to find the materials; rather, s/he can leverage existing expertise to design these authentic scenarios for students.

The rooms, which are designed to segment content (Mayer and Moreno 2003), also include pre-generated prompts that the subject matter experts can include to help catalyze discourse between the mentor and intern. Research shows that classroom management is a challenge in project-based learning (Nariman and Chrispeels 2015; Tamim and Grant 2013), so the choice of using pre-scripted feedback is logistically useful to the extent that it provides ready-made responses for common student questions, assignment administration via email, student submissions, and unique situations such as absences, poor language use during chats, and positive critiques (see Fig. 4). This, in turn, helps the mentors/teachers facilitate synchronous communication among students within these rooms. This systematic design process helps ensure a more equitable scaffolded experience with students. As discussed below, pre-scripted feedback includes consideration of stakeholder perspective and prompts to elaborate student responses.

A unique aspect of the feedback is how it uses conversational agents and semantic analysis to scaffold open-ended discourse during collaborative problem solving. As noted earlier, pre-scripted feedback appears during the live chat below the text box of the mentor’s interface that (a) usually encourage student conversation and (b) focuses on

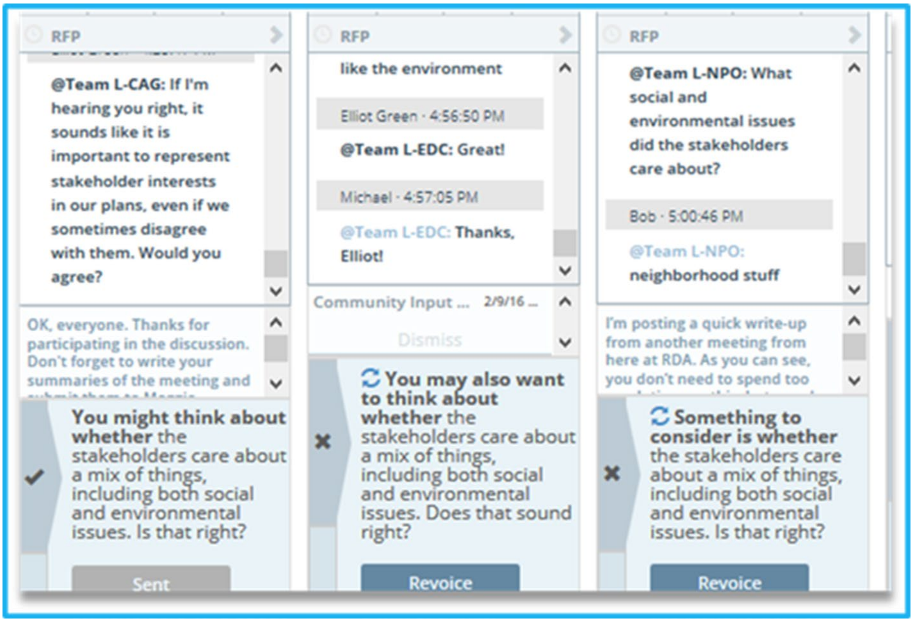

Fig. 4 Pre-scripted feedback as mentors facilitate collaborative problem solving

a particular aspect of the assignment. This automated feedback employs semantic analysis and appears on the mentor's screen based on the class lesson and objectives germane to the room (see Fig. 4). For example, if the class is at the stage where groups come together to discuss stakeholder concerns and solutions, a mentor may notice a group struggling to understand how to satisfy all stakeholder concerns and not take everything into consideration. A prescripted message that may appear for this lesson section is, "You might think about whether the stakeholders care about a mix of things including both social and environmental issues. Is that right?". To avoid overscripting (Dillenbourg 2002), mentors also have the option to edit all pre-scripts so the comment may better address the uniqueness of the situation. This allows the mentor to provide a more targeted and differentiated form of feedback that better aligns with a student's needs.

The software is also designed to address the assessment challenge that is often cited as a problem for project-based learning (Tamim and Grant 2013; Wijnen et al. 2017). Upon completion of the assignment, the mentor's interface on VIA will be aligned with the rubric. In the example of the Land Science internship, a student may submit an assignment that has three passing qualifications: address stakeholder concerns, show zoning proposal, and references used. These gauges also serve as identifiers for the system to know which of the pre-scripted feedback response to send. For example, the system may respond with: 'Good work, I was impressed with your summary of the Stakeholder groups. It seems you have a good handle on the stakeholders concerns and considerations you'll need to take going forward.' Alternatively, the feedback may be populated as the following if the student response was deemed insufficient: 'Your justifications are weak overall. Consider providing concrete examples or elaborating your discussion to include more relevant details.'

3 Emerging Technology in Practice

Once again, the goal of the software is to be a versatile pedagogical platform across all areas of curricular design. To date, VIA has been successfully implemented in several college and high school classes using the virtual internship entitled 'Land Science'. First, the subject matter expert used VIA to upload learning resources and thereby offload some of the initial instructional design challenges for educators who struggle to convey heavy technical information to a diverse group of students. In one implementation, high school students were assigned to take the virtual internship Land Science for the duration of 6 weeks. During the first 4 weeks, students worked individually learning about different aspects of Land Science; the modules were organized by rooms on the interface, with a total of 13 rooms. The first room students encounter was the introductory interview room where students were first introduced to their Land Science Zoning Company. As noted earlier, mentors played the role of planning consultant as they facilitated the ill-structured task. Through live chat, students and mentors discussed the information about zoning, stakeholders, questions, etc. Findings suggested the virtual internships helped teachers organize their lessons to better aid students through analyzing class lecture, chats, resources, timing, student evaluations, and collaborative problem solving.

4 Significant Challenges and Conclusions

Whereas many learning environments are designed for one type of user, VIA scaffolds the instructional design process for subject matter experts, teachers, and students. While this is a more robust solution, it creates unique opportunities and challenges. Prior to the classroom integration, VIA must intuitively allow a non-educator (subject matter expert) to translate their experience and germane technical information in a way that facilitates learning. In terms of the learning activity, VIA must also be designed in a way that engenders mentor-student interaction, as well as learner–learner interaction. In each instance, a set of unique design specifications must be considered to facilitate the user interaction. Moreover, each interaction requires a unique set of metrics to assess success. To address this challenge, the software uses performance tracking to overcome the assessment challenge that is documented in the research. Mentors and teachers have access to an interface that lays out the scores of each individual student for each assignment, as well as, their absences, late submissions and special comments made by mentors on student behavior. This allows for easy tracking of student group progress, as well as individual contributions. Developers are currently working on a feature that will allow VIA to report other visualizations of student performance. The goal is to identify problem areas that may occur throughout a student's progression through the class, and other patterns that may not be readily observable in a traditional classroom setting.

The scope of this project includes additional challenges and opportunities, especially as they relate to the presence of automated agents. In many computer-supported collaborative learning environments, scaffolds are often static prompts displayed at various places on the interface. However, the context-sensitive assessment used in VIA presents additional considerations, such as how students interface with a human mentor or computer agent. Given the inquiry-based nature of the science curriculum, how learners navigated these interactions is something that requires further evaluation.

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