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Enhancing Deep Learning in Geotechnical Engineering through Cognitive Tools and Transmedia Storytelling (Work-in-Progress)

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Abstract

This study explores the integration of Imaginative Education (IE) and transmedia storytelling in an undergraduate geotechnical engineering course. IE applies cognitive tools to create engaging narratives, while transmedia storytelling uses multiple media platforms (e.g. text-to-speech, videos, websites, etc.) to make these narratives more immersive. In particular, this paper focuses on the development of interactive videos led by real-world engineers. Given that women are more likely than men to leave engineering due to a lack of engagement, this study also attempts to make the field more inclusive by showcasing diverse perspectives and experiences.Through these videos, students virtually visit construction sites and later test soils collected from the sites. An assessment plan will be implemented to measure the impact on engagement and students' ability to apply their understanding in near and far transfer.

Introduction

Engineering courses typically focus on covering content while omitting the stories and meta-narratives that bring meaning and coherence to a subject. Such an approach not only misses an opportunity to generate the student engagement needed for deep learning, but it also increases the likelihood of students developing crude or simplistic ideologies and schemas [1]. A pedagogy developed in the learning sciences that utilizes storytelling and other cognitive tools called Imaginative Education (IE) has been developed by Kieran Egan [1, 2]. IE is based on supporting the development of five different types of understanding that enable learners to make sense of the world in different ways. As shown in Table 1, each of these five understandings is associated with specific cognitive tools. These tools are mental devices that help us make sense of the world and operate more effectively in it. For example, a well-crafted story can convey a coherent view of understanding in a memorable form while at the same time helping the learner engage emotionally with the information being communicated.

Table 1. IE understandings with associated cognitive tools (after [2]).

Understanding	Cognitive Tools
Somatic	Bodily senses; emotional responses and attachments; rhythm and musicality; gesture and communication; referencing
Mythic	Story; metaphor; binary opposites; rhyme, meter and pattern; humor; forming images; sense of mystery; fantasy; games, drama and play
Romantic	Sense of reality; extremes of reality; association with heroes; wonder; humanizing of meaning; collections and hobbies; revolt and idealism; context change
Philosophic or Theoretic	Drive for generality; processes; lure of certainty; general schemes and anomalies; flexibility of theory; search for authority and truth
Ironic	Limits of theory; reflexivity and identity; coalescence; epistemic doubt

In an IE curriculum, students become active participants in a learning experience in which cognitive tools are brought to life through hands-on activities and discourse. Ultimately, these aspects of IE help students process information, develop concepts and inform their actions.

Transmedia storytelling can increase the impact of IE by spreading different elements of the narrative across a variety of formats. In particular, featuring diverse voices, including female engineers, can help students envision themselves in the field and increase a sense of belonging. In this study, we have also used AI-generated audio content to create realistic soundscapes and spoken narratives to transform passive learning into interactive experiences consistent with the research from Urmeneta and Romero [3]. Moreover, by converting text-based lessons and technical documentation into audio formats, AI can support students with disabilities, such as visual impairments or dyslexia. We recognize that there are ethical considerations in the use of AI-generated content–such as ensuring that it does not perpetuate biases or misinformation or include nonconsensual usage of faces and voices–that need to be carefully monitored.

Although IE is a popular pedagogy used throughout the world for pre-college education, its use in undergraduate education has been largely unexplored. Raza et al. [4] discuss the promise of IE for making engineering education more effective, inclusive and relevant. Women and underrepresented minorities may benefit from more engaging pedagogies that emphasize storytelling, mentorship, and real-world connections, making this approach especially important for fostering inclusivity. Meanwhile, [5, 6, 7] have been exploring its potential in undergraduate machine learning and geotechnical engineering courses. This study expands on that research by integrating interactive video and AI-generated narrative and soundscapes with IE pedagogy.

Methodology

This study will be implemented in the EGR 340 Geotechnical Engineering class at Smith College. The assessment plan uses a pretest-posttest design to assess (1) learners' capacities to engage in both far transfer (innovation) and direct application (efficiency) of engineering concepts, and (2) assess student engagement with the curriculum. Assessment instruments include student surveys, instructor interviews, course feedback reports, exam performance and open-ended questions measuring students' interpretive understanding needed for future learning.

The success of transfer, or applying content knowledge in new situations, depends on the students' understanding of a principle's underlying reasoning. To answer the first research question, we will use both sequestered problem solving (SPS) and preparation for future learning (PFL) student assessments. SPS assessments measure near transfer and require students to replicate and apply what they learned in situations similar to the context in which they learned them. In contrast, PFL assessments measure far transfer and require students to solve a problem that requires learning something new; seeing a situation from a different perspective; or being able to ask productive questions to engage in inquiry [8,9]. Students will be asked the same PFL question at the start and at the end of the semester to assess changes in their understanding.

Addressing the second research question, learner engagement will be measured by student surveys and course feedback reports. In particular, the course feedback report will ask students the following questions:

- Practicing the dark arts, interacting with geotech personalities, traveling virtually to investigate sites and learning geotech magic tricks are examples of tools used to frame this course. Describe how their use impacted your learning.
- What three imaginative elements of this course stand out as having an impact on your learning?

Ultimately, we will compare the qualitative and quantitative evaluations of student knowledge and engagement with a database holding five years of pre-treatment data to examine if there were changes due to the application of IE and transmedia.

Curriculum

The topics covered in EGR 340 include soil classification, permeability and seepage, volume changes, effective stress, strength and compaction. A variety of strategies are used in the class to balance efficiency and innovation. Additionally, efforts are being made to highlight the contributions of female engineers to the field, ensuring that students encounter role models who reflect the diversity of the profession. These include lecture, discussion, peer teaching, hands-on group activities, labs introducing standard laboratory procedures, labs supporting inquiry, case studies, and real or virtual field trips. Examples of how IE cognitive tools are used in the class are shown in Table 2. They include extensive use of the following cognitive tools: story, mystery, fantasy, heroism, extremes of reality, theoretic thinking and ironic skepticism of theoretic thinking. Further details on these applications can be found in [5,6,7]. New applications to the curriculum are described below in more detail.

Table 2. IE understandings with applications of cognitive tools in EGR 340

Understanding	Examples of Applying Cognitive Tools
Somatic	Students play the role of a soil particle and describe the forces acting on them (for example, in effective stress theory); students feel soil (such as quicksand or clays in different Atterberg Limits states)
Mythic	Soil-focused magic tricks and other activities that present learners with mysteries to be solved and explore why geotech is known as the "dark arts of engineering;" virtual field trips investigating historic sites important to geotechnical engineering such as Pisa, Venice and Daytona Beach
Romantic	Visual and auditory regeneration of important geotechnical engineers interact with students asking and answering questions and providing insightful commentary; quicksand virtual field trip and inquiry quicksand lab
Philosophic or Theoretic	Instructor-generated course concept map; student-generated concept maps and theoretic stories on consolidation theory
Ironic	Knowledge building explorations of topics in which theory is incomplete, such as unsaturated flow in soil, clay behavior, etc.

Interactive Video Series

Based on IE principles, the research team has developed several transmedia activities featuring interactive video tours of construction sites hosted by practicing geotechnical engineers. When students begin the course, they are not familiar with the language specific to the field. Hence, they are at the pre-linguistic somatic stage within the context of geotechnical engineering. At this stage, the material is best understood through the five senses (see Table 1). In addition to hands-on activities during the first classes in which learners interact with various soils and observe their characteristics, an interactive digital platform for homework assignments has been created. Using this platform, the first homework assignment is a virtual video field trip of the Kathleen McCartney Hall construction project that students typically walk by on their way to class (see Figures 1 and 2). The video tour is led by a project engineer who explains the big picture of the construction process and a geotechnical engineer who introduces the geotechnical aspects of the site. During the tour students record their observations and questions in a journal. Later in the semester students revisit the job site for a second tour focusing on the foundation design. During this second tour students are given access to the engineering report for the site (including data, figures and maps) and actual soil samples collected from the job site. Students then begin a project in which they conduct grain-size analyses and Atterberg limits tests on the soil; classify the soil samples; and based on the testing results and site report, make their own foundation recommendations. Later in the semester students revisit the site to study additional cases and work problems.

Figure 1. Screenshot of class website with videos centered around practicing geotechnical engineers. To the left is a digital journal for students to record their thoughts and questions as they progress through the activity. To the right is a point-of-view footage where viewers feel as if they are walking through the site led by the engineers. The camera pans to several points of interest, simulating a student's curious gaze. A sample note is recorded in the student journal.

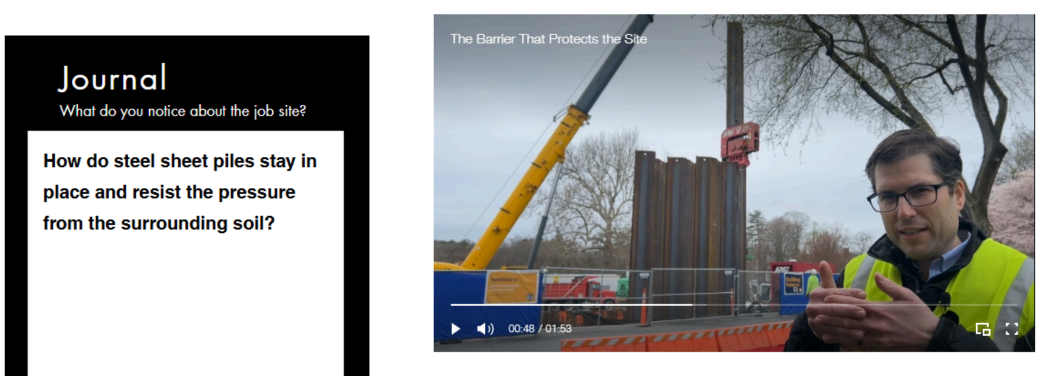

Figure 2. A geotechnical engineer explains the importance of steel sheet piles in the excavation process. Then the students watch as the sheet pile is driven into the ground. A sample question is recorded in the student journal to the left.

Auditory Content

One crucial cognitive tool at the romantic stage of understanding is heroism. Famous figures in geotechnical engineering such as Karl von Terzaghi and Arthur Casagrande are brought to life with text-to-speech AI voice cloning. Through audio embedded in lecture slides, these figures personally retell their stories, ask students questions and clear up common misconceptions. This way, complex technical content is adapted into a more engaging and immersive narrative format.

Anticipated Results

Exposure to an experimental curriculum that integrates AI and transmedia storytelling is anticipated to increase student engagement, content retention, and deep learning. It is expected that female students, in particular, will report higher engagement and a stronger sense of belonging in the course due to the inclusion of diverse role models and narratives. Qualitative data from student surveys and course feedback reports are expected to show that students feel more interested in the course content and that they have learned more deeply and meaningfully compared to a traditional curriculum. Quantitative data, such as exam scores, are expected to show statistically significant increases compared to data from prior iterations of the course.

A preliminary version of the narrative website was sent to four students for beta-testing. Comments included feedback about the content, functionality, clarity and the overall design of the website. The student comments were positive about each of these areas. One student found the story-line to be well-written and engaging and the design was aesthetically pleasing. Based on this formative assessment, the major change in the website based on the beta testing was improving the functionality of the online journal.

Significance

Exploring the use of IE in undergraduate engineering education leverages an innovative and well-developed pedagogical strategy to enhance student learning and engagement. Transmedia storytelling is a natural complement to IE. Together these approaches can potentially transform traditional learning environments to become more interactive and immersive. If successful, this can help students develop more sophisticated schemas and increase engagement and retention. While this research explores the effectiveness of this approach in civil engineering, these strategies are versatile and can be applied across various STEM disciplines.

While the advantages of IE and transmedia storytelling summarized above apply to all students, women are particularly at risk in the typical engineering classroom and may particularly benefit from this research. By featuring female role models through narratives and interviews, students can connect with the experiences of women in the industry, fostering inspiration and encouraging more female participation in engineering disciplines. This approach helps break down gender barriers and promotes a more inclusive learning environment while highlighting women who played significant roles in the past.

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