2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #33650

Work in Progress: Creative Biomechanics Project Using an Interactive Digital Experience as an Alternative Laboratory (IDEAL) – Phase 2

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Valerie Troutman earned a B.S. in Mechanical Engineering from the University of Minnesota (Minneapolis, MN) and earned a M.S. and Ph.D. in Mechanical Engineering from Stanford University (Stanford, CA). After completing her Ph.D., she was a Post-doctoral Research Associate at Michigan State University (East Lansing, MI) before joining the Mechanical Engineering department at the Milwaukee School of Engineering (Milwaukee, WI) as an Assistant Professor.

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Michele J. Grimm is the Wielenga Creative Engineering Endowed Professor of Mechanical Engineering. Her research has focused on injury biomechanics – from characterizing important tissue properties to developing appropriate models for the assessment of injury mechanisms. Most recently, this has included working with obstetricians to identify the pathomechanics of neonatal brachial plexus injury. Based on this work, she served on the American College of Obstetricians and Gynecologists Task Force on Neonatal Brachial Plexus Palsy.

In addition to her scientific research, Dr. Grimm has spent a large part of her career focused on curriculum development and enhancement of student learning in engineering. She served on the faculty of Wayne State University for 25 years, where she developed and implemented both undergraduate and graduate programs in biomedical engineering and helped to establish a department of biomedical engineering. Her endowed professorship at MSU focuses on research to increase the success of students in engineering through creative pedagogical techniques.

Dr. Grimm completed her B.S. in Biomedical Engineering and Engineering Mechanics at The Johns Hopkins University in 1990 and her Ph.D. in Bioengineering at the University of Pennsylvania in 1994.

She has just finished a 3-year rotation as a program director for three BME-related programs at the National Science Foundation. During this time, she served as co-chair of the White House's Office of Science & Technology Policy Task Force on Research and Development for Technology to Support Aging Adults. She was recently named to the National Academy of Medicine's Commission on a Global Roadmap for Healthy Longevity. She is also completing her 5-year appointment as a commissioner with ABET's Engineering Accreditation Commission.

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Active learning is known to improve learning and retention [1], and gamification via a "Choose Your Own Adventure" structure has been shown to improve student motivation to study [2]. We previously implemented Phase 1 of the Interactive Digital Experience as an Alternative Laboratory (IDEAL) for a creative biomechanics challenge problem [3]. Students were asked to analyze musculoskeletal biomechanics data to determine the mechanism of injury and the person-at-fault in a fictional forensic investigation. A storyline and unique characters were incorporated to encourage student-led investigation. Student responses to survey questions were collected after earlier, prompt-based challenge problems and after the IDEAL challenge problem, and responses were compared. Following the IDEAL Challenge problem, students indicated an increased appreciation for solving problems that were more representative of the real world than typical textbook problems. Further, students engaged with the investigation and who collected evidence unprompted performed better on the IDEAL final report compared to less engaged students. Phase 1 was implemented through an email exchange between students and a fictional police contact. Responses were guaranteed between 9AM and 5PM, with an average response time of 11 minutes.

We expanded on and gamified this structure in Phase 2 by fully automating the student-led evidence collection process through a Jupyter Notebook (Project Jupyter, USA) program which was built and run locally on students' computers with Binder (myBinder.org). The Jupyter Notebook program, run by following a mybinder weblink, allowed students to request and instantaneously access evidence through a user interface (UI) that we called the Investigator Terminal. Additionally, we developed witness testimony videos, which can be requested along with previously available evidence such as x-rays, medical records, and gait data. Phase 2 was implemented during the Spring 2021 semester, with data analysis expected by May 2021. As was done in Phase 1, traditional challenge problems were used for the beginning of the semester. Student engagement on the IDEAL problem will be measured by the amount of evidence collected, indicated by an internal code generated as students request and access information, as well as by a qualitative evaluation of investigator journals and glossaries. Not all available evidence was necessary to solve the case and there are several paths that students could take to reach their conclusions. Post problem surveys, administered after both the standard challenge problems and the IDEAL problem, will evaluate student "appreciation" of the content and perceived self-confidence in problem solving.

By using JupyterLab, the student-led investigation was gamified, with the intent of further increasing motivation and engagement with the challenge problem beyond what was seen in Phase 1. **We hypothesize that gamification can be combined with student-led investigation to improve students' learning of core course concepts and students' engagement in the learning process.** We will test this hypothesis by comparing data from team challenge problems (prompt-led), student learning through the IDEAL challenge problem Phase 1 (student-led), and student learning through the IDEAL challenge problem Phase 2 (student-led and gamified).

Implementation of Phase 2

The premise of the IDEAL Forensics Challenge Problem was the same as when implemented in Phase 1 [3]: 17 unique scenarios involving five witnesses and one patient injured

due to a witness' action or neglect. Students need to collect evidence, use biomechanical problem-solving skills learned in the course, and write a report justifying their conclusions. More specifically, students were asked to identify the injury, determine the mechanism of injury, and assess who was responsible for the injury. Up to two students were assigned to a single scenario while remaining anonymized.

We used Jupyter Notebook to provide an automated user interface, called the Investigator Terminal (**Figure 1**), to gamify the challenge problem experience. Within the interface, students were able to perform three actions: **Interview**, **Request**, and [identify] **Injury**. With each of the available actions, students were required to also provide a Keyword, such as a witness' name. After submitting a valid Action and Text keyword, a new piece of evidence became visible as a button in the Investigator Terminal. As students unlocked and viewed more evidence, a progress code was generated internal to the program and referenced to determine if a submitted action was valid. When students ended an investigation session, the progress code was converted to a unique, anonymous ID used to "Login" to their next investigation session. Students were encouraged to record their notes in separate Investigator Journal and Investigator Glossary documents. The journal was meant for students to record their notes and progress code for each session, while the glossary was intended as a repository for key words, names, and evidence that they found throughout the challenge and that might have been useful for all sessions. The journal and the glossary not only reflected UIs found in many investigative point-and-click games (e.g., Phoenix

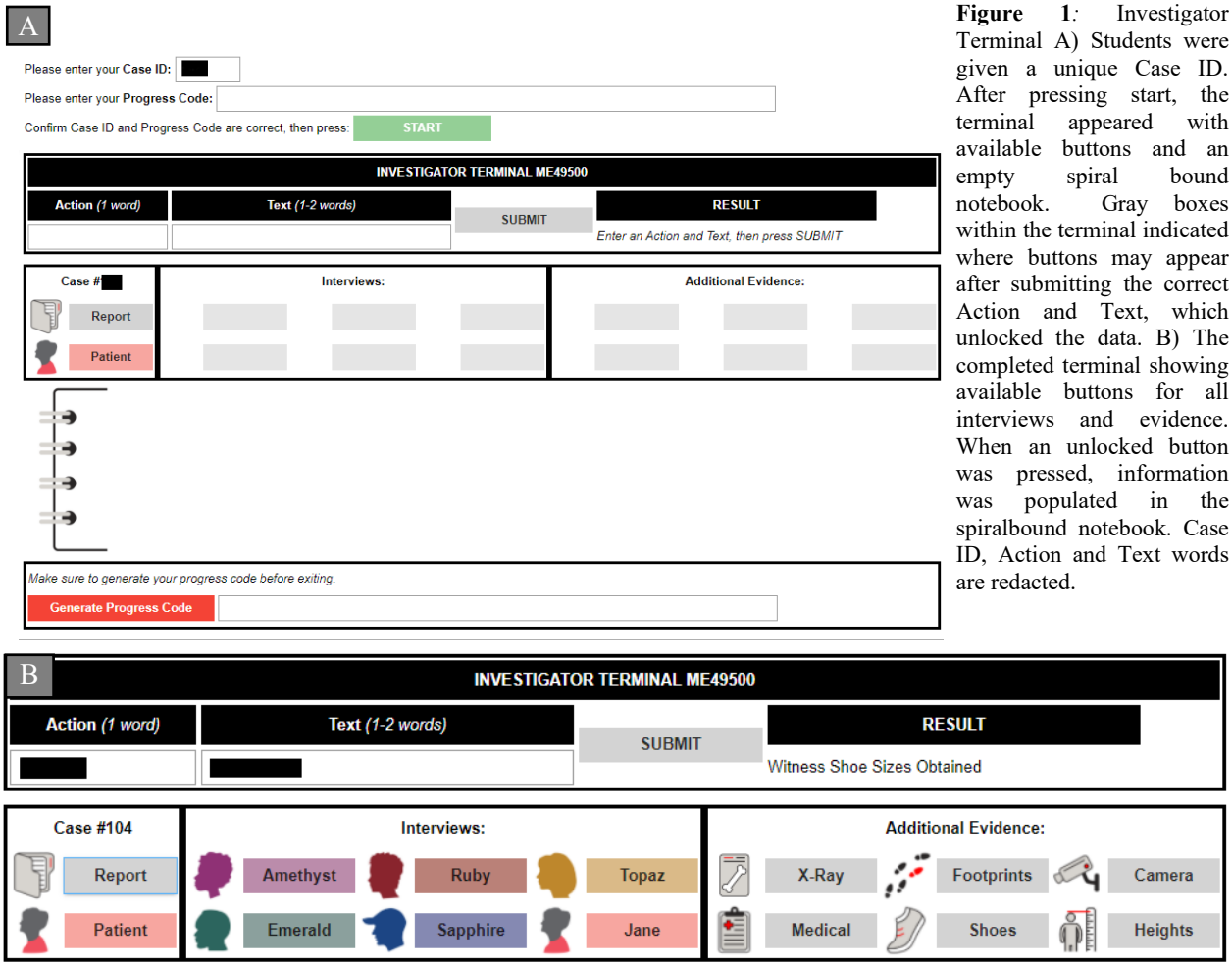

Figure 1: Investigator Terminal A) Students were given a unique Case ID. After pressing start, the terminal appeared with available buttons and an empty spiral bound notebook. Gray boxes within the terminal indicated where buttons may appear after submitting the correct Action and Text, which unlocked the data. B) The completed terminal showing available buttons for all interviews and evidence. When an unlocked button was pressed, information was populated in the spiralbound notebook. Case ID, Action and Text words are redacted.

Wright: Ace Attorney, Professor Layton, etc.), but also provided documents that could be qualitatively analyzed for student engagement with the forensics challenge problem.

The available evidence for Phase 2 provided the same information as Phase 1, but some information was provided in a different medium. Witness Interviews were listed as bullet points in police notebooks during Phase 1; however, Phase 2 witness interviews were scripted, voice acted, and animated (**Figure 2**). ZBrush (Pixlogic, USA) was used to create the basic models for the characters and objects in the witness testimony videos. Maya (Autodesk, USA) was used to texture, rig, and animate the characters. Final videos were compiled and edited in After Effects (Adobe, USA). Video and Audio files were then uploaded to Kaltura Media Space, captioned, and embedded into the Jupyter Notebook code to be viewed within the Investigator Terminal when interviews are accessed.

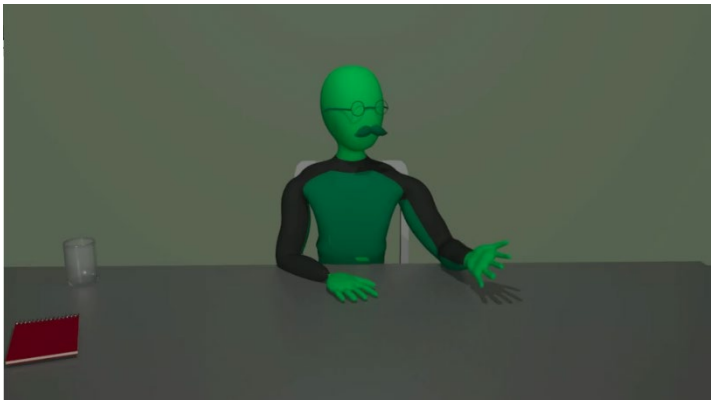

Figure 2*:* Screenshot from video created in Maya, featuring witness Dr. Emerald giving an interview to the West Lansing Police.

Expected Results and Discussion:

During Phase 1, surveys were conducted after the six traditional challenge problems were completed during the semester, as well as after the IDEAL challenge problem [3]. Most questions used a Likert scale, and a few questions were free response. We are continuing this survey method for the current semester; however, we are adding questions to gain feedback on the gamification of the IDEAL challenge problem. The new questions include: "The Investigator Terminal was intuitive to use;" "I wanted more guidance during the forensics challenge problem than the terminal was able to provide;" and "I had fun while solving the forensics challenge problem." As done in Phase 1, we plan to examine the results of the surveys, final challenge problem report grades, and final grades to evaluate self-perceived confidence, "appreciation" of the course material, and achievement of student learning outcomes[3]. Additionally, we will use final progress codes and the completeness of the Investigator Journal and Glossary entries to evaluate student engagement. We will compare these metrics between traditional challenge problems (prompt-led), IDEAL Phase 1 (student-led), and IDEAL Phase 2 (student-led and gamified). Grades will be normalized by cohort when compared between semesters.

The authors plan to make the developed characters, JupyterLab framework, and other project details available to support other faculty who wish to implement similar units within their courses. The Investigator Terminal provides a fun and engaging mechanism for students to obtain information regarding the forensics challenge problem, with students submitting reports similar to reports written in previous challenge problems. However, this framework can be rebranded for other assignments with up to 12 unlockable pieces of information and 2 initial pieces of information, giving instructors the ability to create new scenarios that reflect their topics and learning objectives.

References:

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[3] V. A. Troutman and M. J. Grimm, "Interactive Digital Experience as an Alternative Laboratory (IDEAL): Creative Investigation of Forensic Biomechanics," *J Appl Biomech,* pp. 1-8, Feb. 2021.