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Work-In-Progress: Bridging the Knowledge Gap- Integrating Design, 3D Modeling, Simulation, and Testing in a Junior-Level Biomaterials Course for Improved Student Outcomes and Employability

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Introduction

While gaining knowledge and technical expertise is crucial in any engineering education, including biomedical engineering (BME), the retention of skills that enhance the employability of graduating students is equally important. These skills include but are not limited to teamwork, problem-solving, communication, professional conduct, etc.[1–3] Among these professional skills, problem-solving, systems analysis, scientific knowledge, and learning abilities were the most frequently desired for BME bachelor's graduates in an analysis of over 23,000 job postings across various engineering disciplines [2]. In addition to professional skills, technical skills such as Microsoft Excel, computer-aided design (CAD), and SolidWorks were the top three mentioned in job ads for BME bachelor's graduates [2]. Laboratory modules in engineering courses can offer an excellent opportunity for BME students to boost these skillsets and increase their employability.

As members of the Department of Biomedical Engineering at the University of Arkansas, we have recently shown that early exposure to SolidWorks in sophomore-level BME core courses (Intro to BME in the fall semester and Biomechanical Engineering in the spring semester) helps boost student interest and competence in the software for CAD and 3D simulation[4, 5]. However, our curriculum currently lacks 3D modeling and simulation integration in junior-level core courses. Therefore, a new lab module was developed in a junior-level core course, Biomaterials, to continue SolidWorks exposure and enhance the aforementioned employability skills. In this lab, students working in teams were asked to design and simulate a polymeric sample on SolidWorks, 3D print it, and test its mechanical properties using Instron, where data analysis can be performed on Microsoft Excel. Data on student perception of SolidWorks design and simulation, as well as 3D printing, was gathered via pre- and post-lab surveys. Student competency in these topics was assessed via in-class quiz. Our results show that this new lab module increases student confidence in 3D modeling, simulation, and printing techniques and warrants continued investigation in future semesters.

Methods

Lab Design

In this lab, students were asked to design a spinal implant sample prototype, run simulations on SolidWorks, 3D print the material, measure mechanical properties on Instron, analyze the data, and write a lab report. Poly-methylmethacrylate (PMMA) bone cements served as controls for mechanical testing. Students were asked to design 3D print samples on SolidWorks (Dassault Systems, France). Specifically, students were asked to design disks with 30mm in diameter and 15mm in height made of poly-caprolactone (PCL) and poly-lactic acid (PLA). Infill percentages for each design could vary and were chosen by the students. Designs were then subjected to simulations in SolidWorks. These simulations were not to exceed 2000N and were performed on the materials to be tested after printing the designs. After simulations were performed, designs were saved as a stereolithography (.STL) file, which was required for printing, onto an external drive.

Two Cura Ultimaker S5 (Utrecht, Netherlands) were used to print structures, and each material was loaded into one printer. Cura slicing software was used to slice the structures into layers for printing. Printed structures were then used for mechanical testing. Both bone cement made from poly-methylmethacrylate (PMMA), and 3D printed structures were tested under compression using an Instron (Norwood, MA). Structures were compressed at a rate of 1.5 mm/min until failure or maximum force, 2000N, was reached. Data was collected using integrated Bluehill3 (Norwood, MA).

Quiz

After completing the lab section, students completed an in-class quiz focusing on specific aspects of the lab module. The quiz comprised six questions about SolidWorks design, simulation, and 3D printing.

Survey

Pre- and post-lab surveys were administered online via Qualtrics to measure student interest and confidence levels in the technical aspects of the lab module as well as development/improvement of the key professional skills such as communication, teamwork, problem solving, etc. The study was approved by the University of Arkansas Institutional Review Board (IRB Protocol #: 2209420237). Students were asked about their confidence levels in SolidWorks design and simulation as well as 3D printing and their perception of the importance of these skills in biomedical engineering. Responses were taken on a 5-Likert scale and open-response questions, and the differences in rating between pre- and post-survey were analyzed. Fifty-six students took the course and participated in the surveys.

Results and Discussion

As shown in Figure 1, students showed increased confidence in applying modeling, 3D printing, and simulation techniques in the biomedical engineering field, as less than 8% of students "Disagreed" or "Strongly Disagreed" after the lab. As for the applicability of the lab module techniques in the field, students never showed any kind of disagreement (Figure 2). Interestingly, their responses shifted more to "Strongly Agree" after the course. There was no significant change in the students who responded with "Neither Agree nor Disagree."

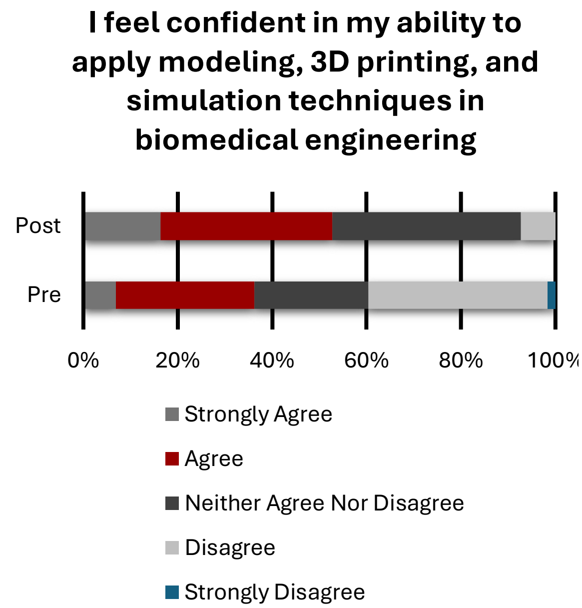

Figure 1. Student responses on confidence levels of the technical components of the lab

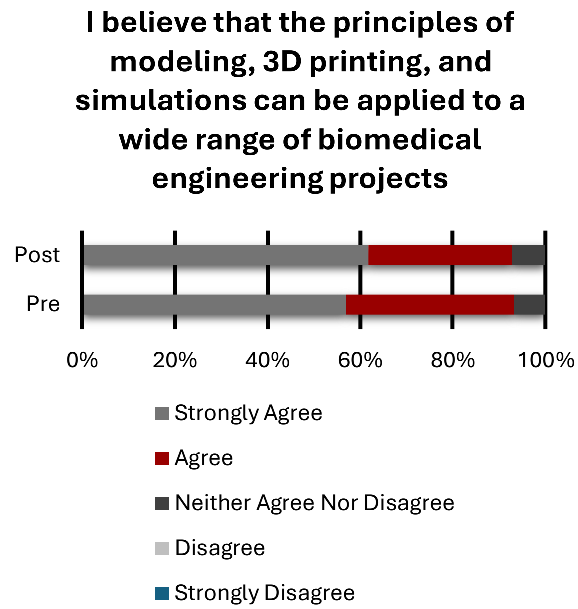

Figure 2. Student responses on perceived importance of the technical components of the lab

When students were asked about the individual technical components of the lab, they showed an overall increase in their confidence levels. As shown in Figure 3, students showed a marked increase in their confidence with SolidWorks, as shown by a reduction in “Slightly" and "Not at all" responses. Similarly, confidence in 3D printing from SolidWorks greatly improved, with over 50% of students reporting no confidence before the lab and 0% post-lab. Further, "Extremely," “Very,” and “Moderately” saw an increase of 7.2%, 3.7%, and 40.2% respectively.

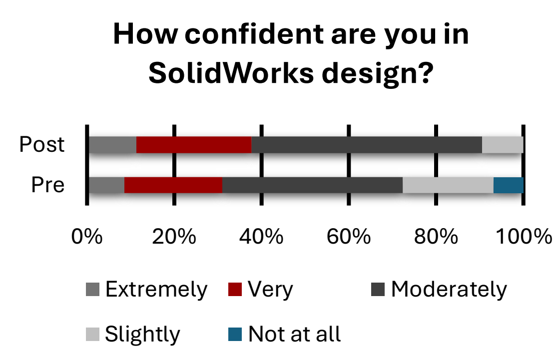

Figure 3. Student responses on confidence levels of SolidWorks design

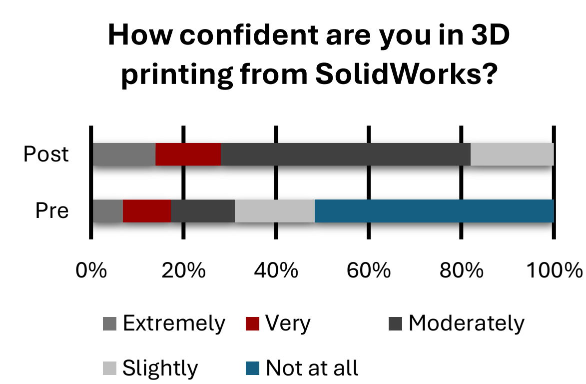

Figure 4. Student responses on confidence levels of 3D printing from SolidWorks

Similar trends were observed regarding creating and analyzing simulations on SolidWorks (Figures 5-6). In simulation creation, the sections “Extremely,” “Very,” and “Moderately” all showed an increase in number of responses while “Slightly” and “Not at all” decreased, which supports the idea of students gaining confidence regarding simulations. As for simulation analysis, the number of extremely confident students seemed to stay mostly constant, with a slight dip in number, but most students moved to the “Agree” option, which saw the most growth after the course. The “Slightly” and “Not at all” options decreased significantly.

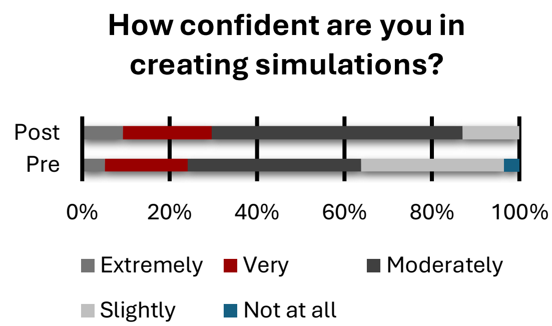

Figure 5. Student responses on confidence levels of creating SolidWorks simulation

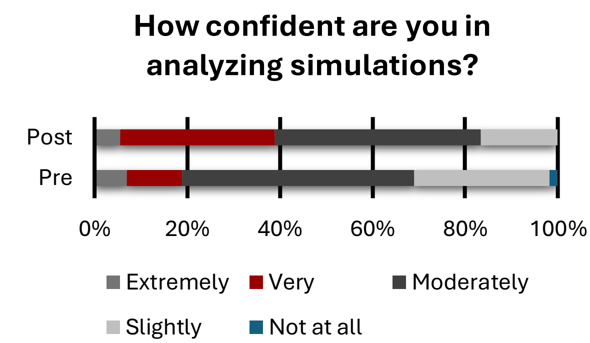

Figure 6. Student responses on confidence levels of analyzing SolidWorks simulations data

Finally, when students were quizzed on the lab module content, they showed a high level of understanding of SolidWorks and 3D design overall. Out of 53 students who took the in-class quiz, all correctly answered SolidWorks terminology question. Over 92% of students correctly answered two questions on SolidWorks part files, while 86.8% answered correctly on 3D printing type.

Conclusions and Future Directions

Overall, the newly created lab module demonstrated potential in improving students' understanding of 3D modeling and 3D printing and warrants continued delivery in our Biomaterials class. Future work will focus on increasing the sample size, as this study was conducted with a single cohort of 56 students, as well as performing a thorough qualitative analysis of the open-ended responses, along with sentiment and thematic analysis of the feedback received. We are also analyzing student responses on non-technical, professional skill developments such as teamwork, problem solving, communication, etc., and the results will be shared in a full paper. Furthermore, SolidWorks and 3D printing quiz will be delivered pre-lab as well as post-lab to gauge students’ true knowledge gain from the lab. Finally, long-term follow-up will be essential to evaluate whether this lab not only enhanced students' sense of identity as engineers and influenced their post-graduation career choices but also determine the benefits of continued instruction in SolidWorks and 3D printing during junior year compared to intermittent delivery in the sophomore and senior years.

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