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Development of a SolidWorks Simulation Toolkit for a Sophomore Level Biomedical Engineering Course

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Development of a SolidWorks Simulation Toolkit for a Sophomore Level Biomechanical Engineering Course

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Abstract

In the engineering industry, computer-aided design (CAD) programs are used to create models and create virtual experiments or studies that allow engineers to observe the real behavior of parts or assemblies under certain conditions. Companies hire students with experience in CAD, as professionals believe that CAD experience is beneficial [1,2]. SolidWorks is among the most popular CAD software used by engineers. SolidWorks has multiple functionalities that also allow for finite element analysis dependent on the license. Users can create simulation studies in SolidWorks Simulation that can be used as an accurate approximation for real results.

The goal of this study is to create a toolkit for students in Biomechanical Engineering that will allow students to access a variety of models and simulations based on homework problems and lecture examples they have seen in class. The purpose of this study is to help students understand core topics being taught within the class as well as introduce students to advanced uses of CAD software such as SolidWorks Simulation. Data is collected from the students via a survey, asking about their experience, interest, and proficiency with using SolidWorks. Students were also asked to give free response feedback as well, allowing them to highlight the problems they had so that they can be fixed in future updates.

The results of this study show that students overall respond positively to the module's implementation. While the students found that it was difficult to use the toolkit and the software, on average students have agreed that SolidWorks Simulation is a useful tool. Students were also only moderately confident in using the software. Going forward, all the student's feedback will be considered to make further progress into the development of the toolkit.

1. Introduction

Computer-aided design (CAD) software is regularly used by engineers for the convenience of creating, sharing, and evaluating designs. SolidWorks is a highly used CAD software across the industry, frequently used by engineers of all disciplines. SolidWorks, made by Dassault Systèmes and SolidWorks Corp. provides engineers with 3D CAD design software, analysis software, and product data management software [3]. SolidWorks excels in advanced modeling of 3D designs and simulations. SolidWorks has functionality that includes finite element analysis (FEA) of systems with static and dynamic properties. This allows engineers to evaluate their designs before doing real-world tests. CAD programs are heavily present in engineering industries and graduates with design software proficiency are highly sought after. This thesis aims to develop a simulation toolkit to help reinforce course topics and expose students to SolidWorks. Students in Biomechanical Engineering will be using SolidWorks Simulation to look through a toolkit of premade models of lecture and homework problems to simulate and compare to solutions. After browsing through the toolkit, students should have a grasp of basic finite element analysis and solution finding within SolidWorks Simulation. The final goal of this project is to foster experience and allow students the opportunity to see how SolidWorks can be used to aid in understanding core topics that are being taught.

1.1. Importance of CAD

In the engineering industry, CAD experience is sought after in new applicants. Being able to use a CAD program places applicants above those with little to no experience. Companies such as AutoCAD and SolidWorks have made certifications for their programs that show a certain skill level by the certified individuals, ranging from beginner to expert level. In a study by Webster et al, a survey was made and distributed across certified SolidWorks users that are industry professionals currently employed in an engineering-related field [1]. The results of their study showed that most respondents have considered SolidWorks certification to be beneficial to students, and 65% of respondents indicating moderate to extreme benefit to students [1]. While another similar study posed to employers and instructors in one statewide survey showed that the respondents believed on average that non-certified students would perform as well as certified students [2]. Regardless of certification, having experience in CAD is beneficial, as Taleyarkhan et al. found that students in design classes using CAD Simulation tools improved significantly in understanding design challenges and building knowledge, which are fundamental engineering skills [12].

In all, having CAD experience has no downsides and would still benefit students, as in the study by Trent et al respondents have said that employers look for experience, CAD proficiency, and people skills as compared to certification [2]. Implementation of CAD into courses early and continuing to do so will allow students to build proficiency over time, helping students post-graduation. We will be investigating student interest in SolidWorks and SolidWorks Simulation and how well the software is received.

1.2. SolidWorks Simulation

SolidWorks Simulation is a part of the SolidWorks suite of built-in premium tools that allow users to use FEA on parts and assemblies created within SolidWorks. The software is capable of several different types of simulation: motion, static, frequency (vibrations and resonance), topology, optimization (or design studies), thermal, buckling, nonlinear (when linear assumptions are violated), as well as drop testing and pressure vessel design [3]. When designing and creating a study, the user defines all the variables corresponding to the study they are setting up. Once the user creates the study, they can run or process the study to produce results. The results of every study will include displacement, stress, and strain by default; however, the user can manually look for reaction forces or other variables such as the Factor of Safety.

In Biomechanical Engineering, all the topics are static in nature which makes SolidWorks Simulation a good candidate for a module in the class, since SolidWorks is a powerful tool that can be used to simulate all the homework problems and examples in the course. In this study, SolidWorks Simulation will be used as a tool to enhance the education of the students, to promote their understanding of Biomechanics, and to introduce them to more applicability of SolidWorks.

1.3. Implementation

Adding a SolidWorks module introduces to students a fundamental skill that engineers use. Other universities have done this by integrating short activities or modules involving CAD into existing classes or have created CAD classes on their own [4,5,6]. In a study by Martín et al., they used short activities to guide their Fluid-Mechanical engineering classroom using SolidWorks Flow Simulation [5]. The activities they did were like problems students would see in class, and the purpose of their study was to establish core understanding through simulation without experimentation [5].

In another study by Whalen et al. an extra-curricular and student-driven course was created to reinforce student's skills with SolidWorks corresponding to graduating student's input from their first co-op experience [4]. The modules in the course focused on supplementing first-year courses and transition into their first co-op [4]. In the post-course assessment, they had an overall positive response from students where they had an average response of 4.73 (on a scale of Strongly Disagree = 1 to Neutral = 3 to Strongly Agree = 5) for the statement "I am glad to have taken this course" and 4.33 for the statement "I have developed additional SolidWorks skills, and I now feel more prepared for co-op after taking this class" [4].

Shaikh et al. also implemented a similar approach; the instructor of the course used another FEA software to teach the mechanics of materials in a structural engineering course [9]. Students expressed in this study that the tutorials and assignments helped them to understand the analysis of structures, as well as preparing them for work in the industry or graduate school [9]. In this study, a simulation toolkit is created to allow students to visualize and analyze problems and examples in class to help create a core understanding of class topics. Feng et al. did another similar experiment with similar results to Shaikh et al., however they used ANSYS FEA to improve classroom teaching [9,10].

A study by Wu et al. has more similar content to this thesis [11]. In their study, an undergraduate student taking an undergraduate biomechanics course was running FEA through ANSYS on a broken femur with a plate [11]. While this study was about an individual's work, the student and class after a discussion determined that implementation of FEA in bioengineering course held high importance [11].

In summary, this study focuses on the development of a simulation toolkit as a learning module for students to hone their understanding of course topics and to develop skills in SolidWorks that could help in later courses. This will be a developing study that does not end with this paper and will continue to be developed for the course. At the time of writing this thesis, the toolkit is in its elementary stages and the current focus is on the development of the toolkit and teaching students to use the toolkit. As such, the data collected for this thesis is qualitative so that the toolkit and module can be optimized in the future.

2. Materials and Methods

To create the simulation toolkit and to allow the students to use them, SolidWorks simulation is required. There are two ways for students to access Simulation for free on campus, one method is through visiting the BMEG Computer Lab in ENGR 109. This method might not be available to all students, as during the writing of this paper the COVID-19 Pandemic was still ongoing which might restrict some student's from in-person activity. Students were primarily shown how to access SolidWorks virtually.

The second way for students to access Simulation was by using Citrix, a virtually hosted workspace that allows users to access applications on their personal computers, with any operating system, without having to obtain a license for those applications [7]. Since Citrix is not a regularly used application by most students and requires an administrator to grant access to it, there is great potential for errors to occur in the process of initial installation. Another issue with Citrix is the limitation of the service. Since it is a virtually hosted application the user's processing power is limited by the server. This means that simulations being run through Citrix could take much longer than locally hosted simulations. While this can be a downside, Citrix can still allow students to open and look at simulations already compiled and run, making it is a great tool for analyzing data.

This paper will outline the creation of the toolkit as well as feedback from students to determine areas that can be improved. For this thesis, students enrolled in BMEG 2813 – Biomechanics for the Spring 2021 semester were given the opportunity for extra credit by voluntarily completing an assignment involving the simulation toolkit. Instructions given to students for the assignment are included in Appendix I. To determine what needs to be improved for future implementation, a survey is accompanied by the assignment. Qualtrics is used to deliver the survey to the students online.

The extra credit assignment is based on three requirements for completion. The first is to watch the demos, the second is to screenshot the corresponding results in the simulation results window to the homework or lecture being modeled, and finally taking the survey. Upon verification of completion, the students will be awarded 2% extra credit to their overall grade.

2.1. Toolkit

Regarding the Simulation Toolkit provided to students, all the models and simulations were created in SolidWorks and were designed specifically after homework problems or lecture examples in the class. In some events, approximations were necessary as the parameters for 2D problems may not lay out enough necessary information for a 3D transition. Even so, the creation of models was manageable and had no issue. Creating simulations for each problem or example was more challenging than creating models. Each problem when translated from paper can be easily set up; however, issues arise when configuring models for their respective simulations. For example, for Homework 7, problem 5, the cross-sectional moment of inertia across the principal axis was reversed from the problem statement, meaning the principal axis was reversed for the model in SolidWorks. This did not cause an issue with the simulation since the percent error between the solution and the simulation result was 2.1%. Depending on the size, the number of connections, and other variables within the simulation, the results will rarely be equivalent to the solutions by hand. This is due to the way SolidWorks processes studies through FEA.

The toolkit consists of 14 different simulations: 11 homework problems and 3 lecture examples. These were selected over a variety of different topics such as Moments, Stress, Axial Loading, Bending, Shear, Beam Deflection, and Equilibrium. In the toolkit are 5 videos: a video on accessing SolidWorks, another on familiarizing students with SolidWorks Simulation, and three demo videos that walk students through creating and analyzing Simulations. The demos were made for problems that contained components present in other examples, but also because of specific scenarios and solutions required from the problems.

Demo 1 covered homework 6, problem 5, and it was chosen because it was a simple exercise for students to familiarize themselves with the software. In the demo, the stress of the beam was found because the problem asked students to find the stress of the beam. Demo 2 covered the 6th example of the equilibrium lecture. This example was chosen because it asked students to find the reaction forces and it allowed students to see two different ways to set up the same study and achieve the same results. Demo 3 showed the process of simulating homework 7 problem 5. The solutions asked for the displacement of the beams in the problem, which covers the third major result that can be obtained in simulation. Since there are many specific connections in homework 7 problem 5, it was ideal to demo since it was another study that differs from other simulations.

All these files were packaged into a box folder that is shared to the students. Every student has viewer permissions to the box folder, allowing them to download and preview its contents. Only the instructor, teaching assistants, and investigators are allowed access to edit and share the box folder.

2.2. Survey

The survey was completed by all students opting for the extra credit assignment, done online through Qualtrics. A Harvard University document was referenced to help create the survey [8]. To verify the status of completion for each student, participants were asked for their name and email address for instructors to distribute their points.

Primarily there are three categories of questions asked: experience, evaluative questions, and interest questions. The experience questions ask students about their experience in design and CAD software. All these are yes or no questions and serve to evaluate the potential difficulty that the students might have when using the software. It also is a benchmark for what exposure they have had prior to the assignment.

Evaluative questions are used to determine the effectiveness of instruction and if the students were able to complete their tasks. Students are asked about the difficulty of navigation through SolidWorks, the difficulty of following along the instructional videos, and if they encountered errors while completing the assignment.

The interest questions ask students about how confident they are in operating SolidWorks, their interest in CAD software before and after, how useful SOLIDWORKS Simulation is, and the likelihood of using SOLIDWORKS before and after. These questions are rated on a linear scale from extremely likely to extremely unlikely (or not at all). Data from the interest-based questions will show how well the assignment is received by the students and if having a SolidWorks module incorporated into the class will impact students.

Students are asked in the survey to provide a free response in the form of a comment or suggestion. These responses will be the most important since direct feedback will drive the future of the project as it continues to be implemented into the course. A full copy of the survey will be listed in Appendix I.

Data collected from the students is preserved on Box and is only accessible by the faculty advisor and investigator(s) (since this is a continuing project the data will be transmitted to new investigators). All data collected from the students and to be used for the purpose of this thesis or the class is non-sensitive and presents no personal information of individual students.

3. Results

Information regarding student's experience with CAD software is catalogued in Table 1. Experience data will allow tailoring of the toolkit to fit the proper skill levels of students. As shown in Table 1, only 3 (13%) participants have had experience using CAD programs and 1 participant (4.35%) has had experience using SOLIDWORKS. None of the students have had experience using SolidWorks Simulation.

Table 1. Student's overall experience using CAD software prior to the assignment.

Question	Yes	No	Total Students
Do you have previous experience in design (CAD or otherwise)?	13.04%	86.96%	23
Do you have previous experience in CAD programs?	13.04%	86.96%	
Do you have previous experience in SOLIDWORKS?	4.35%	95.65%	
Do you have previous experience using SOLIDWORKS Simulation?	0.00%	100.00%	

Students evaluated the toolkit which serves as a benchmark of the active parts of the toolkit to show areas that need improvement. Students were asked in question 7 how many videos they watched, and only one of 23 students has watched less than 5 videos. Questions 8 and 9 yielded the results shown in Figure 1. These two prompts are on a linear scale from extremely easy to extremely difficult (1 to 5). Question 8 asks students "How difficult was it to navigate through SolidWorks?" and question 9 asks "How difficult was it to follow along with the instructional videos?". Figure 1 shows that overall respondents find that SolidWorks is difficult to navigate, with a mean score of 3.83. Figure 2 shows that the instructional videos were neither easy nor difficult to follow along, with a mean score of 2.7.

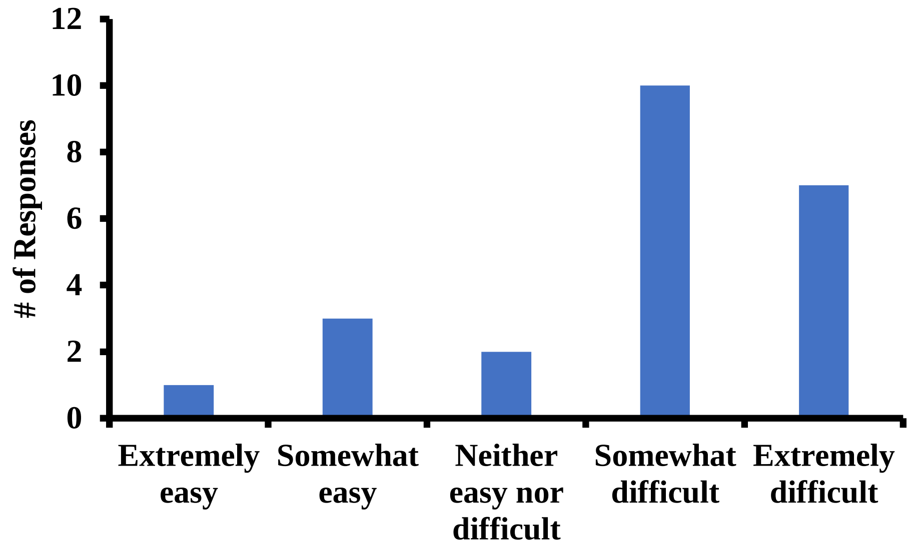

Figure 1. Responses from students rating the difficulty of navigating SolidWorks.

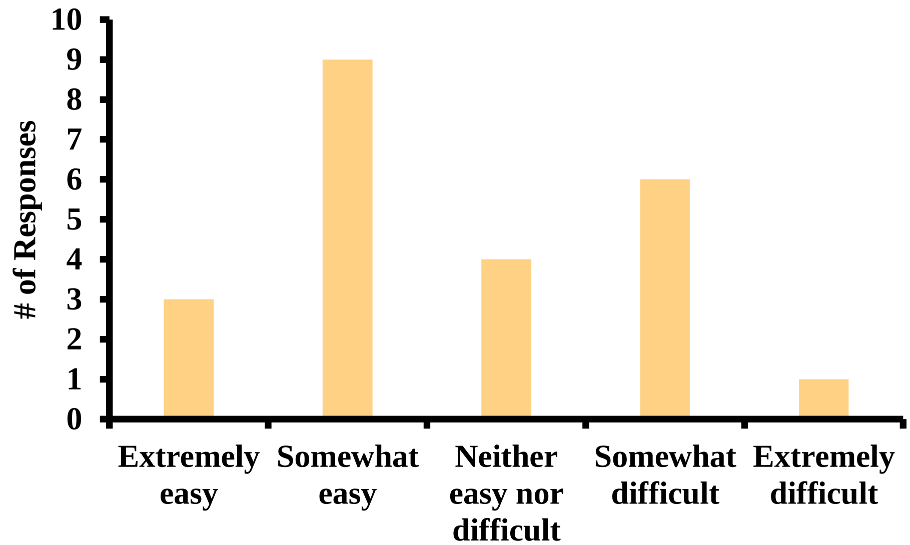

Figure 2. Students rate the difficulty of following the instructional videos.

Questions 10-12 are yes or no questions that ask students if they were able to complete the assignment instructions as well as if they encountered any errors. The results are shown in Table 2. Most students were able to replicate the study as well as view the results from the studies; however, most students also encountered errors while completing the assignment.

Table 2. Assignment completion by participants

Question	Yes	No	Total
Were you able to replicate the simulation study?	73.91%	26.09%	23
Were you able to analyze and compare your results?	69.57%	30.43%	
Did you encounter any kind of error?	73.91%	26.09%	

The questions asking students about their interest in SolidWorks are used to gauge student reactions to the module and to gain preliminary validation for the implementation into the course. Question 13 asks students how interested they were in CAD software before and after the assignment on a linear scale from extremely to not at all interested (1 to 5). As depicted in Figure 3, students on average said they were slightly to moderately interested in CAD before (mean = 3.65), and moderately interested after completing the assignment (mean = 2.91).

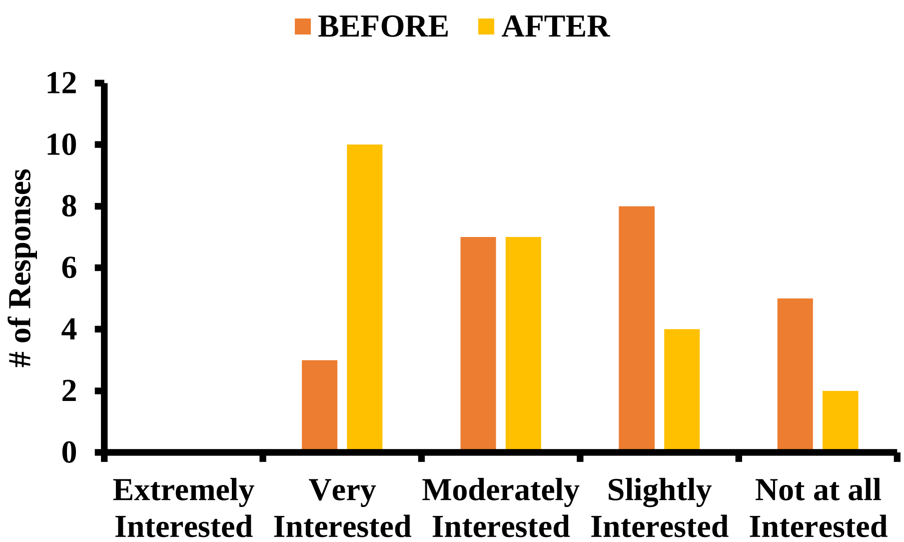

Figure 3. Student interest in CAD software before and after the toolkit assignment.

Question 14 asks about the confidence of students in using SolidWorks, creating simulations, and analyzing simulations. As depicted in Figure 4, students showed they were slightly to moderately confident in all three categories (mean ranging from 3.65 to 3.74, standard deviation ranging from 0.74 to 0.81).

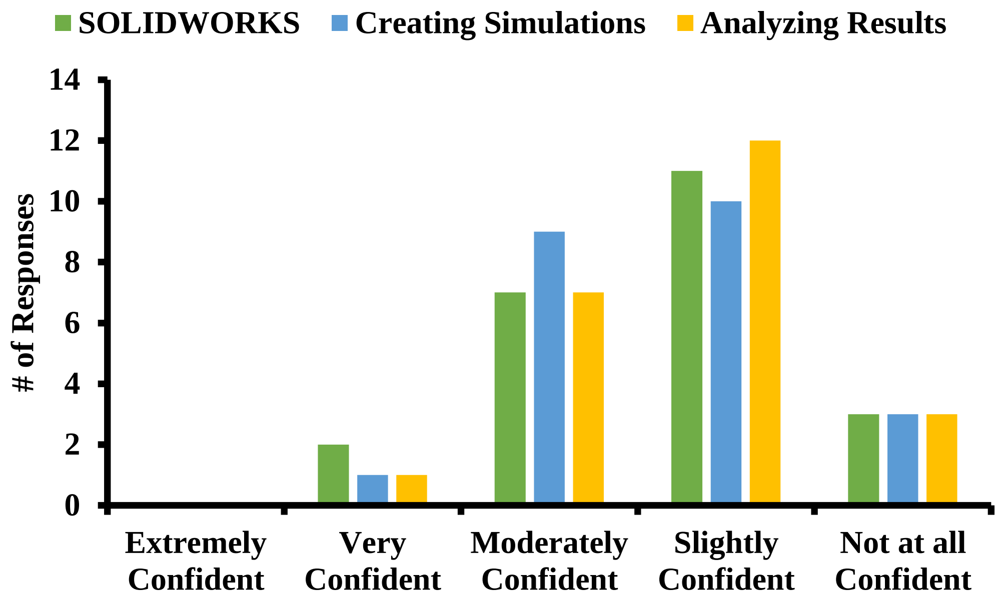

Figure 4. Student confidence in three activities the assignment covered.

Students were asked how useful SolidWorks Simulation is in question 15. This question gauges student's thoughts on the applicability of the software. Like previous questions, the scoring is from extremely to not at all useful (1 to 5). Figure 5 shows that students on average, with a mean of 1.78, said that the software was very useful.

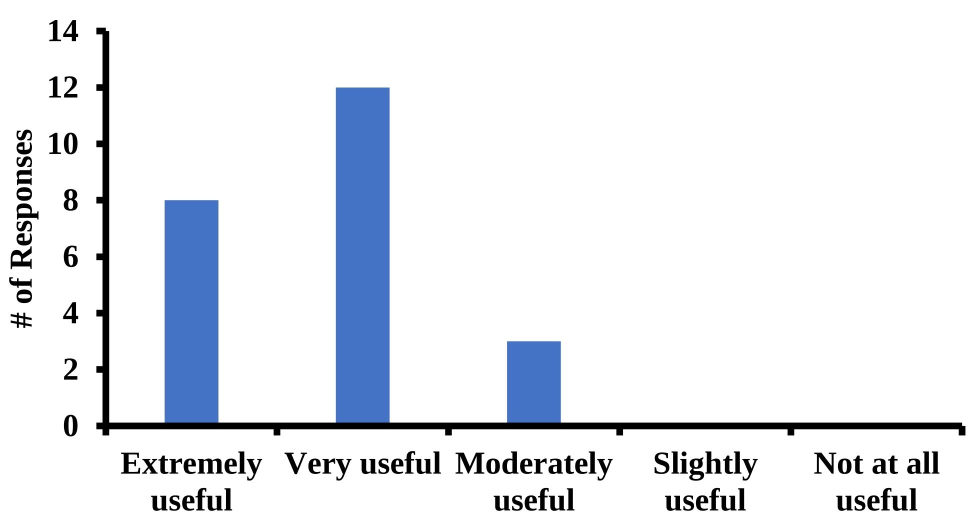

Figure 5. The usefulness of SolidWorks Simulation rated by students

Finally, question 16 asks students how likely they were to use SolidWorks before and after the assignment. Question 16 gauges the overall effectiveness of the activity to familiarize students with SolidWorks and potentially carry on these skills. The responses range from extremely likely to extremely unlikely (1 to 5). Figure 6 shows that students before were somewhat unlikely to use SolidWorks before the assignment (mean = 3.87), and afterward they were somewhat to very likely to use SolidWorks in the future (mean = 2.57).

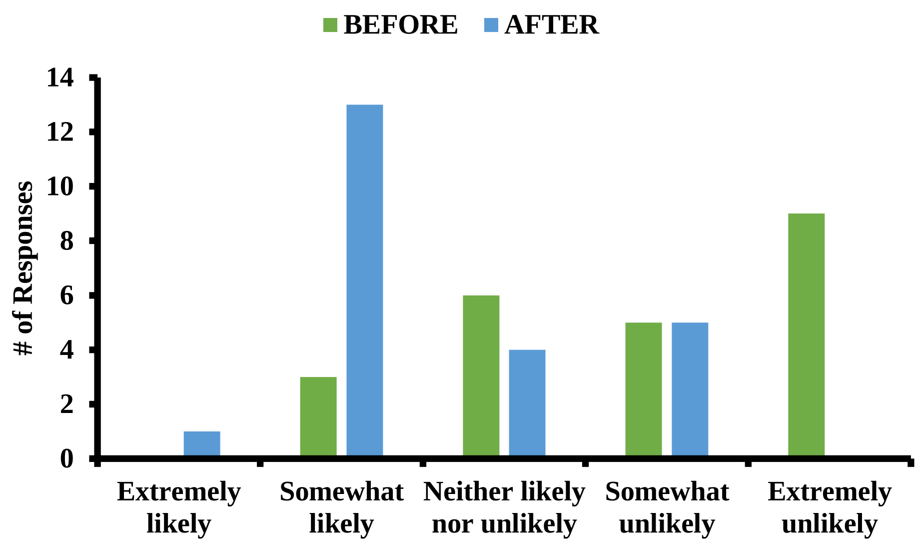

Figure 6. Likelihood of students using SolidWorks before and after the assignment

Students were given a comment and suggestion box so that they can give their feedback about the module. Table 3 shows these comments and suggestions from the students. Multiple students stated that they had issues or great difficulty running SolidWorks through Citrix, or that the instructions need to be more clear or precise, or that the activity was much easier in the BMEG labs where the software is installed locally.

Table 3. Student feedback

[N/A]
I had some trouble downloading the files. I saw that there were videos posted, but they were a bit too late for me to see and finish by the deadline. Otherwise, I think the instructions were helpful and the software seems useful!
The wait time for running the simulations takes way too long nearly 45min per simulation, so maybe figuring out how to reduce this time
N/A

I wish the instruction were more clear because [I] honestly did not know what to do even after watching the videos. I downloaded the files and pulled them up on solidworks but it looked as though the whole thing was done. I did see the text files that had values in them but [I] had no idea where to input those values. This was just overall difficult and the videos were presented as though someone had prior knowledge of solidworks. Instead it should be formated as solid works for [beginners] because thats how basic [I] need the instructions if [I'm] going to actually figure out how [I'm] going to do it.
Solid works is a very useful tool. However, it was really hard for me to keep track of everything. It was hard to follow the instructions because they were not clear. That took a lot of time. Then, my computer were not able to run the studies, and it was hard to go to campus to use the ones in the computer lab. I had also too many assignations from other classes, which left me with little to no time at all to complete it. I'd like to learn how to use the program in the future because I think is very useful and easy to manipulate after long hours of practice.
I really enjoyed using this program, I would have never used it if it was not for this class. Very useful content.
N/A
I enjoyed the solidworks. I believe that it is extremely useful for understanding what is happening in our class. The solid works is an easy way to understand how the forces are working on a rigid body
This was a good way to learn how to use [SolidWorks]
the software through [Citrix] was very slow to load projects and process commands
If the entire course could be taught with SolidWorks incorporated as a drill section maybe, that would really have aided in my understanding throughout the course. It really helps to visualize and interact with models.
Solidworks is undoubtedly a very useful tool for engineering students, but it takes practice to know how to use it
Replicating to simulations was pretty difficult at first. I also had trouble accessing all of the complete assembly files.
Solidworks was very slow and I could not get the simulation to work
It was a good project, but starting it was hard. It is also very bad to use on a personal computer. I worked on it for multiple hours to very little avail. My main piece of advice is to emphasize how much better it is in the computer lab rather than on a personal computer. The time difference in comparison was incredibly large.
I liked the extra credit, i just wish it described how to do run solid works on your computer better, or highly encouraged us to go to the BMEG computer lab like I ended up doing.
I don't know if it was just my computer but I ran into multiple errors. I think the errors came from downloading the simulations so I would suggest doing it in the computer lab with Solidworks already on the computer.

This is very interesting, it would have been cool to go through more simulations with this for a project.
I had [a lot] of trouble accessing this software. I think it can be very helpful way to analyze structures without doing all calculations by hand. However, I am just not very familiar with the software and it was very difficult for me to operate.
I noted in the document I uploaded that one of the simulations had an issue where I couldn't get the contact to work, so there was unwanted penetration, and I couldn't figure out what the issue was. I also just set everything to the default steel when the material wasn't already given.
It was so difficult to get to be able to open first [Citrix] and then SolidWorks, I feel that the simulation access video can be a little bit more specific on how to open everything and what to do if somehow it does not look like it should. Like possible issues we could encounter and how to solve it. Or maybe give us a kind of [license] to us students, so that we can download the program and use it as normal. Thanks!
Once I was able to troubleshoot the issue I was having with the simulations taking so long, I was able to use SOLIDWORKS without any issue.
More detailed explanations.

4. Discussion

Overall, the addition of a SolidWorks module into Biomechanical Engineering was perceived positively by students. The survey results suggest that students believe that SolidWorks is a great tool for the work they were tasked to do. Students were able to accomplish the task the instructor gave them and some without issues. These results are promising as they provide some evidence that the toolkit activity is an appropriate addition to the course. One student responded to the survey indicating SolidWorks would help them in the course, they said “If the entire course could be taught with SolidWorks incorporated as a drill section maybe, that would really have aided in my understanding throughout the course. It really helps to visualize and interact with models.”

One of many issues at the time of this writing is the COVID-19 pandemic. If full participation in person were possible, the module could be learned in the computer labs much easier, especially for those that cannot participate in person given the effects of the pandemic. As a workaround, Citrix is used to allow students to remotely access this software. This is a difficult method to use since simulations run through Citrix can require anywhere between 10 and 40 minutes to complete a study. As stated in the feedback, some students opted to go to the computer lab and found it much easier than using Citrix. One student suggested “It was a good project, but starting it was hard... My main piece of advice is to emphasize how much better it is in the computer lab rather than on a personal computer. The time difference in comparison was incredibly large.” Other students expressed that they were lost and could not operate the software well, as a student responded “I had [a lot] of trouble accessing this software… I am just not very familiar with the software and it was very difficult for me to operate.” Given this, the toolkit has room to be revamped to meet student needs, especially for those without time to use the toolkit.

At the time of the assignment being delivered, students were busy with a quiz and an exam in Biomechanics, as well as content from other courses. Students in Biomechanics are primarily sophomores and many of the courses they take have high workloads. A student noted "…I had also too many assignations from other classes, which left me with little to no time at all to complete it. I'd like to learn how to use the program in the future because I think is very useful and easy to manipulate after long hours of practice." Considering this, it would be ideal to deliver the toolkit early or extend the timeframe students have access to it.

During the administration period, many students encountered specific issues. Mac users when attempting to access Citrix were unable to download the application from the website. No students specified the operating system issue in the survey, but these issues were fixed during email exchanges. To allow Mac users to use SolidWorks from home, they were instructed to manually download the Citrix Receiver to install on their computers. Students had issues browsing the files, which is an easy problem to troubleshoot as Citrix had shared files between the server and the local computer, meaning students needed more guidance on accessing their files through Citrix. There were few issues that could not be corrected by the systems administrator, meaning that should Citrix be recommended in the future, a Q&A form can be created for easy manual troubleshooting.

5. Future Directions

The simulation toolkit is intended to be a continued project until it becomes more sustainable and user-friendly. The number of simulations available to students will increase so that they have a library of models to choose from to understand key course topics. As well as expanding the toolkit, making clearer instructions, and streamlining the delivery of content to students is a major focus for future work. Data collection can be revamped to include collecting student performance in the course to obtain evidence that the module benefits students academically.

6. Acknowledgements

Without my Honors thesis advisor, Dr. Mostafa Elsaadany, without his guidance and support, this project would not come to fruition. I would also like to acknowledge the help of Jonathan Ward, the BMEG Scientific Research Technician for his assistance in giving students access to materials for this study, as well as troubleshooting. Finally, I would like to acknowledge the help of the Biomechanical Engineering teaching assistants, Anna McCoy and Mary Jia for designing several of the models and providing assistance.

Work Cited

1. Webster, R., & Ottway, R. (2018). Computer-aided design (CAD) certifications: Are they valuable to undergraduate engineering and engineering technology students? *Journal of Engineering Technology, 35*(2), 22-32. Retrieved from https://search.proquest.com/scholarly-journals/computer-aided-design-cad-certifications-are-they/docview/2149602444/se-2?accountid=8361
2. Trent, D. I. (2011). *Efficacy of computer aided drafting (CAD) certifications* (Order No. 3479684). Available from ProQuest Dissertations & Theses Global. (897101419). Retrieved from https://search.proquest.com/dissertations-theses/efficacy-computer-aided-drafting-cad/docview/897101419/se-2?accountid=8361
3. 3D cad design software. (n.d.). Retrieved April 20, 2021, from https://www.SolidWorks.com/
4. Whalen, R., & Patel, C., & Tortoriello, D. J., & Baldacci, J., & Speroni, J. (2013, June), *Augmenting a First-year Design Course with an Undergraduate Student Administered SolidWorks Module* Paper presented at 2013 ASEE Annual Conference & Exposition, Atlanta, Georgia. 10.18260/1-2--19247
5. Rodríguez-Martín, M., Rodríguez-Gonzálvez, P., Patrocinio, A. S., & Martín, J. R. (2019). Short simulation activity to improve the competences in THE Fluid-mechanical ENGINEERING classroom using solidworks® flow simulation. *Proceedings of the Seventh International Conference on Technological Ecosystems for Enhancing Multiculturality,* 72-79. doi:10.1145/3362789.3362809
6. Fadda, D., & Rios, O. (2019, June), *Online Computer-aided Design Class* Paper presented at 2019 ASEE Annual Conference & Exposition , Tampa, Florida. 10.18260/1-2--33144
7. Citrix: People-centric solutions for a better way to WORK - Citrix. (n.d.). Retrieved April 20, 2021, from https://www.citrix.com/
8. Questionnaire design tip sheet. (n.d.). Retrieved April 20, 2021, from https://psr.iq.harvard.edu/book/questionnaire-design-tip-sheet
9. Dr Faiz Uddin Ahmed Shaikh (Lecturer) (2012) Role of commercial software in teaching finite element analysis at undergraduate level: a case study, Engineering Education, 7:2, 2-6, DOI: 10.11120/ened.2012.07020002
10. Feng, W., Yurong, M., Yaqiong, J., Dan, L., & Haifei, L. (2020). Application of ansys finite element analysis in teaching of mechanics of materials. *E3S Web of Conferences, 198*, 01049. doi:10.1051/e3sconf/202019801049
11. Yi Wu, A. Khalilollahi and P. Martone, "Incorporating FEA in an undergraduate biomechanics course," *2016 IEEE Frontiers in Education Conference (FIE)*, Erie, PA, USA, 2016, pp. 1-3, doi: 10.1109/FIE.2016.7757627.

12. Taleyarkhan, M., Dasgupta, C., John, M. G., & Magana, A. J. (2018). Investigating the impact of using a CAD simulation tool on students' learning of design thinking. *Journal of Science Education and Technology*, *27*(4), 334-347. doi:http://dx.doi.org/10.1007/s10956-018-9727-3

Appendix I: Survey

BMEG 2813 - Simulation Toolkit

Q1 First and Last Name

____

Q2 Email address (ex. registra@uark.edu)

____

Q3 Do you have previous experience in design (CAD or otherwise)?

- Yes (1)
- No (2)

Q4 Do you have previous experience in CAD programs?

- Yes (1)
- No (2)

Q5 Do you have previous experience in SOLIDWORKS?

- Yes (1)
- No (2)

Q6 Do you have previous experience using SOLIDWORKS Simulation?

- Yes (1)
- No (2)

Q7 How many of the videos did you watch?

▼ 1 (1) ... 5 (5)

Q8 How difficult was it to navigate through SOLIDWORKS?

- Extremely easy (1)
- Somewhat easy (2)
- Neither easy nor difficult (3)
- Somewhat difficult (4)
- Extremely difficult (5)

Q9 How difficult was it to follow along with the instructional videos?

- Extremely easy (1)
- Somewhat easy (2)
- Neither easy nor difficult (3)
- Somewhat difficult (4)
- Extremely difficult (5)

Q10 Were you able to replicate the simulation study?

- Yes (1)
- No (2)

Q11 Were you able to analyze and compare your results?

- Yes (1)
- No (2)

Q12 Did you encounter any kind of error?

- ◯ Yes (1)
- ◯ No (2)

Q13 Before or after viewing any content, how interested were you in CAD software (SOLIDWORKS)?

	Extremely (1)	Very (2)	Moderately (3)	Slightly (4)	Not at all (5)
BEFORE (1)	◯	◯	◯	◯	◯
AFTER (2)	◯	◯	◯	◯	◯

Q14 How confident are you in the following?

	Extremely (1)	Very (2)	Moderately (3)	Slightly (4)	Not at all (5)
SOLIDWORKS (1)	◯	◯	◯	◯	◯
Creating Simulations (2)	◯	◯	◯	◯	◯
Analyzing Simulations (3)	◯	◯	◯	◯	◯

Q15 How useful is SOLIDWORKS Simulation?

- ◯ Extremely useful (1)
- ◯ Very useful (2)
- ◯ Moderately useful (3)
- ◯ Slightly useful (4)
- ◯ Not at all useful (5)

Q16 How likely were you to use SOLIDWORKS before and after?

	Extremely likely (1)	Somewhat likely (2)	Neither likely nor unlikely (3)	Somewhat unlikely (4)	Extremely unlikely (5)
BEFORE (1)	○	○	○	○	○
AFTER (2)	○	○	○	○	○

Q17 Please provide any comments or suggestions. Please elaborate and be detailed.

Appendix II: Assignment Instructions

BMEG 2813 – Biomechanical Engineering

Extra credit

Simulation toolkit for Biomechanical Problems

A simulation toolkit is available here: https://uark.box.com/s/u1aq5yt2nnfat5vg3t8eh4d9589cc1n5. You have been given access to this folder using your UARK email. This is our intellectual property, and you are not allowed to publish these documents or share them with anyone.

In order to receive the maximum amount of the 2% extra credit (from the overall course grade), you will need to do the following:

1. You have to watch the following demos (We have access to check that you have watched the full videos):
1.
1.
   I. What is Solidworks simulation
   II. Simulation access
   III. Statics - Lecture 3 problem 6
   IV. Homework 6 problem 2
   V. Homework 7 problem 5
2. Download SolidWorks simulation files and access at least 7 from the 14 simulations in the box folder.
3. Take screenshots from the Solidworks simulations showing the simulation results.
4. Add the screenshots to a word document and upload to Blackboard under the Simulation Toolkit Extra Credit assignment
5. Complete 5-10 minutes Qualtrics survey (the survey link will be provided to you on Blackboard).