Curriculum Service Learning Workshop for STEM Outreach

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PUBLICATIONS (Dr. Alam has published over 20 refereed journal papers/conference proceedings.)

List of Selected Peer-Reviewed Publications:

1. M.S. Alam, M.A. Wahab and C.H. Jenkins, "Mechanics in Naturally Compliant Structures," Journal of Mechanics of Material, 39, pp.145-160, 2007. 2. M.A. Wahab, M.S. Alam, Su-Seng Pang and Jerry Pack, "Stress analysis of non-conventional composite pipes" Journal of Composite Structures, 79(1), 2006, pp. 125-132. 3. M.A. Wahab, M. S. Alam, M.J Painter and P.E. Stafford, "Experimental and Numerical Simulation of Restraining Forces in Gas Metal Arc Welded Joint," American Welding Journal (Research

Supplement) 85(2), February, 2006. 4. M.S. Alam and M.A. Wahab, "Modeling of Fatigue Crack Growth and Propagation Life of Joint of Two Elastic Materials Using Interface Elements," International Journal of Pressure Vessel and Piping, 82, 2005, pp. 105-113. 5. M.S. Alam and C.H. Jenkins, "Damage Tolerance Design in Naturally Compliant Structures," International Journal of Damage Mechanics, 14(4), 2005, pp. 365-384. 6. M.S. Alam and M.A. Wahab, "Finite Element Modeling of Fatigue Crack Growth in Curved-Welded Joints Using Interface Elements," Journal of Structural Integrity & Durability, 1(3), 2005. 7. M.A. Wahab, J.H. Park, M.S. Alam and S. S. Pang, "Effect of Corrosion Prevention Compounds on Fatigue Life in 2024-T3 Aluminum Alloy," Journal of Material Processing Technology, 174, pp. 211-217, 2006. 8. M. A. Wahab and M.S. Alam, "The Significance of Weld Imperfection and Surface peening on Fatigue Crack Propagation Life of Butt Welded Joints," Journal of Material Processing Technology, 153-154, 2004, pp.931-937. 9. M.S. Alam and M.S. Baree, "An Estimation of Wave Spectrum by Applying Fast Fourier Transform," Journal-Institution of Engineers, Malaysia, 61(2), June, 2000. 10. M.S. Alam and M.A. Wahab, "A New Technique for Modeling of Fatigue Crack Growth in Welded Tubular Joints and Structures," Proceeding of the International Mechanical Engineering Congress and Exposition, Florida, USA, 2005. 11. M.S. Alam and M.A. Wahab, "An Analysis of Fatigue and Micro Characteristics of Weld-Repaired Joints of Al-6061 Plates" International Conference on Computational & Experimental Engineering and Sciences, 2007, Miami, Florida. 12. M.A. Wahab and M.S. Alam, "Finite Element Prediction of Distortion and Residual Stress in Gas Metal Arc Welded Joint," Proceeding of 11th Annual International Conference on Composites Engineering, 2004. 13. M.S. Alam, M.A. Wahab and C.H. Jenkins, "Reverse Engineering of Naturally Compliant Structures, Computer Modeling in Engineering and Science, in press. 14. M.A. Wahab, M.S. Alam, S.S. Pang, Jerry Alan Peck and R.A. Jones, "Buckling of Polygonal Fiber Reinforced Polymer (FRP) Composite Tubes," Proceeding of 14th Annual International Conference on Composites Engineering, Boulder, Colorado, 2006. 15. M.S. Alam, Guoqiang Li and Walid R. Alaywan, "Experimental and Numerical Analysis of Flexural Properties of FRP Composite Sandwich Beam," Proceeding of 14th Annual International Conference on Composites Engineering, Boulder, Colorado, 2006. 16. M.S. Alam and M. A Wahab, "The Effect of Torsional Interaction of a Circular Porosity and a Solidification Crack on Fatigue Crack Propagation Life of Butt Welded Joints," Proceeding of 10th Annual International Conference on Composites Engineering, New Orleans, 2003. 17. M.S. Alam and M.A. Wahab, "The Significance of Weld Imperfection and Surface peening on Fatigue Crack Propagation Life of Butt Welded Joints," Proceeding of the International Conference on Advanced in Material and Processing Technology, Dublin, Ireland, 2003, pp.990-993. 18. C.H. Jenkins and M.S. Alam, "Use of Experimental Mechanics in Biomimetic Structural Design," Society of Experimental Mechanics Annual Conference, Milwaukee, WI, 2002. 19. M.S. Alam and M.S Baree, "A Regression Analysis for the Derivation of Wave Spectrum Formula," Proceedings of the Sixth Annual Paper Conference, Institute of Engineers, Bangladesh, 2000. 20. M.S. Alam and M.S Baree, "Prediction of Rolling Motion of a Ship at Hiron Point of the Bay of Bengal," Proceedings of the 3rd International Conference on Fluid Mechanics and Heat Transfer, Dhaka, Bangladesh, December 1999.

OTHER QUALIFICATIONS/EXPERIENCES Dr. Alam has six years research and thirteen years industrial experience. He has extensive technical and research intelligence, training and experience in structural mechanics, mechanical system design for oil & gas industries for more than fifteen years. He has proven capacity for employing Finite Element and classical stress analysis techniques in design evaluation of offshore and subsea structures. He has strong background on the design, analysis and evaluation of offshore platforms and subsea structures, equipment as per API, ASME, ABS, DNV and other standards. Dr. Alam has very strong proficiency in finite element analysis (static (linear, nonlinear), dynamic, Impact, Thermal, CFD) using ANSYS and ABAQUS. He did design and analysis of offshore and subsea product for BP, Exxon, Total, Murphy, Statoil, etc. oil companies.

SYNERGISTIC ACTIVITIES 1. Dr. Alam has received 2 research grants from two agencies to support his research prior to join at TAMUK. 2. Dr. Alam applied for several grants to several agencies prior to join at TAMUK: Defense Advanced Research Projects Agency (DARPA), Office of Naval Research (ONR), Louisiana Space Consortium (LaSPACE). 3. Dr. Alam has reviewed over 10 papers for six archival journals: Composites B: Engineering, Engineering Structures, International Journal of Damage Mechanics, Journal of Polymer Composite, Journal of Composite Material, Proceeding of the 2006

ASEE Gulf-Southwest Annual conference 4. He is an active member of American Society of Mechanical Engineers (ASME).

Dr. Farzin Heidari, Texas A&M University, Kingsville

Dr. Heidari currently serves as Associate Professor of industrial management and technology at Texas A&M University, Kingsville. Dr. Heidari has 28 years of experience in manufacturing and CAD/CAM/CNC courses. He is currently serving as the Graduate Coordinator for the Industrial Management program.

Curriculum Service Learning Workshop for STEM Outreach (Evaluation)

Introduction

STEM education and outreach activities have implemented various contents and frameworks, including curriculum service learning that is a powerful teaching and learning methodology. When tied to classroom curriculum, service-learning can deliver important academic, civic and social outcomes. When students are well-prepared for the service experience, they attain the impact of service learning (Chicago Public Schools report, 2016). A service learning activity was developed by bringing a virtual environment, i.e., Home I/O, into classrooms (Riera, Emprin, Annebicque, Colas & Vigario, 2016), to prevent students making dangerous mistakes, especially if the students are not familiar with the sophisticated equipment as the STEM education is expected to anticipate potential student errors and to allow students to learn from mistakes (Boy, 1996). As the computer based learning can be a risk free, affordable, and easy to replicate educational tool, simulation software tools can replace physical industrial plants in automation education (Callaghan, McCusker, Losada, Harkin & Wilson, 2009), effectively allowing a safe training environment for participants, e.g., high school students, who might not have sufficient resources for necessary training to be around the laboratory equipment during potential STEM outreach collaboration with K-12 educational institutions. Proper collaboration and associated curriculum service learning activities, prospective K-12 students are better engaged in universityactivities, better connected to the college culture, and are in a position to acquire deeper understanding of STEM disciplines. The effective college and K-12 partnerships are shown to be the likely instrumental reason for the student knowledge acquirement (Fonseca et al., 2016). In addition, the student engagement may not be enhanced if there is no student motivation, as important informal learning aspects were discussed and were said to be associated with skill developments in urban planners and architects (Gray, Nicosia & Jordan, 2012). It has been observed that high school student experiences on the college education prepares the students for a professional career environment and for following their potential role models in STEM fields (Dakeev, Heidari &, Elukurthi, 2016). Moreover, knowledge is often acquired via collaboration, and people become learners and teachers alike (Banks, Au, Ball, Bell, Gordon, Gutierrez & Heath, 2007), indicating another appeal for a curriculum service learning type activity that is efficient for both STEM outreach and college student superior undergraduate learning experiences and higher confidence and motivation in their individual abilities as well as with their technical backgrounds for their respective STEM fields (Dakeev, Mazumder, Yildiz & Baltaci, 2015). As suggested (Reisel, Walker & Cancado, 2016), engineering undergraduate students change their discipline after learning more about their majors, implying that the undergraduate engineering students are dependent on the material content to remain in their respective STEM disciplines.

STEM outreach activities have utilized various concepts during curriculum service learning activities, such as 3D software and associated computer-aided design exercises. The expected proficiency level requires effective as well as early intervention of K-12 students' technology education to motivate towards STEM disciplines. As high school students are inquisitive, imparting an enthusiasm in timely manner could potentially motivate them to STEM disciplines. The adaptation of teaching contents in hands-on 3D modeling and 3D printing technology has emerged as an engagement tool for students (Fonseca, Valls, Redondo & Villagrasa, 2016), in addition to other popular robotics and computer architecture concepts (Yilmaz, Ozcelik, Yilmazer & Nekovei, 2013; Yilmaz, Yilmazer, Guillen & Torres, 2013, Yilmaz, Ren, Custer & Coleman, 2010), with the successful implementation of undergraduate mentorship services for the prospective middle- and high-school students.

This 3D workshop study investigates the efficacy of a curricular service learning activity for STEM outreach. The project goal is to attract high school students to STEM disciplines via a collaborative workshop with a hands-on three-dimensional (3D) modeling and 3D printing activity. One of the objectives of the current 3D workshop is to expose to the participating high school students to college-level STEM environments, where the participants are able to discuss the potential impacts of an inaccurate design of a manufactured part on the respective engineering implementation, company budget, etc., as a scaled-down version of their expected STEM curriculum. This project also involves high school students from Corpus Christi School of Science and Technology (CCSST) in a collaborative learning in a university environment with Texas A&M University-Kingsville students. In addition, this hands-on project offers undergraduate and graduate student mentorship to participating high school students on 3D modeling and 3D printing, with an implied guidance for STEM fields. This active learning method will help mainly achieve college environment experience through interaction between high school and college students for effective STEM outreach, with additional benefits for superior undergraduate student comprehension through active mentoring of high school students and supervisory role experiences for graduate students as team leaders. The project also aimed to study the changes in participating undergraduate student interests to consider changing their majors/programs within a year of the workshop completion. The project involved transportation of CCSST student participants to Texas A&M University-Kingsville for four weeks, with three - hour hands-on experience each week. The students learned basics of 3D modeling and 3D printing, participated in mixed group STEM discussions, and experienced college-level class environment, including professor-college student interactions.

Classroom Background

A curriculum service learning workshop was organized at Texas A&M University-Kingsville to examine college and high school students' motivation and engagement in both institutions towards STEM fields. The project faculty members collaborated with a local high school administration to identify potential students. The participating school has a program for students that are interested in STEM areas, where students are encouraged to participated in STEM related activities. A project faculty member and four graduate students visited the high school to present and discuss the proposed workshop benefits to students in high school's STEM program. The interested students were transported to the university to blend with the undergraduate engineering students during the junior and senior level computer aided design classes. Out of twenty high school applicants, seventeen (eleven female & six male) were able to participate in the activity. Additionally, a total of 17 (14 males and 3 females) and four graduate (2 male & 2 female) students participated to the 3D workshop activity (Figure 1).

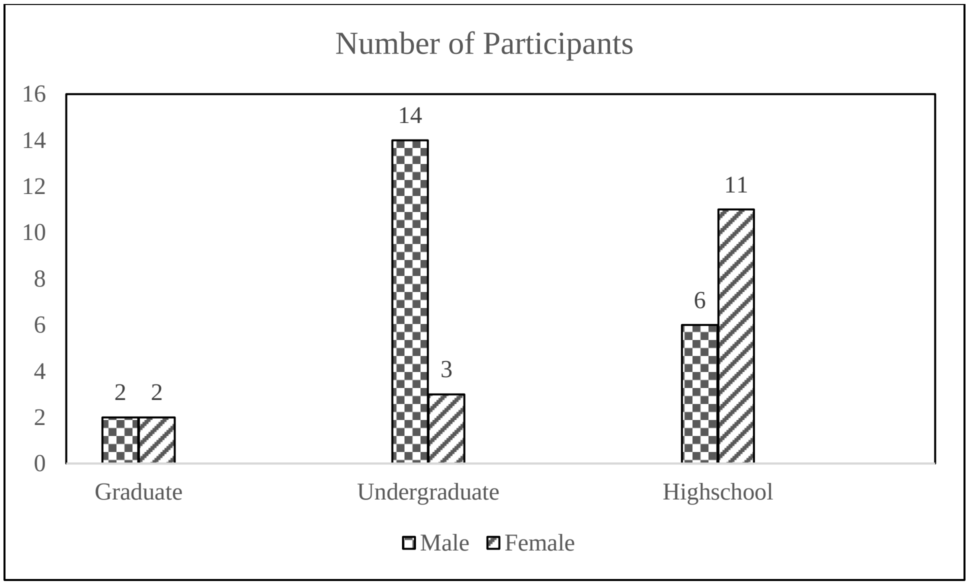

Figure 1. The number and gender of 3D Workshop high school, undergraduate, and graduate participants

The workshop curriculum included basics of 3D modeling using Creo Parametric software and 3D printing with CubePro 3D printers, during the graphics and modeling classes when the high school participants were transported to Texas A&M University-Kingsville to participate and could return to their other extracurricular activities.

The workshop activity was comprised of four phases that comprehensively covered basic sketching, 3D modeling, drawing, assembly, and 3D printing concepts. Each phase was separated with learning, mentorship, and an independent skill test sections. After the project faculty member explained the concept and showed the necessary skills to develop parts, the participating high school students led the developments and worked with the undergraduate students on a number of exercises and discussed the spatial visualization of the part as well as the final model. Each section of each phase ended with the independent part development to evaluate the project development steps and learning outcomes of the high school students. Undergraduate students received extra credit points if the high school students in their respective groups successfully completed the task. This reward mechanism was additional extrinsic motivation for undergraduate students to effectively mentor the high school students. The roles of graduate students were strictly limited to providing guidance and suggestions that led to possible solutions for the problem, without solving or tackling the problem. Additionally, the graduate students continuously monitored the progress of student involvement in discussions, independent work activity, and time keeping as shown in Figure 2. As the main interaction of the activity is expected to take place between the CCSST participants and undergraduate students, the graduate students are assigned a supervisory role to oversee the learning activities of both undergrads and high school students, and provide necessary guidance only when necessary. As undergraduate and graduate students at Texas A&M University-Kingsville are required to take relevant laboratory safety trainings, the participating high school students were exposed to safety guidelines during the workshop orientation and were provided minimal-risk hands-on experiences.

Figure 2. High school, undergraduate, and graduate students are involved in collaborative 3D workshop activities

The Workshop

The participating high school administration transported 17 project participants at 11^{th} and 12^{th} grades to Texas A&M University-Kingsville (TAMUK), once per week during the regular school hours, throughout four weeks, during the Spring-2016 Semester.

During the first week, the students were introduced to safety guidelines, to each other, and blended (college and high school) student groups were formed. Each week the department chair, various faculty members (Figure 3), as well as the registrar representatives interacted with the students and discussed different available engineering programs, admission, financial aid, and daily university operations. As the students departed the university, all groups were given additional assignments to maintain their 3D modeling skills.

Figure 3. The engineering faculty member presenting various available programs at university

During the second week, the students learned 3D tools such as extrusion, revolves, ribs, shell components of part development. Each part was uploaded in a cloud storage for easy accessibility to complete later, if necessary.

During the third week, the class assembled various parts they had developed in the previous weeks. This assembly practice allowed the students to review and correct their previously developed parts in case of the assembly error. Majority of the students were excited to see how their parts matching seamlessly during the assembly stage. By this time, the participating high school students had developed satisfactory 3D modeling skills, based on the visual examination of parts, to explain potential sources of mismatching assembly parts (Figure 4).

Figure 4. CCSST and TAMUK students examining the accuracy of modeled parts for the final assembly

During the fourth week, the students printed their final drawings for the previously developed parts and physically inspected them against the expected project specifications and for the successful completion. Additionally, all participants developed individual keychains with their names, or any text they preferred, in Creo Parametric, and prepared for 3D printing. All students 3D printed their keychains as a souvenir and the high school students expressed their experience and opinions in a final presentation (Figure 5).

Figure 5. CCSST student participants presenting their overall experience

Upon the successful completion of the workshop activity both in terms of technical and interpersonal skill achievements, individual participant certificates were presented to both high school students and the school administration by the respective department chair (Figure 6).

Figure 6. All CCSST school participants received their certificates for participation

Questionnaire and Data Analyses

A paper survey was distributed to all thirty-eight students at the beginning and at the end of the workshop activity to collect pre-and post-data. The survey was prepared to reflect the relevant previous studies and to understand the workshop impact with respect to its goal and included a number of questions to indicate whether the activity improved student technical and skill learning (high school students), mentorship confidence (undergraduates), and ability to teach 3D modeling class independently (graduates). A total of 38 students participated in the study (22 males and 16 females). The participants indicated that none of the high school nor undergraduate students were exposed to 3D printing previously, and only 1 high school student was familiar with 3D modeling concepts. At the beginning of the workshop, the students were asked to estimate their degree of knowledge, usability, and experience in 3D modeling and specifically in 3D printing. To design the pre-and post-tests, a structured test was distributed to the high school, undergraduate, and graduate students. All the questions were scored on a 5-point Likert scale (1=never or strongly disagree, 5=always or strongly agree). The project investigators collectively analyzed the project survey data with the IBM's SPSS statistical package to compare mean outcomes.

The first t-test in 3D modeling experience provided all (100%) high school students significantly learned a new concept ($p=0.00< 0.05$ alpha level, mean pretest=1.8, mean posttest=2.90, SDpretest=0.78, SDposttest=0.30) according to the survey question “Describe your competency in 3D Modeling”. Additionally, all (100%) high school students significantly improved their knowledge and experience in 3D printing ($p=0.00<0.05$ alpha, mean pretest=1.55, mean posttest =2.36, SDpretest=0.52, SDposttest=0.50). The questions related to the purpose of attending the activity did not change ($p=0.16>0.05$alpha, mean pretest=4.1>3.63, SDpretest=0.33, SDposttest=0.92) as indicated in Table 1.

Table 1: The Pre-and Post-Survey results for High School Students

Description	Type	Av.Score	Sig.2-tailed	SD
Describe your competency in 3D Modeling	Pretest	1.88	0.00	0.78
	Posttest	2.9		0.30
Describe your competency in 3D printing	Pretest	1.55	0.00	0.52
	Posttest	2.36		0.50
The purpose of attending	Pretest	4.11	0.16	0.33
	Posttest	3.63		0.92

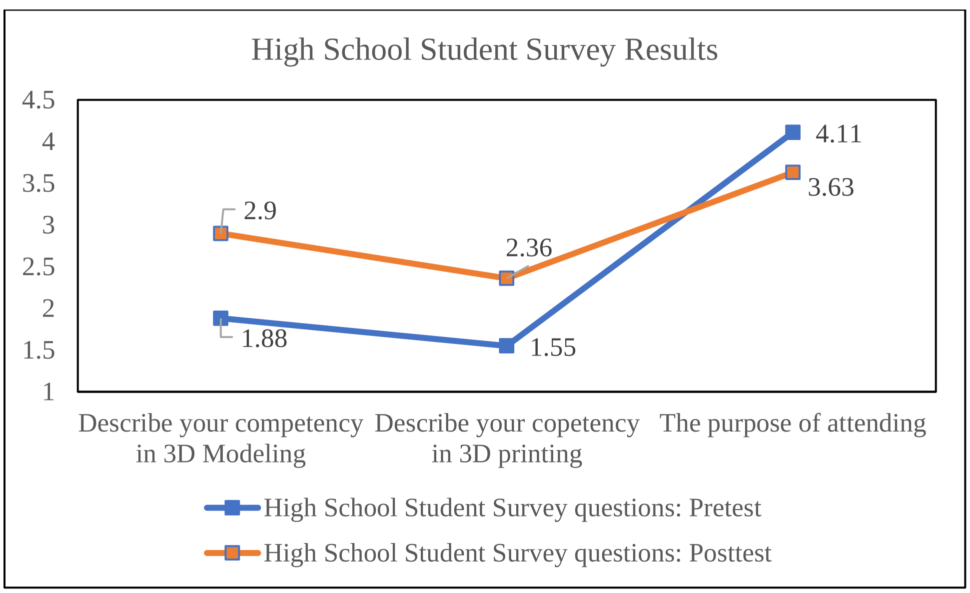

Figure 7: Visual illustration of Table 1 for Pretest and Posttest results for high school questionnaire

“The purpose of attending” statement in Table 1 was worded differently for the pretest and posttest surveys for high school students to measure the workshop impact on the participants. The pretest questions stated “What are your expectations from this 3D workshop?”, and the posttest question stated “Please indicate how satisfied were you with the 3D Workshop” as shown on Figure 7. The second test for undergraduate students were formulated differently than the high school participants to identify advantages of working in a mixed group in this voluntary study. The pre-and post-tests were conducted to evaluate the mentorship skills, and experience of undergraduate students. Out of 17 initial undergraduate pretest participants, only 9 could complete the posttest survey due to missing the class for athletics and other similar reasons. The t-Test results of the undergraduate student self-reporting strongly suggest significant improvements in their general mentorship skills (p=0.01<0.05alpha, mean pretest=2.46<mean posttest=3.67, SDpretest=0.66, SD posttest=1.32). Additionally, the students indicated that the mentorship to high school participants influenced their understanding of the subject matter (p=0.00<0.05alpha, mean pretest=2.38< mean posttest=3.33, SD pretest=1.45, SD posttest=1.32). However, the undergraduate students did not find the mixed group tutoring significantly improved their specific 3D modeling mentorship skills (p=0.35>0.05alpha, mean pretest=1.31<meant posttest = 1.56, SD pretest=0.52, SD posttest=0.50), as implied by data in Table 2 and Figure 8.

Table 2: The Pre-and Post-Survey results for Undergraduate Students

Description	Type	Av.Score	Sig.2-tailed	SD
Describe your general mentorship skills	Pretest Posttest	2.46 3.67	0.01	0.66 1.32
Describe your general mentorship skills in 3D Modeling	Pretest Posttest	1.31 1.56	0.35	0.52 0.50
Mentorship improves understanding	Pretest Posttest	2.38 3.33	0.00	1.45 1.32

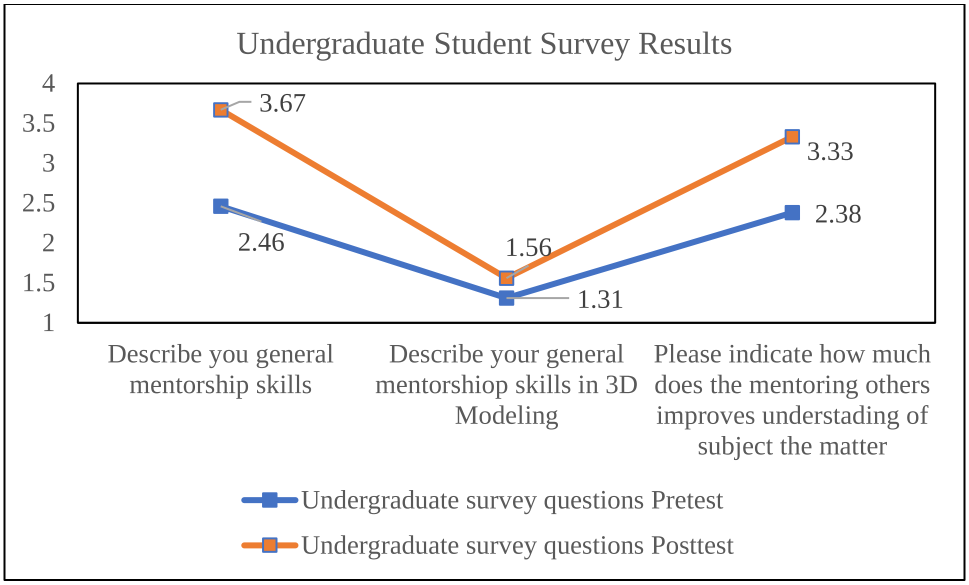

Figure 8: Visual illustration of all three survey questions for undergraduate students and Table 2 data for Pretest and Posttest results for undergraduate questionnaire.

The third test was for 4 graduate students, who were assigned only to oversee and supervise the project activity. The survey asked the level of 3D modeling experience and the comfort level of the students in teaching 3D modeling classes independently. The results of the analyses, as given in Table 3 and Figure 9, indicate that the graduate students improved their 3D modeling experience as well as teaching confidence (Figure 3), however, did not have significant improvement on the 3D modeling experience (p=0.18>0.05alpha, mean pretest=2.0<meant posttest=2.5, SD pretest=0, SD posttest=0.57). Additionally, the workshop activity supervision did not have significant effect on the graduate students' teaching confidence (p=0.18>0.05alpha, mean pretest =2.25 < mean posttest =2.75, SD pretest=0.5, SD posttest=0.5).

Table 3: The Pre-and Post-Survey results for Graduate Students

Description	Type	Av.Score	Sig.2-tailed	SD
3D modeling experience	Pretest	2.00	0.18	0.00
	Posttest	2.5		0.57
Teaching confidence	Pretest	2.25	0.18	0.50
	Posttest	2.75		0.50

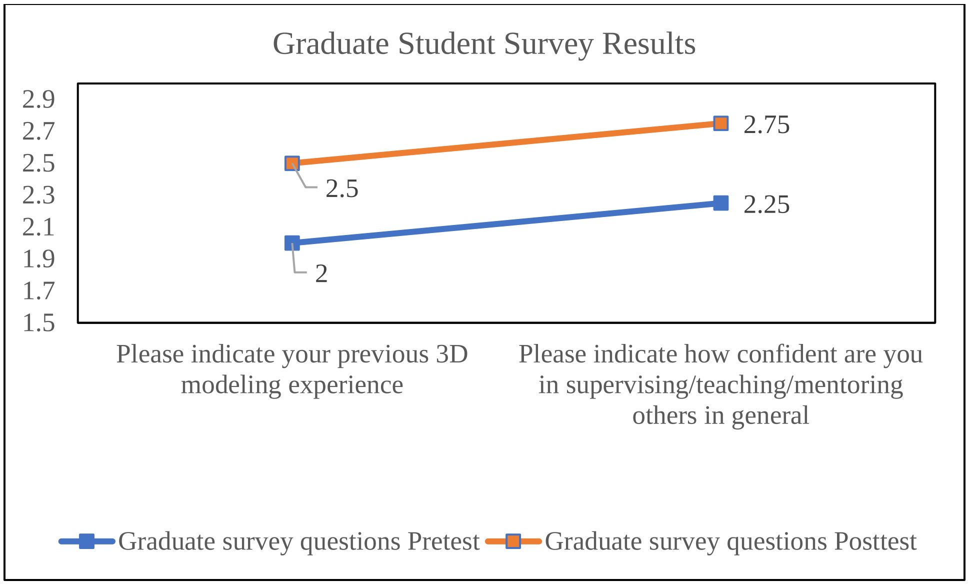

Figure 9: Visual illustration of all two questions for graduate students and Table 3 data for Pretest and Posttest results for graduate questionnaire

Overall, the study results reveal that the participating students' means, from both high school and the university, positively increased in various surveys, indicating the success of the activity. In addition, the participant testimonials reflected the project accomplishments, as one high school student said "-We are highly satisfied with the teams allocated to us, we had a real time experience with 3D Modeling & 3D Printing", one undergraduate student expressed "We have improved our mentoring skills, it was a good opportunity for us", and a graduate student wrote "It was a good experience for me to be able to coordinate in conducting this workshop, it provided me the opportunity to get in depth knowledge about the subject".

Conclusion

One of the objectives of the study was to attract high school students to STEM disciplines via a 3D modeling and printing activity. At the end of the project, all high school student participants submitted application to various engineering programs within the university, indicating a strong link between the workshop and its expected outreach impact. Another objective of this study was to investigate whether the mixed group activity in learning 3D modeling and 3D printing would improve the learning, experience, motivation, and mentorship skills of students in high school and college levels. The assessment comments illustrate that the high school participants were excited about the allocated group members, which included college undergraduate students. The successful completion of high school student participant independent project assignment and associated mentorship seemed to be an extrinsic motivation to receive an extra credit for the undergraduate student mentor. An undergraduate student indicated that his/her mentorship skills improved with this collaborative learning activity. Additionally, a graduate student expressed that the study provided a superior opportunity to understand the 3D modeling and printing concepts.

The evaluation results also indicate that the collaborative learning between high school and engineering undergraduate students significantly improves their 3D modeling, 3D printing, and tutoring skills. The average experience and confidence levels of graduate students changed insignificantly when the graduate students provided guidance to the mixed group of learners. Although the admission rate for high school student participants currently available, the participating students indicated a great deal interest in the future collaborations as well as consideration of the institutions and would recommend to their peers.

Authors are seeking for more collaborative learning possibilities with other high schools locally. Higher number of participants with different interest levels of STEM will be pursued for stronger results in future activities.

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