How an Augmented Reality Tool May Benefit to Improve Spatial Cognition

Ulan Dakeev
Texas A&M University–Kingsville
Ulan.dakeev@tamuk.edu

Recayi Pecen
Sam Houston State University
regpecen@shsu.edu

Farzin Heidari
Texas A&M University–Kingsville
farzin.heidari@tamuk.edu

Faruk Yildiz
Sam Houston State University
fxy001@SHSU.EDU

Shah Alam
Texas A&M University–Kingsville
shah.alam@tamuk.edu

Abstract

This project was developed to restructure ITEN 1311: Technical CAD, offered in the fall 2017 semester. The objective of the project was to develop spatial orientation skills for freshmen and junior-level engineering students. The redesigned course introduced 3D printing of the objects as well as an augmented reality (AR) tool for visual representation of two-dimensional drawings in 3D. The objective of this study was to explore if there was a significant difference between the conventional way of classroom delivery methods (demonstration of objects' orthogonal views) and analyzing the prototype in AR. Each student developed a 3D model and 3D print as an individual project. Moreover, groups of students collaborated to develop an assembly of their individually modeled parts within the software. Statistical t-test analysis was conducted to report the influence of the augmented reality application to improve spatial orientation skills for incoming freshman engineering students. This project may benefit the IAJC community to restructure their introductory computer-aided design courses for enhancement of the spatial cognition of students. The results showed the students were able to develop the 3D model of a prototype part when they were exposed to the AR tool prior to the start of the exercise.

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Introduction

Spatial cognition is the process of information and skills that could be improved via appropriate pedagogical strategies (Perez-Fabello, Campos, & Felisberti, 2018). The development of better working strategies to improve students' performance in first-level engineering computer-aided design courses could be an effective educational tool. Through virtual reality (VR) and augmented reality (AR), users navigate and interact within three-dimensional environments (Dakeev, Pecen, Yildiz, Alam, & Heidari, ASEE, 2018). AR provides the ability to rotate objects as well as experience immersive interaction on a virtual overlaid environment. Since spatial skills are one of the strongest predictors of success in using CAD software (Dakeev, Pecen, Yildiz, & Heidari, CIEC, 2018), students are also likely to draw correct structures and diagrams when they have high spatial orientation scores (Pribyl & Bodner, 1987). Additionally, Sorby and Baartmans discovered considerable improvement in spatial cognition skills in both men and women when augmented reality and virtual reality tools were used (2000). This study explores how an AR tool influences the spatial cognition of first year engineering students in introductory CAD courses.

Students were introduced to 3D modeling software at the beginning of the academic semester with basic concepts and modeling tools of the software. The students analyzed a pre-defined part to comment on various views such as front, right side view, top, bottom, etc. After completing their analysis, the students participated in a virtual tour of the part (in an open field) to circulate the part and see the identified views. Each student developed the same part in 3D modeling software, 3D printed the prototype, and manufactured individual group project parts on portable CNC equipment. The final 3D printed product was compared to the pre-defined (original) part for accuracy. Three deliverables, 3D modeled part, 3D printed object, and CNC-cut product, defined the successful completion of the project. Overall, project reflection summaries were captured from students' experiences.

Spatial cognition and 3D modeled outcomes, from orthogonal views, are required skills every engineer must possess in the automotive industry (Sorby, Casey, Veurink, & Dulaney, 2013). Engineering technology students may hold positions such as quality engineers, manufacturing engineers, plant or workshop supervisors, design engineers, continuous improvement coordinators, etc., all of which require explicit understanding of 3D models and their blueprint readings prior to manufacturing. Therefore, the redesigned course may prepare our students for their future professional lives and give them a stronger competitive advantage.

Methodology

Researchers developed an augmented reality tool for android devices to illustrate the three-dimensional representation of the model from its orthogonal (2D) views. The students downloaded the AR tool called "Midterm_AR" (Figure 1) from the Google play market to direct the phone’s camera onto the reference blueprint provided to the student (Figure 2). The authors collected pre- and post-test data to investigate how significantly the proposed method impacted the spatial orientation skills of students, when compared to the conventional method of teaching. At the beginning of the fall 2017 semester, the students participated in an online spatial cognition test (123test.com) to observe their current standing in spatial orientation.

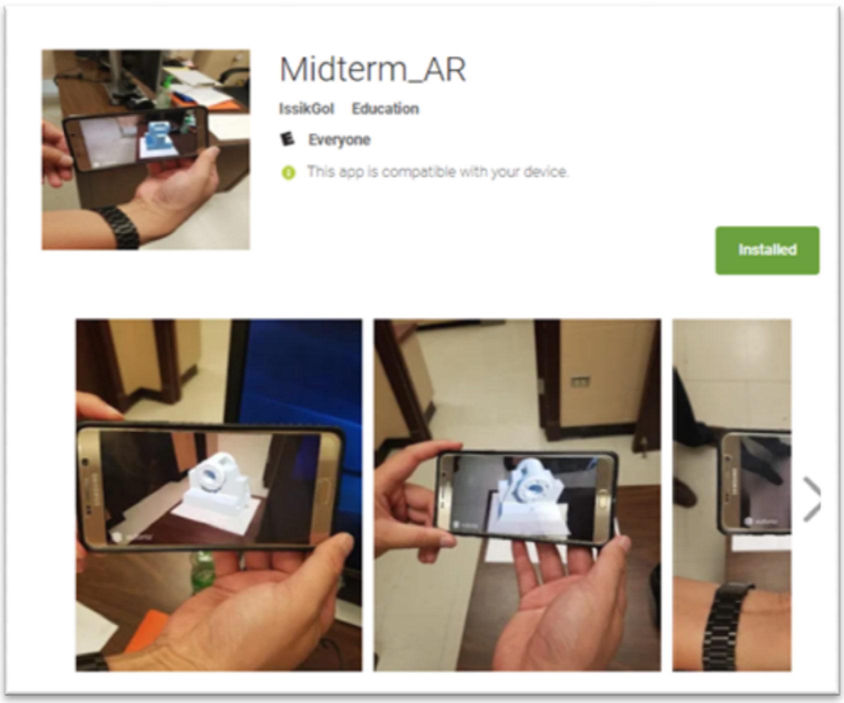

Figure 1. Augmented reality tool for visualization from a blueprint.

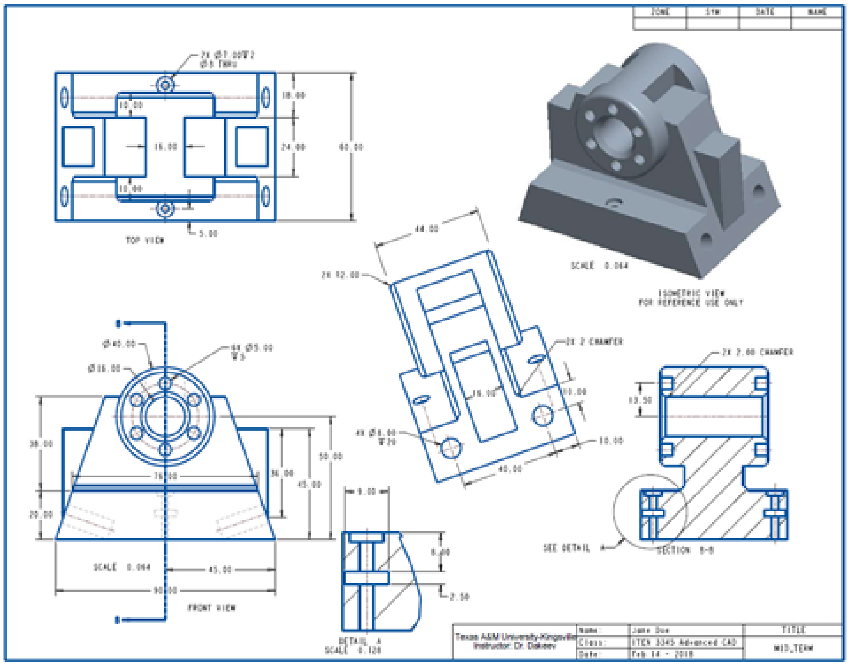

Figure 2. Orthogonal view of a blueprint as an image target for the AR tool.

The instructor delivered conventional, tutorial-based, lectures to demonstrate both two-dimensional sketch and three-dimensional modeling, using 3D tools such as extrusion, revolve, helical sweep, etc. prior to administering the post-test for data analysis. Creo Parametric is one of the most popular 3D modeling programs, with a free academic license available to students, which was one of the factors that the software was chosen for this study. Additionally, Creo Parametric has an embedded augmented reality feature, “Thingworx,” that provides AR experience via Vuforia. Figures 3 and 4 illustrate sample, in-class assignments that students developed as part of the evaluation.

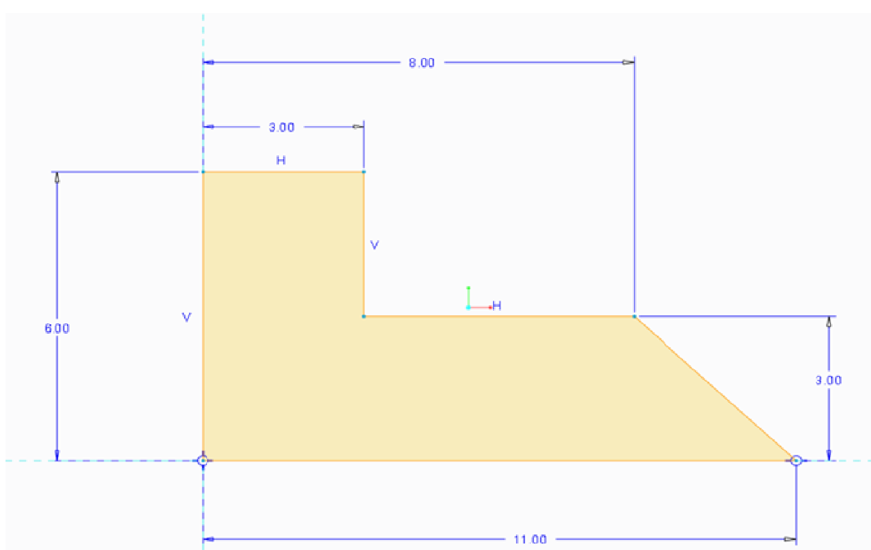

Figure 3. Two-dimensional sketch for Introductory CAD course.

Figure 3 illustrates the orthogonal views of a model, where the students visualize the end product's (the prototype part) two-dimensional features.

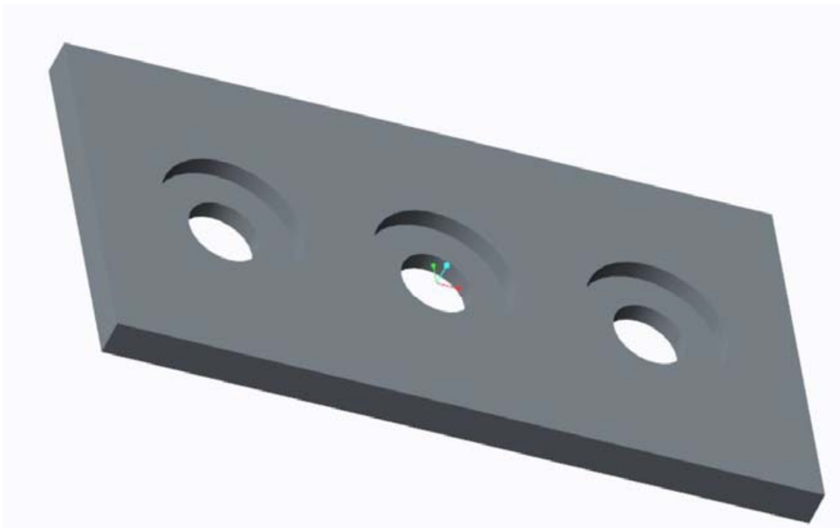

Figure 4. Three-dimensional model for introductory CAD course.

Figure 4 shows the extruded features of a product details within Creo Parametric. In this exercise, students develop both additive and subtractive extrusions of materials. Most students must be able to develop independent 3D models, of moderate complexity (Figure 5), independently and demonstrate their 3D orientation skills.

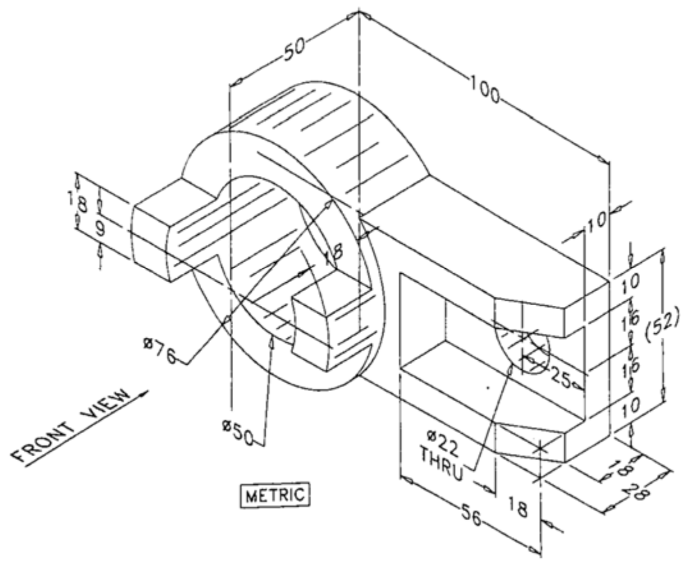

Figure 5. Three-dimensional model after four weeks of the course.

Assessment and Results

The purpose of the study was to investigate how an augmented reality tool may influence the spatial reasoning skills of freshmen/sophomore level engineering students. Additionally, the study explores how the prototyping exercises such as 3D printing and CNC manufacturing influenced student learning. The experimental group's outcomes were compared to the previous CAD courses (fall 2016 and spring 2017), which were delivered in conventional way by the same instructor. Although all 35 students completed their projects successfully, three students needed additional time and coaching to verify their models were accurate. The pre-test survey results, in SPSS, showed the overall mean (mean pre-test=1.42) was less than the post-test results (mean post-test=8.58) when the augmented reality tool was introduced in the discussion, as illustrated in Tables 1 and 2. The paired sample t-test outcome revealed that the introduction of the tool significantly influenced (p value=0.001<0.05 alpha level) student spatial orientation skills. Although the t-test analysis resulted in significant difference between the pre-test and post-test score means, the correlation (r=0.418) revealed that there was a less than 50% correlation between the two average means. This result motivates the researchers to collect more data and investigate whether the new restructured approach improves the correlation of scores.

Table 1. Paired samples statistics.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pretest	1.42	19.00	0.69	0.16
	Posttest	8.58	19.00	0.84	0.19

Some of the project challenges included incorrect orientation of features of the models within the software that extended the project duration for some students. For example, a developed fidget spinner's ergonomic design was reversed during the dimensioning process, which had to be reviewed for further analysis. Class discussion and virtual inspection in augmented reality and the number of other projects were revised and updated accordingly. One hundred percent class satisfaction and engagement suggested that the study was successful, and all projects were submitted on time.

Table 2. Paired samples test.

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pretest - Posttest	-7.16	0.83	0.19	-7.56	-6.76	-37.40	18.00	0.00

The second phase of the study was to manufacture the prototype for physical inspection and 3D print it. Two 3D printed prototypes are illustrated in Figure 6.

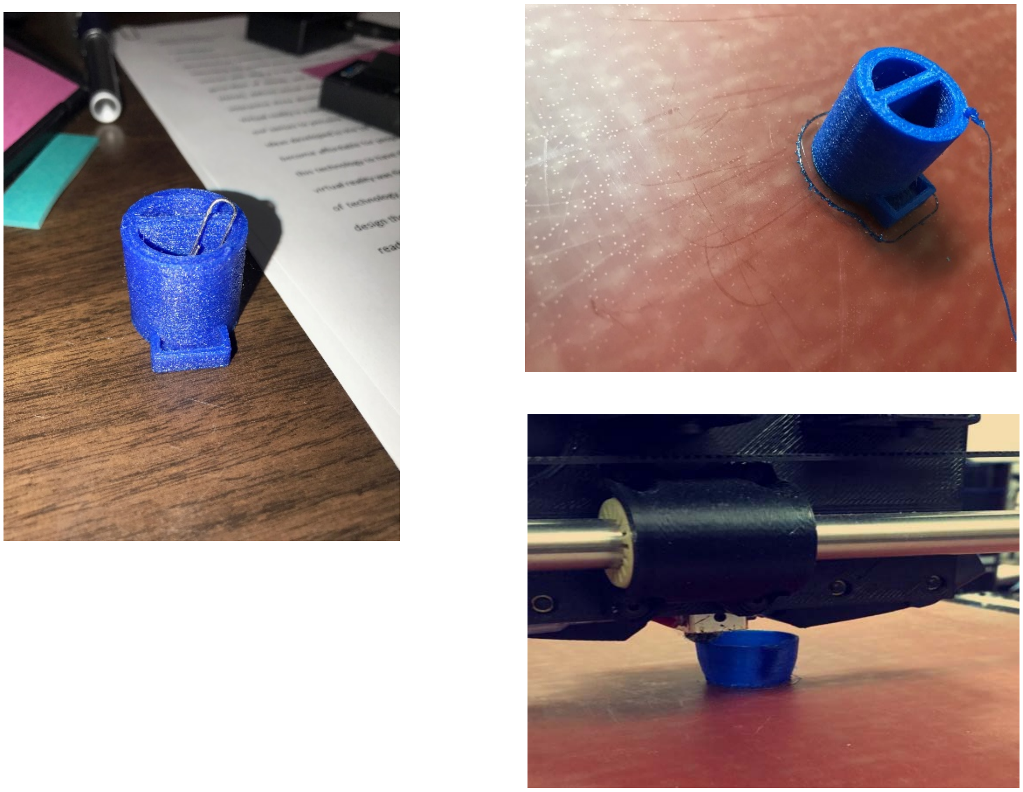

Figure 6. 3D printed pencil holder and a cup (scaled down).

The subtractive manufacturing of the prototype involved splitting the class into groups of 3-5 students and propose a project to the instructor for final submission at the end of the semester. Each group member modeled a 3D part independently, generated a toolpath for the post processing, cut the work in a router, and provided the fully assembled result to the instructor, as shown in Figure 6. Some projects such as plaques (Figure 7) could not be assembled; however, the individual CNC practice assignment was fulfilled.

Overall, the class was satisfied with the projects and their outcomes, some of the students expressed their class experiences as follows:

> I tried my best to put together the whole assembly but some of it did not come out the way I wanted to be because I was inexperienced with the assembly function. But I must say that I had a lot of fun towards the end because I had a better understanding of how to develop the models, especially the last project where I developed a coffee mug and printed it on a 3-D printer. Being able to 3-D print a model that I developed was very cool to do and I have never in my life been able to do such a thing. It was a very good experience to see how it worked and being able to watch the printer actually make the whole entire structure. Although my overall grade was not quite how I wanted it to be I still enjoyed being able to use

this software and I can see myself doing this in the future at my future job. I really enjoy using the program and I hope to find a job working with cad.

Figure 7. Group project with CNC product and final assembly.

Our project has been one of the most interesting things I've done while attending TAMUK. Even though my pencil holder is tiny, I am proud of what I have accomplished and what I learned today. I never would have thought I would be able to learn how to print from a 3D printer. Learning how the machine heats up the filament and how the tip distributed it was mesmerizing to watch. Also, I found it interesting to learn that some of the parts of the 3D printer were also 3D printed… Overall, this class has quickly become one of the most interesting classes I have taken and I feel it will be one of the most useful if I decide to go into the manufacturing industry.

Conclusion & Continuation of Project

The researchers investigated how an AR or VR tool influences the spatial cognition of first/second-year engineering students. The objective of the project was to develop an AR tool for student use to analyze various features of a 3D model and compare to the conventional way (provide 2D orthogonal views, inspect the perspective 3D isometric view of the part, and hunt for the dimensions from corresponding views) of CAD course delivery method. The example image target (Figure 2) can be used as a reference source to visualize the 3D representation of the part via developed an AR tool (Midterm_AR).

The comparative statistical analyses revealed, with a 95% confidence interval, that the AR tool provided significant improvement ($p=0.01<0.05$ alpha level, and mean pre-test = 1.42< mean post-test =8.58) in spatial orientation skills of students. The outcomes of the project were satisfactory; therefore, the newly restructured course will continue to gather more data for further analyses and discussion. Moreover, similar activities, such as the development of AR tool for kindergarten children to provide engaged learning, will be incorporated in other computer-aided design classes such as Advanced Graphics and Modeling and Architectural CAD in the spring 2018 semester. Vasilyeva & Lourenco (2012) believe that the spatial cognition skills can be improved in earlier ages, such as 3-6 and 7-11, with high impact and later in the adulthood with special treatment. This project reveals that the incorporation of AR tools in introductory CAD courses may benefit instructors in spending more time on practical aspects of the course, IAJC community in developing similar AR tools for their areas of discipline for further explorations, as well as the students in engaged learning of the CAD program in their early careers.

References

Dakeev, U., Pecen, R., Yildiz, F., Alam, S., & Heidari, F. (2018). Development of virtual environment to introduce spatial reasoning to first and second year engineering students. *Proceedings of 125th ASEE Annual Conference & Exposition.* Washington, DC: ASEE.

Dakeev, U., Pecen, R., Yildiz, F., & Heidari, F. (2018). Student spatial orientation improvement in introductory CAD courses with the integration of 3D printing and CNC technologies. *Proceedings of the Conference for Industry & Education Collaboration*. Retrieved from http://www.indiana.edu/~ciec/Proceedings_2018/Files/2018_Session_Index.htm#ETD

Perez-Fabello, M., Campos, A., & Felisberti, M. F. (2018). Object-spatial imagery in fine arts, psychology, and engineering. *Journal of Thinking Skills and Creativity*, *27*,131-138.

Pribyl, J. R., & Bodner, G. M. (1987). Spatial ability and its role in organic chemistry: A study of four organic courses. *Journal of Research in Science Teaching*, *2*(3), 229-240.

Sorby, S., & Baartmans, B. J. (2000). The development and assessment of a course for enhancing the 3-D spatial visualization skills of first year engineering students. *Journal of Engineering Education*, *89*(3), 301-307.

Sorby, S., Casey, B., Veurink, N., & Dulaney, A. (2013). The role of spatial training in improving spatial and calculus performance in engineering students. *Journal of Learning and Individual Differences*, *26*, 20-29.

Vasilyeva, M., & Lourenco, S. F. (2012). Development of spatial cognition. *WIREs Cognitive Science*, *3*, 349-362.

Biographies

ULAN DAKEEV is an assistant professor in the Industrial Technology Department in the College of Engineering, Texas A&M University–Kingsville. His areas of research include augmented and virtual reality, renewable energy (wind energy), quality in higher education, motivation, and engagement of students. Dr. Dakeev can be reached at Ulan.dakeev@tamuk.edu.

FARZIN HEIDARI currently serves as associate professor of industrial management and technology at Texas A&M University–Kingsville. Dr. Heidari has 26 years of experience in manufacturing and CAD/CAM/CNC courses. He is currently serving as the graduate coordinator for the Industrial Management program. Dr. Heidari can be reached at farzin.heidari@tamuk.edu.

FARUK YILDIZ is currently an associate professor of Engineering Technology at Sam Houston State University. His primary teaching areas are in electronics, computer-aided design, and alternative energy systems. Research interests include low-power energy harvesting systems, renewable energy technologies, and education. Dr. Yildiz can be reached at fxy001@shsu.edu.

REG PECEN is a Quanta Endowed Professor of Engineering Technology, College of Science & Engineering Technology, Sam Houston State University, Huntsville, Texas. He holds Ph.D. in EE from University of Wyoming, and an MS in EE from CU Boulder. He was a former VP for Edu, Go-Link Energy, a division of ALMx-Security, Inc. and former president & CEO, North American University in Houston, Texas. He served as a past chair (2013-14), chair (2012-13), chair-elect (2011-12), and program chair (2010-11) of the Energy Conversion Conservation Division, American Society for Engineering Education. He also served as a professor, program coordinator of Electrical Engineering Technology and Department of Technology graduate degree (MS & doctoral) programs (1998-2012) at University of Northern Iowa, Cedar Falls, Iowa. He is the recipient of 2011 UNI C.A.R.E Sustainability Award for the recognition of applied research of renewable energy applications at UNI & Iowa and recipient of the Diversity Matters Award to acknowledge individual contributions to the advancement of diversity-related goals at UNI. Contact Dr. Pecen at regpecen@shsu.edu.

SHAH ALAM. Education: PhD, Louisiana State University, 2005; MS, South Dakota School of Mines & Technology, 2002; MS, Bangladesh University of Eng. & Tech, Bangladesh, 1998; BS Bangladesh University of Eng. & Tech, Bangladesh, 1993. Registration: registered professional engineer in Texas (TBPE No. 113655). Research interests include composite structures design and analysis, mechanical system design and analysis, solid mechanics, fatigue and fracture mechanics, computational biomedical system analysis, finite element analysis (static, dynamic, impact, CFD, thermal, etc.), renewable energy, structural integrity of aerospace, offshore, and subsea structures. Dr. Alam can be reached at shah.alam@tamuk.edu.