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Improving the Aerospace Capstone Design Experience Through Simulation Based Learning*

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A key role of universities is to prepare students to work in their chosen profession upon completion of their degree program. Engineering capstone design courses are often the only required courses that challenge students to draw on nearly all of the students' previous collegiate learning experiences and to synthesize and apply these to creating a new solution to an engineering problem. Aside from internship and co-op experiences, these are often the first courses that expose engineering students to some of the technical and political issues that they will often face in their professional engineering careers. Industry often looks at these design experiences in addition to work experience when evaluating new graduates. While beneficial, there remains a perceived disconnect between what academia is producing and what industry is seeking. Industry is seeking 'engineers' who are well versed in the application of science to problem solving whereas academia is producing 'engineer scientists' who are well versed in the science, but lacking in the application of knowledge gained through experience. While some context-based learning opportunities are emerging much earlier in the engineering curriculum, the needs and means to provide such experiences remain limited. This paper discusses a pilot study that was conducted during the first term of a two term capstone design class in aerospace engineering aircraft design at Virginia Tech. The study explored the educational impact of utilizing realism and simulation to introduce the aircraft design process with the aim of determining if such an approach could help remedy the academia/industry disconnect and at the same time make for an engaging design experience for the students. Results indicate that the use of simulation was welcomed by the participants of the study and can help prepare students to think as working design professionals, not limited by the generic design solutions often found in academic de-contextualized design problems.

Keywords: aerospace engineering; simulation; engineering education; anchored instruction

1. Introduction

A key role of universities is to prepare students to work in their chosen profession upon completion of their degree program. One of the requirements for ABET accreditation in the United States is that engineering programs must demonstrate that students attain an 'ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability' [1]. The aim of such efforts is to produce capable engineering graduates who can pursue professional opportunities both in industry and in academia. Though graduates are being produced that are fulfilling the overall needs of industry in the long term, some perceive that there is somewhat of a 'disconnect' between academia and industry in the preparation of engineering graduates. Industry seeks 'engineers' who are well versed in the application of science to problem solving whereas academia is producing 'engineer scientists' who are well versed in the science but lacking in the application of knowledge gained through experience [2]. What can be done to close this gap and produce engineers that meet the 'ready to work' desires of industry and the limitations of time and resources that exist in universities?

Efforts such as the *Conceive, Design, Implement, and Operate* (CDIO) and the *Learning Factory* have attempted to provide possible frameworks for a new type of engineering design education by integrating design, manufacturing and business realities into the engineering curriculum [3–4]. These efforts utilize problem based learning, or *PBL,* which is supported by the theoretical principles that learning is a constructive process, metacognition affects learning, and social and cultural factors affect learning [5]. Industry has responded positively to these efforts. Is there an alternative way to educate and train students (in particular aerospace engineering design students) that provides the experience and skills desired by industry other than the experience provided by *CDIO* and the *Learning Factory*

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that are limited to the privileged few attending the universities providing these programs? Simulation has been used to train military pilots and medical professionals [6]. It is postulated that simulation and virtual environments may be an alternative way to provide some of the experiences gained in the aforementioned *PBL* based efforts.

There have been number of studies indicating that simulation in combination with traditional teaching approaches can enhance student learning. The majority of these studies subscribe to situated learning theory [7]. Under this theory, learning depends on and is influenced by the situation in which the learning takes place. This theory is related to the *PBL* approach used in *CDIO* and the *Learning Factory* in that both acknowledge the key role that the environment plays in learning. Environments can be geared to replicate real world situations and thus help to better prepare students for the 'real world' of engineering practice. It is within this framework that this study was conducted.

2. Past simulation in engineering education efforts

The literature on the use of virtual reality and simulation in engineering education can be roughly grouped into to two time periods. There are a number of articles that occur around the mid 1990s followed by a relative lull and then resurgence in published research in the mid to late 2000s.

2.1 Simulation efforts in the 1990s

Articles in the 1990s timeframe are characterized by an optimism of the potential of the computer to assist in education and simulations are viewed as an application for this tool. Mosterman et al [8] report on a study where electrical engineering undergraduates took part in the testing of a computer-simulated laboratory. Results of the study indicated that a virtual lab when used as a pre-lab did in fact reduce the time and number of requests requiring help from Teaching Assistants. Reamon and Sheppard [9] discussed the use of simulation in a mechanical engineering design course where student pairs, using different sets of resources (e.g., pencil and paper versus computer) were tasked to design a four-bar toggle clamp mechanism. Results indicated that a team using simulation software created the most effective solution technique to the problem [9]. The authors felt that the 'software simulation' alone was not an optimal learning experience but that a combination of hands-on experience, traditional lecture and simulation could produce the best learning environment.

Looking in the field of medicine, Davies and Helmreich [10] discussed the benefits of simulation and virtual reality to medical training. A drawback with the systems of the day was that the simulators didn't allow multiple participants to work in the same high fidelity simulation at the same time. Gibson et al [11] noted how simulations could be used in medical education, surgical training, surgical planning, and intra-operative assistance. In aviation, Allerton [12] discussed the history of flight simulations used to train pilots and how simulations in the 1990s were starting to be used to train maintenance personnel.

The efforts in the 1990s typically involved relatively small sample sizes ($n<50$) and the level of simulation was limited by the computing power available at the time. They indicated that virtual reality and simulation had a positive effect on learning by allowing students and professionals to examine material in a different medium and in the case of the Mosterman et al study, gave the students a 'virtual run-through' of an actual exercise that the students were going to conduct later. This 'experience' did make the students more comfortable with actual tools once they were able to use them in the lab. These studies limited the use of virtual reality or VR and simulation to preparing the students for experiences in the academic setting. These studies helped to set a tone for the future studies that occurred in the 2000s.

2.2 Simulation efforts in the 2000s

By the time of the 2000s, research articles treated the use of computers in the classroom as an accepted norm and the questions turned to how to best implement and use simulation and virtual reality in the classroom. Fang, Stewardson, and Lubke [13] discussed the results of a study where they examined the use of computer simulation to enhance student learning in a metal machining course that was part of manufacturing engineering. As with Reamon & Sheppard's 1990s study, this study also found that simulation in combination with other activities such as formal instruction, real world labs and guest lecturers created the best learning environment providing the students with a way to bridge theory and practice [13].

Squire and Klopfer [14] explored 'augmented reality simulation' in which virtual data and real-world locations and contexts interact. The goal of the study was to determine if handheld augmented reality technologies and game play could be used to 'enrich inquiry and provide a new pedagogical paradigm for environmental science education' [14]. Results indicated that augmented reality did help the students to understand science as a social practice and move beyond the idea that it was just facts, processes and procedures. The 2010 Horizon Report [15] further supported augmented reality efforts by noting that augmented reality had the potential to provide contextual learning experiences and opportunities for discovery of the connected nature of information in the real world.

The literature presents a fairly consistent theme that virtual reality and simulations can enhance student learning. In the 1990s, one observes a potential for the use of such tools in engineering education with various experiments conducted within particular exercises within particular courses. The experiments looked promising and researchers indicated that more experiments that are larger in scope were needed. The main hindrances to their broad use in engineering education appeared to be the lack of computing power to run sophisticated simulations and the fact that personal computer usage in engineering education was still in a growth stage. By the 2000s, the personal computer and technology related to it, were fully integrated into nearly every facet of society in the US, this included engineering education. The research no longer mentions the potential of using computers in engineering education, but instead examines the best ways to implement that power to enhance the learning experience. The engineering education related experiments evolve from a simulated electrical engineering laboratory on a desktop computer (Mosterman et al) to powerful handheld computers with global positioning capability used in field (Squire & Klopfer).

The experiments in the 2000s continue to show that virtual reality and simulations can help students have a better learning experience, but as was mentioned in Reamon & Sheppard in the 1990s, the simulations need to be properly integrated into a course and combined with other teaching methods and learning activities in order to be most effective. Augmented reality comes the closest to somewhat seamlessly merging simulation and real world experiences. This speaks well to the continued potential of using simulation and virtual environments in engineering education.

All of the literature reviewed encourages further experiments and research in the use of virtual reality and simulation in engineering education. The gap that appears in the approaches explored in the previous research is that they have not looked at using the capability to explicitly train students for experiences beyond the university experience. Though the Squire and Klopfer study comes the closest to achieving this, by using high school students and engineering freshmen, it still is more geared to enhancing an experience that the students will have in the future within academic settings such as a lab or senior capstone design related experience. It may be noted in particular that there appear to be no studies reported in open literature exploring the use of simulation with senior aerospace engineers in an aerospace capstone design course.

It is also observed that researchers have largely failed to consult industry or potential employers about the use of VR and simulation in the training of future employees. Though the studies tended to be geared to academia, insights from industry could be beneficial in designing future simulations. Situated learning theory appears to support the approach of using simulations and virtual environments to prepare the seniors to the ways of the communities of practice. Thus it is believed that future research should explore these areas and continue to build upon the foundation established by this previous work.

3. Research question

This study explored the impact of the use of simulation and virtual environments in engineering design on students' design skills and thinking. In particular the study attempted to answer the following research question:

Can the use of simulation and virtual environments in aerospace capstone design increase student design skills and produce students more 'industry ready' in the area of aircraft design?

Utilizing situated learning theory, this mixed methods study explored how the simulated experience of being an engineer in an industrial aircraft design setting impacts students' engineering design thinking. The work builds upon the studies of the 1990s and 2000s and expands upon them by examining the impact of simulation and virtual environments on senior engineering students in capstone design. The following sections discuss the findings of a pilot study exploring the use of simulation in a senior aircraft design class in the first term of the 2010–2011 academic year at Virginia Tech. This study provided valuable information that will be used to modify the aircraft design simulation experiment to be formally conducted in the fall of 2011.

4. Methods

4.1 Participants

Participants in this study were members of the senior class of the Aerospace and Ocean Engineering (AOE) Department. These students were enrolled in the senior capstone design projects dealing in aircraft design. The population of aircraft design students numbered 55. Virginia Tech contains one of the larger aerospace engineering classes in the country and routinely is ranked one of the leading undergraduate aerospace engineering programs in the country [16].

Of the class population of 55 students, the simulation study had a sample size of 25 students (24 males and one female) who volunteered to participate in the pilot study after being briefed about the study at the beginning of the academic term in order to comply with Institutional Review Board (IRB) requirements for such a study. Given the small population, Rea and Parker [17] suggest that the sample size for such a study be around 50% of the population which translated into a need of around 28 students to participate. Though the sample size fell short by three people, it was felt that the study would provide valuable information on the simulation experiment design and provide an indication of results that may be encountered in the later rerunning of the experiment.

Participants were randomly assigned to control and experimental groups for the study. The Control group consisted of 10 students (all male) with the remaining 15 in the Experimental group (14 male and 1 female). The students stayed in these groups throughout the exercise. Of these students 10 had previous engineering experience as co-ops or interns while 5 had family members or family friends that were design engineers.

4.2 Research design

The overall experiment was a *Pre-Test-Post-Test Control Group Design* [18] with both the experimental and control groups being assessed before the intervention and after the intervention by way of two instruments discussed in the next section. A mixed methods research approach was utilized with quantitative data obtained through the use of a questionnaire along with qualitative data obtained through semi-structured interviews. This questionnaire instrument was applied to members of industry who have worked as aircraft design engineers. The responses of the industry professionals formed a benchmark upon which the results of the students were compared. The experiment was conducted over four class periods during the beginning of the design course. Students in the experimental group met in a computer lab away from the main class which included the control group, while those in the main class met in a conventional classroom.

The simulation experience was a case of anchored instruction which puts the students in the context of a problem-based story where the students 'play' an authentic role while investigating the problem, identifying gaps to their knowledge, researching the information needed to solve the problem, and developing solutions [19]. In this case, the anchored instruction had the aim of providing students with the experience of being an aircraft design engineer for a large defense contractor. The simulation used a combination of electronic tools and real world role playing in order to simulate the aircraft designer experience. Students were exposed to the use of real world aircraft design tools such as the computer aided design tool CATIA by Dassault and the synthesis tool ModelCenter® by Phoenix Integration. Students also had access to aircraft analysis tools used in aircraft design at the university level such as *Tornado*, a visual vortex lattice method program maintained by a combination of companies in Sweden and the United Kingdom [20]. The students used a combination of personal tablet notebooks, paper and pencil and workstations with the Computer Aided Design or CAD software and other aircraft design analysis tools to develop their concepts. Artifacts such as memos with a company letterhead were issued to the students with invitations to group meetings and notification of the latest developments on the design effort that were occurring between the simulated company and a potential US government customer.

The students in the experimental group assumed the role of new hires in the engineering leadership development program of a fictional large defense contractor named *Ace Aero*. As such, the students (new hires) rotated between a series of engineering positions within the company in order to become more familiar with its products, processes and people. In this exercise the new hires were rotated into the Conceptual Design group of the company that is responsible for designing the new aircraft concepts and next generation airplane products that the company will produce. The group is headed by the class instructor playing the role of supervisor to the new hires providing assignments and direction as needed and informing the students about good design practices such as always being able to legitimately support all design decisions made. In the simulation scenario, *Ace Aero* has been producing fighter aircraft for 20 years and their Washington DC business representatives have learned that a new competition is about to be announced to develop an uninhabited aerial vehicle (UAV) that has the maneuverability of a manned fighter like the F-16. The design group of the company has been tasked to develop concepts that may be shown to the potential customer ahead of the official competition in the hopes of making an impact on the requirements that the government will issue for the new aircraft. The new hires have been invited to be a part of this study and are asked to develop concepts of their own that will be reviewed by management at the end of the exercise.

Students experienced an abbreviated aircraft design process. The exercise was broken into four stages: requirements development, brainstorming, conceptual level design analysis and CAD model development, and concept presentation. The instructor provided a brief introduction to each stage and provided the students the necessary background information to perform tasks required of that stage. The students worked individually during the requirements and brainstorming stages of the simulation, but were formed into teams of three and four during the conceptual design and presentation stages. During requirements development, the students examined a mock Request for Proposal (RFP) to develop requirements and specifications for their design. In the brainstorming exercise, students were tasked to explore the web for reliable sources that could provide information on previous vehicle concepts that had capabilities similar to those requested in the RFP. The students were also tasked to sketch up concepts on paper that they felt could meet the design requirements.

Once the students formed teams, they were tasked as a team to select a concept that as a team they would explore further and present at the end of the exercise. The students also had to assign roles to team members as analysts or designers in order to meet the deadlines set by the supervisor/instructor of the class. Here the students utilized a CATIA aircraft model that was parameterized for ease of use and used a combination of spreadsheet sizing tools and the *Tornado* program for aircraft analysis. This required the students to experience teamwork and practice compromise in order to accomplish the team goals. In the final stage the students were tasked to develop a two slide presentation describing their team's concept and be able to present it to the other teams and instructor. From there the instructor would select a concept that would proceed into preliminary design within the world of the simulation. Figure 1 contains sample artifacts from the simulation experience with the experimental group.

As the students in the experimental group were creating designs for the fictional company, students in the control group along with the balance of the design class (who chose not to volunteer for this study) were receiving formal instruction on the same aircraft design content that was being covered in the design exercise with the experimental group. Students were presented material on the design process and the various roles of aircraft design team members. The material was presented using PowerPoint slides by an experienced aircraft design professor with some aerospace industry experience. Here the instructor followed the more traditional teacher-centered teaching model practiced in many engineering classes in the U.S.

4.3 Instruments

A review of the literature at the time of the study revealed the lack of an existing proven close-ended questionnaire instrument designed to assess design thinking and skill. As a result, for the pilot study, a new instrument was created called the Professional Skills Questionnaire (PSQUES). The goal of this

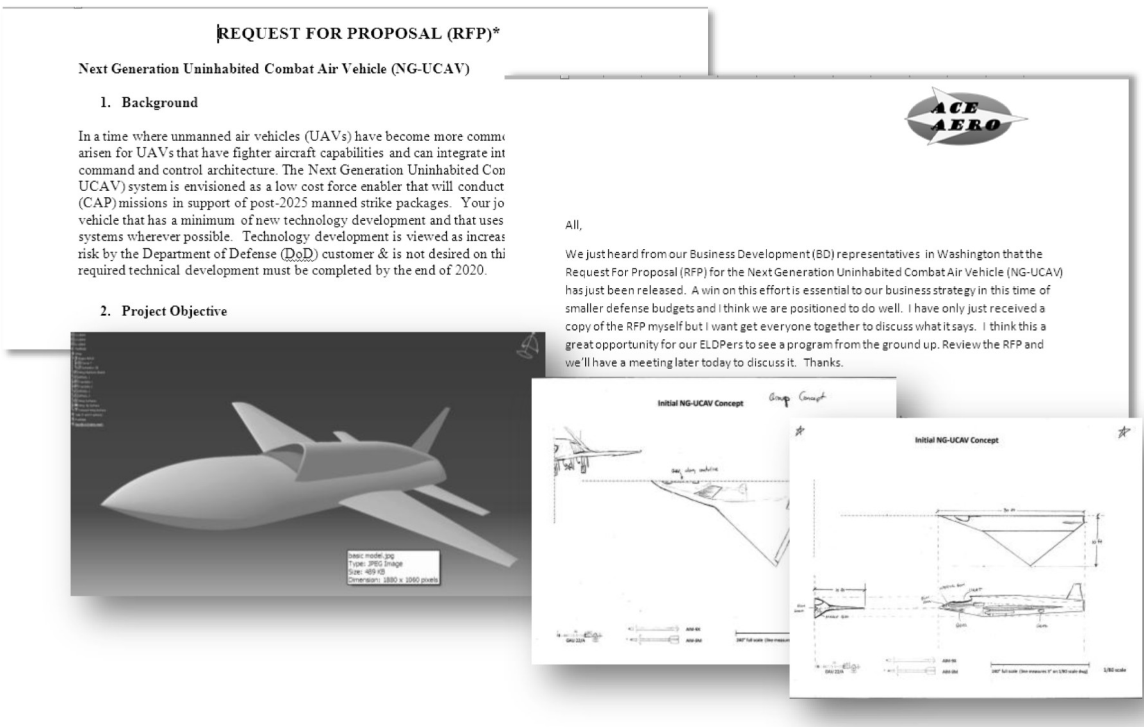

Fig. 1. Sample Artifacts from the Experimental Class: RFP, Company Memo, Parametric CATIA Model & Student Sketches.

instrument was to provide a way to assess design thinking and professional skills in a format that would not take long for respondents to complete. The instrument was designed using findings of a combination of previous studies exploring the differences of experts versus novices along with addressing the desired traits that the aerospace industry has expressed as being desired in new engineers in the papers by Nicolai [21] and McMasters [22]. This 23 item instrument contained a combination of knowledge assessment questions and 11 opinion related questions using a Likert 5-point scale requiring the individual to consider the relative importance of a variety of topics encountered in design such as 'awareness of trade-offs' and 'cost.' It is the responses to these 11 Likert scale items relating to design that are analyzed and discussed in the following sections. Appendix A contains the list of items that were under consideration.

In addition to the student participants of the intervention, the PSQUES was also taken by 13 professional engineers in industry in order to provide a benchmark upon which the student results could be compared to help determine if the experimental group responded more 'industry like' than the control group following the intervention. An expert panel was employed to review the instrument and partially address the reliability of this new tool. The panel provided recommendations on ways to improve upon the initial instrument and the pilot study provided the initial field testing of this combination assessment and survey approach. Given the newness of the PSQUES, its complete reliability and validity levels remain to be determined at this time. The PSQUES was administered manually as the participants filled out paper copies of the survey during the regularly scheduled design class time. These surveys were then collected before the end of class and the data was input into electronic form for subsequent analysis.

In addition to the PSQUES, a total of eight audio recorded semi-structured interviews (four from the control and four from the experimental group) were conducted with the participants. All interviews were voluntary and started shortly after the intervention for a two week period. The participants were asked 12 questions with flexibility given to the interviewer to explore responses in more depth should additional clarification be needed. The questions explored how the students felt about the experience of simulation in aircraft design, what the students knew about the design process following the experience and what they thought about certain characteristics of design as practiced in industry such as the role of teamwork and compromise. Interviews typically took around 30 minutes and the recordings were transcribed for analysis.

4.4 Data analysis

The statistics program SPSS was used to analyze the Likert scale items contained on the PSQUES. Descriptives from the statistical analysis provided the means and standard deviations of the samples. Given the small sample size, non-parametric testing using the independent samples Kruskal-Wallis method was used to compare the experimental and control groups along with comparing both groups to the benchmark created by the professional engineers. Dependent samples non-parametric testing using the Related Samples Wilcoxon Signed Ranks test was used to compare the experimental and control groups' pre and post intervention with the PSQUES. Interviews were reviewed to determine common themes among the interviewees.

5. Findings

5.1 Questionnaire results

Results of the Kruskal-Wallis Test for independent samples evaluating the experiment, control, and industry groups pre-intervention showed none of the 11 items to be statistically significant (with a 95% confidence level) except the for the item 'Awareness of trade-offs / Design space exploration' where $H(2) = 7.586$, $p = 0.023$ (two-tailed). The significant pairing here was between the industry and the control groups. The Kruskal-Wallis Test between the experiment, control, and industry groups post-intervention again showed none of the 11 items to be statistically significant (to the 95% confidence level) save for the item 'Awareness of trade-offs / Design space exploration' where $H(2) = 10.011$, $p = 0.007$ (two-tailed).

Results of the Related Samples Wilcoxon Signed Ranks Test for related samples, examining only the control group before and after the intervention, indicated no statically significant difference between the two test periods for this group. In the case of the experimental group, there were also no statistically significant differences (to the 95% confidence level) between the test periods save for the two items of 'Cost' and 'Manufacturing' where $Z = -2.807$, $p = 0.005$ (two-tailed) for cost and $Z = -2.124$, $p = 0.034$ (two-tailed) for manufacturing.

5.2 Interview results

The interviews with the students revealed a positive response to the simulation experience by the experimental group. Common themes that appeared in the transcripts for the experimental group students were a preference for learning situations where the students could have 'hands on experience.' A number of students expressed a personal preference for 'learning by doing.' A uniform complaint was that the students felt the exercise was too short and rushed at times. Students desired more time to work with the tools such as CATIA. When asked if the students would prefer the simulation approach in other classes, uniformly the respondents felt that though this approach was great for design, it was not really appropriate for classes such as mathematics and there was a stated preference, in those instances, for the traditional lecture and teacher-centered approach most often used today. When asked to describe the basic aircraft design process, the experimental group interviewees tended to recall aloud the events of the exercise as the way to describe the process. One student when describing the experience stated that 'instead of just sitting there reading off line after line . . . this is the design process, this is what you do . . . we actually went through and did part of the design process. You know, little tidbits of it . . . I think I remember it better that way.'

Control group interviewees showed a comparable level of content knowledge to the experimental group when asked to describe the aircraft design process. A common theme among this group was a dislike for 'being talked at' in a lecture format for extended periods of time. One student described the experience as 'just having to sit there and being bombarded' while another mentioned 'information overload.' Students indicated that they had been exposed to a number of different aspects of design and heard some rules of thumb by the instructor during the exercise but that hours on end of PowerPoint slide material could be boring. A number of students welcomed more interaction with the instructor while one member of the control group suggested that for future design classes that it would be beneficial to have small design exercise at the beginning of the term to become familiar with the basics of aircraft design before beginning work on their major design projects for the class.

When asked about the importance of teamwork and compromise in aircraft design, both groups equally considered both items to be critical for design success. A student in the control group when speaking of teamwork stated 'I think one of the biggest most important factors in good quality original design is having multiple angles of attack, so to speak. And I don't think anybody can cite me an aircraft that's actually been designed and built from the ground up by one person.' Both groups viewed analysis as being interrelated with design and as a way to validate one's design and assumptions.

6. Conclusions

The results appear to indicate that the simulation based learning approach has promise for an aircraft design class as a way to help students become more industry ready. It is conjectured that differences in the quantitative results between groups from the PSQUES may be due to the fact that the experimental group students had the experience of having to make trade-offs and consider the design space, cost and manufacturing impacts during the exercise whereas the control group students were only exposed to those topics and told of their importance. Though there were not many statistically significant differences between the participants as measured with the PSQUES, there was a clear and understandable preference for educational experiences that were more engaging. Measuring aircraft design skill and thinking in the form of a questionnaire with Likert scales is a challenge given the nearly unlimited possibilities of design and the inherent limitations of the questionnaire format.

Interviews revealed that a number of students preferred the hands on aspect of a simulation class when it comes to design. Along these lines, it was also found with some in the control group that more interaction with the instructor as opposed to being lectured to was preferable indicating a desire for a fuller class experience than the classic teacher-centered presentation approach. Students in both approaches successfully learned the aircraft design process as a procedure that could stated but the experimental group students appeared to have gained the additional insight to a process that is gained through having real experience with the process. It is this insight that is a key part of the experienced engineer's repertoire and helps to set the experienced engineer (desired by industry) apart from the novice.

Future work will include refining and further testing the PSQUES. Streamlining the simulation experience and allowing it to proceed for longer periods of time will provide greater insight into the impact of simulation based learning in aircraft design. All of these modifications should also be combined with testing larger sample sizes in a variety of aerospace capstone design courses at different universities in order to begin to address generalizability of the results.

Digital game based learning may provide an alternative approach to the live action simulation used in this experiment. Challenging the student to an aircraft design scenario in the context of a game or digital simulation may allow for integrated assessment by permitting design steps and decisions of the student to be recorded during the game for later analysis as the student solves a scoped design problem.

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Appendix A

List of Likert 5 point scale items used in the Pre-Test-Post-Test Control Group Design of the study. Respondents rated each item from 'Low Importance' to 'Great Importance':

(1) Consideration of the issues (relevance of various design issues)
(2) Reason behind a process or component in a design
(3) Reference to past designs and studies
(4) Questioning Data / Verification of analysis results
(5) Keeping Options open
(6) Awareness of trade-offs / design space exploration
(7) Awareness of limitations
(8) Supporting design decisions
(9) Communication of ideas and results
(10) Cost
(11) Manufacturing

Wm. Michael Butler is a 20 year air vehicle design industry professional on educational leave pursuing a PhD in Engineering Education from Virginia Tech. His research is focused on the use of design tools in engineering design education as a means to better prepare students for industry. He is a Senior Member of AIAA and a member of ASEE. He has a B.S and M.S. in Aerospace Engineering from Virginia Tech and is co-inventor on two patents relating to air vehicle design.

Janis Terpenny is the department chair and inaugural holder of the Joseph Walkup Professorship in Industrial and Manufacturing Systems Engineering at Iowa State University (ISU). She comes to ISU from Virginia Tech, where she was professor in the Department of Mechanical Engineering and in the Department of Engineering Education and an affiliate of the Department of Industrial and Systems Engineering. Dr. Terpenny has served as a program director for the Division of Undergraduate Education at the National Science Foundation (NSF). She was one of the founders and has served as the director of the Center for e-Design for several years. Her research focus is engineering design and design education. She has industry work experience with the General Electric Company (GE), including the completion of a 2-year corporate management program. Throughout her career, she has managed over $7 million of sponsored research and is the author of over 140 peer-reviewed publications. She is a Fellow of IIE, a member of ASME, ASEE, INCOSE, and INFORMS and serves as an associate editor for the Journal of Mechanical Design and for the Engineering Economist. She has received numerous awards for excellence in teaching, in research, and for service. She received her BS in applied mathematics from Virginia Commonwealth University (VCU) and her MS and Ph.D. degrees in industrial and systems engineering from Virginia Tech.

Richard M. Goff is currently an Associate Professor, and Assistant Department Head of the Department of Engineering Education. He is also currently Director of the NSF I/UCRC multi-university Center for e-Design, Co-Director of the Engineering First-Year Program, and Director of the Frith Freshman Engineering Design Laboratory in the College of Engineering at Virginia Tech. His Ph.D. is in Aerospace Engineering from Virginia Tech. Richard is the recipient of several teaching awards including the W.S. 'Pete' White Chair for Innovation in Engineering Education in 2006, the W.E. Wine Award for Exemplary Teaching in 2003, the Dean's Award for Excellence in Teaching in 2001, and the Diggs Teaching Scholar Award in 2001, among others. Dr. Goff's research interests include structural mechanics, design and design education as well as innovative pedagogy and curriculum development. He has participated in several university wide Task Forces; Core Curriculum Reform, Student Engagement, e-Portfolio, and Human Diversity and Community. Richard's passion is creating engaging, hands-on, learning environments and facilitating real design projects with actual clients. He is the faculty advisor of the Virginia Tech Mechanical Engineering Baja SAE Team as well as one of the teaching team that created the ROXIE (Real Outreach eXperience In Engineering) Project.

Rajkumar S. Pant has Bachelors, Masters and PhD degrees in Aerospace Engineering. His areas of specialization include Aircraft Conceptual Design Air Transportation, and Optimization. He has been a member of faculty of Aerospace Engineering Department at the Indian Institute of Technology Bombay since December 1989. He has been teaching the Capstone course in aircraft design for more than 15 years. Currently, he is a visiting faculty at Department of Aerospace & Ocean Engineering at Virginia Polytechnic Institute and State University, on a one-year sabbatical from his parent institute. His prime assignment at Virginia Tech is to develop polynomial response surface based surrogate models for structural optimization of panels with curvilinear stiffeners for aerospace applications, for an ongoing project sponsored by NASA Langley. In addition, he is also the prime instructor for the Capstone course in Aircraft Design in the department. Dr. Pant is an alumnus of College of Aeronautics, Cranfield University, UK, where he did his PhD under Commonwealth Scholarship Scheme, and IIT Madras where he did his Masters. He has also worked for five years in Hindustan Aeronautics Limited as a Design Engineer. He has published and presented around 65 scientific papers in international journals and conferences. He was a visiting scientist at Imperial College London in 2006 and Cambridge University in 2008.

Heidi M. Steinhauer is currently an Associate Professor of Engineering at Embry-Riddle Aeronautical University and PhD candidate in the Department of Engineering Education at Virginia Tech. Heidi has received several awards for diversity including The Women's Vision and the ABET President's Award for Diversity. Her research is focused on the development of assessment tools for measuring spatial visualization, the development of 3D modeling frameworks, and exploring the pedagogical structure of signature ways of knowing in engineering education. She is a Senior Member of ASEE, COE, and SAE. She is a faculty co- advisor of only All Women's Baja SAE Team, faculty co-advisor of the Galapagos UAV project, as well as the founder and faculty mentor for the FIRST (Female Initiative Reaching Success Together) Program.