Veterans’ Contributions to Enhancing the Capstone Learning Experience of Engineering Cohorts

Dr. David Blake Stringer, Kent State University, Kent

D. Blake Stringer, Ph.D. is an assistant professor of aeronautics at Kent State University. Prior to joining the faculty at Kent State, Dr. Stringer served in the Army for 20 years as an army aviator, West Point faculty member, and research engineer. He holds a bachelors degree in aerospace engineering from the US Military Academy, a masters degree in aerospace engineering from Georgia Tech, and a doctorate in mechanical and aerospace engineering from the University of Virginia. Prior to his retirement, he led the Army Research Laboratory’s vehicle propulsion division, conducting basic and applied research of engine and drive system technologies. His research interests are varied and include unmanned aerial systems, the aerodynamics of vertical axis wind turbines, rotating mechanical components, rotordynamics, and engineering education pedagogy. As an aviator, he has been rated in both rotary and fixed-wing platforms. He also holds a FAA commercial airman’s certificate.

Prof. Maureen McFarland, Kent State University, Kent

MAUREEN McFARLAND is currently the Aeronautics Senior Program Director and an assistant professor at Kent State University. Prior to joining the faculty at Kent State, Prof. McFarland served in the Marine Corps as a navigator at which time she transitioned to the Marine Corps Reserve, retiring after 20 years of service. She holds a bachelor’s degree in aerospace engineering from the US Naval Academy, a master’s degree in business from Boston University, and is a doctoral candidate in educational psychology at Kent State University. Her research interests include assessment, effective teaching practices using instructional technology, and engineering education pedagogy.
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Abstract

The capstone course sequence in an engineering or engineering technology program brings together all elements of the curriculum into a comprehensive learning experience. A team of students works together, combining the topics learned during their undergraduate coursework to complete a substantial design project. Design courses can be uncomfortable for many students because of the open-ended nature of the requirement, leading to many questions such as “Are we on the right track? Do I have the right answer? Are we approaching this the right way?” Due to their unique experiences, student veterans in engineering are well positioned to enable their cohorts to overcome these challenges. The military experience teaches veterans to become problem-solvers. Military experience in harsh operating conditions such as desert, mountainous, and combat environments further enhances their problem-solving skills. These environments have also provided veterans with opportunities to engineer their own solutions to overcome limitations. This paper briefly discusses some of the skills attributed to veterans. It then provides examples of veterans in the field engineering solutions to technical problems. It then follows the course of one veteran through the aircraft design capstone course of an engineering technology program, and how this veteran’s experience enabled the class to achieve several “firsts” for a capstone team in the program. Based upon the input from several peers, this veteran played a significant role in the team’s success and accomplishments.

Introduction

The capstone course sequence in an engineering or engineering technology program brings together all elements of the curriculum into a comprehensive learning experience. A team of students works together, combining the topics learned during their matriculation to complete a substantial design project. In an aeronautics curriculum, the capstone often takes the form of an aircraft or spacecraft design, whereby the students develop a design concept to meet customer requirements. These courses can be initially uncomfortable for many students because of the open-ended nature of the requirement, leading to many questions such as “Are we on the right track? Do I have the right answer? Are we approaching this the right way?”

Due to their unique experiences, veterans are well positioned to better enable their cohorts to overcome these challenges. Military experience teaches veterans to become problem-solvers. Military experience in extreme operating conditions such as desert, mountainous, and combat environments further enhances their problem-solving skills. These environments have also provided them with opportunities to engineer their own design solutions to enhance technological capabilities.

This paper briefly discusses some of the skills attributed to veterans. It then provides examples of veterans in the field engineering solutions to technical problems. It then follows the course of one veteran through the aircraft design capstone course of an engineering technology program. It describes how this veteran’s experience enabled the group of students to achieve several
“firsts” for a capstone team in the program. Based upon the input from several peers, this veteran’s contributions played a significant role in the team’s success and accomplishments.

**Background**

Not since the end of World War II has such a significant number of veterans had access to higher education. With the Post-9/11 GI Bill, enrollment of veterans at universities across the nation has increased significantly. Statistics from the Department of Veterans Affairs (VA) show a steady increase since the year 2000. In particular, there was a 42% increase from 2009 to 2010, when the Post 9/11 GI Bill took effect. In 2000, just under 400,000 veterans received educational benefits from the VA. In 2012, that number had increased to just under 950,000, a 238% increase [1].

Since 2009, the National Science Foundation has funded efforts to attract veterans to engineering programs, determine appropriate academic credit for military-related training, and develop pathways for veteran success[2]. Specifically, it is the veterans’ familiarity with high-tech weapons, communication systems, and other equipment as users and maintainers that provides the underlying technical base for success in engineering[3].

While many institutions of higher learning are focused on the resources, avenues, and support mechanisms necessary for transitioning veterans to the academic environment, it is also important to keep in mind the resources and mechanisms that the veterans themselves bring to the academic environment. Brawner, et. al.[4], provides a discussion of the assets of student veterans to the academic environment, as well as some of the challenges of student veterans in the classroom. Student veteran assets include determination, motivation, flexibility, and work ethic. Their challenges include balancing family and academic requirements, working in a less-structured environment, dealing with service-related disabilities, and seeking assistance when needed.

A recent report provided university data of four engineering institutions. Out of approximately 18,000 engineering students across these universities, only 180 or 1% are veterans receiving GI Bill benefits[5]. Access to these student veterans by their cohorts is therefore very low.

**Veterans as Problem-Solvers**

How are veterans suited to engineering design? The design process is at its core a problem-solving process. Although formalized in many different ways, the fundamental design activities are problem definition, information gathering, concept generation, concept evaluation, product architecture, configuration design, parametric design, and detail design[6]. The underlying precept of any engineering capstone is to solve a problem with a technological solution.

Veterans become problem-solvers during their military service. From some of their first exercises in basic training such as the small-unit Leadership or Leaders’ Reaction Course (LRC) to other unit training exercises, veterans are exposed to problem-solving strategies [7]. These translate to operational missions in a combat environment, where veterans are determining ways
to overcome difficulties and find solutions to complex problems, often with limited resources and limited time.

The recent wars in Afghanistan and Iraq provide numerous examples of veteran innovation, not only in tactical operations such as the “Surge” in Iraq, but also particularly with technology solutions. As in previous wars, the requirements of this past decade resulted in several new types of military equipment being sent to our armed forces in the field.

To support technology requirements and evaluations in theater, all military branches deployed technology elements consisting of civilian and uniformed science advisors. These advisors interacted with military units to serve as a link between the operational unit and the Department of Defense engineering community. As such, these advisors evaluated the effectiveness of new military equipment. More importantly, these advisors witnessed and were able to describe the innovation of military personnel in improving the equipment. Some of these innovations translated directly to permanent technology solutions or product upgrades. Further information describing the roles and typical experiences of these advisors can be found in Dean[8].

One of the authors has personal experience as a science advisor supporting military forces in Iraq. One of these personal examples of veteran innovation deals with the RG-33 Mine-Resistant Ambush-Protected (MRAP) Vehicle used in the Iraqi theater. During one of these science advisory interactions, the users pointed out that the environmental system design was faulty because the left-side vents belonged exclusively to the cooling system, whereas the right-hand vents belonged to the heating system. In the extreme desert heat, this made those on the right-hand side of the vehicle significantly uncomfortable when on patrols of several hours. The engineer unit depicted in Figure 1 developed an innovative solution combining empty water bottles (left) to vector the airflow into the right-hand system reserved for heating (center) in order to cool the passengers on the right-hand side of the vehicle (right).

![Figure 1: Innovative design – Iraq 2010](image)

Experiences such as these provide the problem-solving basis for pursuing and excelling at highly technical degrees. This innovative problem-solving fits nicely into Mumford’s[9] model of Leader Characteristics on Leader Performance (Figure 2). Mumford’s model provides the link between one’s environmental influences, career experiences, and personal and social characteristics in determining their problem-solving ability and performance.
Applying this model to the veteran, we assert that the complex military environment as well as the sometimes near-life-and-death experiences within those environments greatly influence the veteran’s problem-solving abilities. Additionally, the social camaraderie of the military has been chronicled by numerous authors, such as Stephen Ambrose in *Band of Brothers*. These experiences combined with the camaraderie and the veteran’s personal attributes, solidify the veteran’s problem-solving capabilities.

### The Challenges of a Capstone Course and its Group Dynamics

The traditional design course structure presents challenges to students for a myriad of reasons. These include but are not limited to (1) lack of guidance for establishing and keeping a design schedule while proceeding through lecture material, (2) a lack of student comfort with the “open-endedness” of a design project, (3) an inherent reluctance or hesitation of students to begin the project as soon as possible, due to their unfamiliarity with the material, and (4) an unfamiliarity of working in a large group with deliverables over an extended period of time.

While non-traditional students with previous experience in manufacturing or design might have an advantage over their peers in a design course, student veterans tend to be even more prepared for the above challenges because of their experiences in problem-solving. In particular:

1. **Lack of guidance for establishing and keeping a design schedule.** Veterans understand a schedule, since most of their military career involves adhering to either an operational schedule or a training schedule. Understanding the deadlines in a design course allows veterans to quickly develop a schedule and supporting documentation to best facilitate team efforts.
2. **Lack of comfort with the open-endedness of a design project.** Military leadership provides missions and objectives to subordinates. Subordinates develop their own mission plans and objectives and push to the next subordinate level. The process continues downward until it reaches the lowest level. With the exception of coordinating certain elements, the method of mission accomplishment is open-ended. This provides lower military units with the flexibility to adapt and accomplish the objectives in whatever manner they see fit.

3. **Inherent reluctance of students to begin as soon as possible.** Students sometimes have a difficult time beginning a project and want to wait until they have a clear and defined path for the way forward. Many veterans (but not all) have experienced great levels of uncertainty in their past but fundamentally understand that sitting and waiting is not an option that best propels them to success.

4. **Unfamiliarity of working in large groups.** Veterans learn teamwork during their first week of basic training and continue that culture throughout their military careers and beyond. Veterans come from organizations of large teams working together to accomplish a common goal. Veterans generally have an idea of where they fit into the “big picture.” The camaraderie element that veterans possess and their familiarity with group dynamics prepares them for functioning well on integrated product teams (IPTs).

Dieter[6] lists attributes of an effective team member. These include taking responsibility for, or buying in, to the success of the team, meeting deliverable deadlines, being a contributor to team discussions, communicating and listening effectively, and providing constructive feedback. Dieter also discusses the roles of team leadership and describes leadership types from the design management perspective. These are similar to other leadership models. He groups leaders into three categories: traditional, passive, and facilitative. These categories follow in Table 1.

### Table 1: Categories of leadership

<table>
<thead>
<tr>
<th>Traditional</th>
<th>Passive</th>
<th>Facilitative</th>
</tr>
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<tbody>
<tr>
<td>Directive and controlling</td>
<td>“Hands-off”</td>
<td>Open environment</td>
</tr>
<tr>
<td>“Just do it.”</td>
<td>Too much freedom</td>
<td>Encourages input</td>
</tr>
<tr>
<td>The decision-maker</td>
<td>Too little oversight and guidance</td>
<td>Provides guidance</td>
</tr>
<tr>
<td>Nontrusting</td>
<td>Extreme empowerment</td>
<td>Embraces creativity</td>
</tr>
<tr>
<td>Ignores input</td>
<td>Uninvolved</td>
<td>Considers all ideas</td>
</tr>
<tr>
<td>Autocratic</td>
<td>Figurehead</td>
<td>Maintains focus: goals versus criteria</td>
</tr>
</tbody>
</table>

The military provides leadership development training to personnel of all ranks such that the veteran is well exposed to each of these styles. In both the civilian and military workplaces, leaders and supervisors approach their subordinates with different styles based upon each subordinate’s capabilities.

Based upon their military experience, veterans have the qualities inherent in being effective team members and team leaders. However, there are some challenges that student veterans bring to a
academic group dynamic, which have been addressed in previous work such as Kim\textsuperscript{[10]} and Allen\textsuperscript{[11]}. Some of these challenges are

1. **Lack of confidence in their own academic abilities.** Some student veterans lack confidence in their math or analytical capabilities in the early design stages of technology. Often, this stems from long periods of time away from academia combined with being users and maintainers of high-tech equipment versus being designers and developers of new equipment, and competing requirements out of class, (i.e., family).\textsuperscript{[12]}

2. **Lack of social skills when dealing with classmates.** Student veterans often find it difficult to interact with people without a military background. Military linguistics, job titles, job descriptions are foreign to civilians. Veterans have a common background, shared or similar experiences that bind them socially. Veterans have to learn how to interact with their non-military classmates.\textsuperscript{[12,13]}

3. **Lack of team appreciation of military skills and drive.** This does not imply a disrespect for military veterans. There can be a tendency for student veterans to apply a martial tone in the civilian or academic workplace, resulting in resentment by other team members. Civilians can react negatively to supervisor-subordinate behavior that would be considered common in the military. Some of this could be attributed to the current disconnect between the country and its military.\textsuperscript{[13,14]}

These particular challenges can cause some veterans to prefer or seek supporting roles in the IPT environment versus leadership roles.

**Description of aircraft design course**

In the current curriculum at Kent State University, the capstone experience of the aeronautical systems engineering technology degree is a course in aircraft design. As an engineering technology course, the students use the design and systems engineering processes to develop initial aircraft sizing and performance estimates, as well as the selection of main aircraft systems. It also forces the integrated product team to study other aspects equally important to the technical design. These aspects include economic analysis, safety and certification analysis, and production and manufacturing preparation.

In the last offering of this course (Spring 2015), the design class consisted of twelve students. The aircraft under consideration was a 3,500 lbf personal light jet or jet trainer using two small turbofan engines, each producing approximately 500 lbf of thrust.

Kent State recently procured a virtual engine bench (Figure 3), simulating the operation and performance of these engines. This bench provides data and visual analysis under several different flight conditions and when procured in 2015 was one of only three such benches in the United States. This engine was and continues to be the fundamental basis for the aircraft design.
The course totaled 4.0 credit hours and met two days a week for one hour forty minutes each. Individual coursework comprised only 35% of a student’s overall grade, with the remaining 65% consisting of group efforts. The course instructor divided the class period into 60% lecture and 40% IPT time. The instructor was available during the IPT segment to assist and offer advice as necessary.

An Army veteran and current aviator in the National Guard volunteered to serve as the IPT lead. She had operational deployment experience in Iraq and technical experience as a maintenance pilot in an Army helicopter unit. Her roles and responsibilities in the course included

1. Controlling and facilitating the IPT section of the class period.
2. Maintaining the data drive for the group.
3. Managing the assembly of the team documents.
4. Maintaining close discourse with the instructor on design progress.
5. Advising the instructor on student contributions to the overall effort.

Group Results and Student Feedback

The group’s efforts proved highly successful, for which the IPT lead deserves much of the credit. This particular class completed several “firsts” in the 19 iterations of this course at Kent State University since it originated in 1996. It was so successful in fact that it significantly challenges both the instructor and subsequent capstone groups to ensure that each successive iteration aspires to the same achievements.

The group’s “firsts” include

1. The first group to prototype the airplane design via 3-D printing and post-processing (Figure 4).
2. The first group to test its prototype in a wind tunnel to estimate the zero-lift coefficient of drag.
3. The first class able to use real engine data upon which to base its design.
The final individual requirement at the end of the course was a paper answering specific questions reflecting on the students’ design experiences. Many students commented on the team lead’s leadership abilities and credited her efforts to the success of the project. Some of these comments follow.

Student 1: “This large team was a hard problem to overcome since I believe others felt the same as I did but I feel the project manager helped immensely at coordinating everyone. With her help I was able to know who I needed to contact should I come across another’s project. Most of my previous classes focused on presentation skills and “team work” but I feel that working with two or three people is not the same as working with fifteen, especially when in a corporate setting.”

Student 2: “This class was also the first chance I’ve had at Kent State University to work in a strong team environment to create a final deliverable product. I think that the notion of creating something technically sound and having that work potentially displayed was a strong motivating factor. The ability of our class to create prototypes of our design was perhaps one of the single best experiences of being at Kent State. I believe the strong team atmosphere, led by [team lead’s name deleted], as well as the guidance of [course instructor’s name deleted] helped.”

Student 3: “I feel like working on a team with others to design a new product is exactly what the industry is looking for, and now I can confidently say that I have experience doing that. Working on an IPT, working with customer requirements, and making tradeoffs based on what would be the best for a company are all skills that were acquired during the class.”

Student 4: “I learned that I can really succeed in a team atmosphere. I would walk with teammates and we would bounce ideas off of each other and it help[ed] me think of ideas that did not occur to me before. I never enjoyed working with others before, but I really did this time around, and I look forward to the next team project.
that I will be a part of. With the completion of this course, I think I am prepared to walk into the structure of a design process and know what role I need to fill.”

Student 5: "If I end up in a job where I take part in activities similar to what we did in this class then I will be happy with my choice of career." This class taught me how to work together in a group, working on a single project long-term, and the ups and downs that come with that.”

Every other team member’s comments were similar to these. Finally, the veteran’s own comments about her experience:

“I learned that I am a half-decent manager and I probably did that better than any part of the designing process itself. I found it easy to relay my vision of the end product and easy to encourage the rest of the team to constantly do more/do better on their particular part. My background significantly helped me in this role, too. I feel that I will make a good manager in, perhaps, a manufacturing plant or a good teammate for a company that performs aeronautical research and/or testing (NASA, FAA, NTSB, etc.). Within this course, I have learned much more than I expected, especially just how long of a process aircraft design really is.

These results clearly illustrate veteran contributions to their academic peers. These comments indicate the facilitative leader described in Table 1. Another important consideration is that the team lead’s influence assisted in developing her peers’ senses of professionalism.

Conclusion

This paper discussed some of the positive and challenging attributes of veterans when returning to institutions of higher learning. It presented some examples of veterans’ design abilities in the military, followed by a discussion of the attributes necessary for successful design work in a capstone design course. Military veterans possess many of those attributes. The paper then provided a description of one capstone course in aircraft design and the class results under a student veteran as the IPT lead. The IPT was the most successful with the student veteran receiving much of the credit for the team’s success.

In the current iteration of the course (Spring 2016), the project lead is also a student veteran with a helicopter maintenance background, but working with a smaller team. It will be interesting to see how the results of the current cohort compare to those presented in this paper.

Bibliographic Information


