ASEE'S VIRTUAL CONFERENCE
At Home with Engineering Education
JUNE 22 - 26, 2020 #ASEEVC
Paper ID #29558

Analyzing the Effectiveness of Competition and Interdisciplinary Teams in Student Learning

Col. Aaron T. Hill Jr., United States Military Academy

Colonel Aaron Hill is an Assistant Professor and Design Group Director in the Department of Civil & Mechanical Engineering at the United States Military Academy, West Point, New York. He holds a Bachelor of Science degree from West Point, a Master of Science degree in Engineering Management from Missouri S&T, a Master of Science degree in Civil Engineering from Virginia Tech, and a PhD in Civil Engineering from The University of Texas at Austin. Aaron has served in the military for 23 years as an Engineer Officer with assignments around the world to include Afghanistan, Egypt, and Bosnia-Herzegovina. He is a licensed professional engineer in Virginia and a Project Management Professional. Aaron's primary areas of research are engineering education, the behavior of steel structures, and blast. Aaron mentors students by serving as an advisor for capstone projects and through service as an Officer Representative for Women's Volleyball and Men's Basketball. His passion for teaching and developing tomorrow's leaders resulted in his selection in 2009 for the American Society of Civil Engineers New Faculty Excellence in Teaching Award and the 2013 Outstanding Young Alumni Award for the Department of Civil and Environmental Engineering at Virginia Tech.

Lt. Col. Kevin P. Arnett P.E., United States Military Academy

LTC Kevin Arnett is a fifth year Assistant Professor at the US Military Academy. He received his B.S. in Civil Engineering from USMA in 2001, his M.S. Civil Engineering from U.C. Berkeley in 2011, and his PhD in Structural Engineering from UCSD in 2019. He teaches structural analysis and design of steel structures, and is a licensed Professional Engineer in California and Missouri.

Cosme Alejandro Lopez Jr.
Mr. James Anthony Baglino, United States Military Academy
Mr. Nicholas Perovich, United States Military Academy
Adriel Evan Moran, United States Military Academy
Adam Thomas Hebert, United States Military Academy
Anthony Bradley, United States Military Academy

Analyzing the Effectiveness of Competition and Interdisciplinary Teams in Student Learning

Competition is meant to incentivize optimization within the world of engineering. In most situations, when engineering companies are bidding for a project to be completed, their goal is to optimize and make the most cost-effective product for the customer. The American Institute of Steel Construction (AISC) Student Steel Bridge Competition (SSBC) is such a project. By normalizing for past performance and comparing the long-term performance of cadets who did capstones involving student competitions versus those who did not, the overall effectiveness of these academic endeavors may be estimated. Through the incorporation of multidisciplinary objectives stemming from the involvement of cadets with a major background other than civil engineering participating in a historically civil engineering dominated capstone, educational advantages, and broadened perspectives can be provided, and Groupthink can be avoided. In addition, through the analysis of functionality between interdisciplinary versus non-interdisciplinary groups, the overall level of student learning is enhanced.

The West Point Steel Bridge Design Team is a group of six undergraduate seniors working on designing and building a steel bridge for the annual AISC SSBC. This comprehensive competition in which students must design, fabricate, erect, and test a steel bridge has provided a unique opportunity for undergraduate students to broaden their understanding of real-world engineering issues. The ability of a student team to follow detailed rules, understand and apply effective project management, and optimize the bridge's strength, stiffness, and cost for a client provides opportunities for both student learning and assessment of their learning. Historically, student teams that have competed in the SSBC have done so solely with civil engineering majors. Motivated by a desire to demonstrate excellence at the competition and to improve student learning, West Point's Steel Bridge teams have adopted an interdisciplinary approach by incorporating a law major and a systems engineering major into the team over the past two years, respectively. Building off of the successes and lessons learned from these recent experiences, the West Point 2020 Steel Bridge Team once again adopted an interdisciplinary approach, with five students majoring in civil engineering and one student majoring in operations research. Given that few real-world engineering projects are completed without the utilization of multiple disciplines, the inclusion of students with different areas of expertise allows them to learn from each other, while taking advantage of each other's strengths. While West Point's 2020 Steel Bridge team is not the first in-depth undergraduate interdisciplinary project, the effectiveness of such projects within the context of competition is largely unexplored.

Surveys of recent graduates will serve as the primary assessment tool for the effectiveness of interdisciplinary versus non-interdisciplinary teams and competition versus non-competition teams. The authors will assess both the impact of student competitions on learning and the impact of interdisciplinary teams on the learning and effectiveness of competition teams. Additional assessment tools will include competition scores and feedback received from faculty members based on the performance of the 2020 West Point Steel Bridge Team.

Introduction

It only takes a quick look at the news over the past few years to see that the world is changing at a rapid pace. Infectious disease is on the rise, leaving doctors, scientists, healthcare experts, and governments with challenging work ahead. Climate change and sea-level rise are impacting food harvests and threatening coastlines, leaving businesses that rely on agricultural produce, real estate investors along beaches, engineers, fossil-fuel investors, and governments with real challenges in an uncertain tomorrow. Engineering societies have paid attention and are embracing the ever-changing world. For example, the American Society of Civil Engineers (ASCE) recently launched the "Future World Vision: Infrastructure Reimagined" project as a way to challenge civil engineers to adapt their way of designing, building, operating, and maintaining infrastructure systems [1]. ASCE points to the uncertain tomorrow where engineers must work together to create innovative solutions to climate change, technological advances in alternative energy, autonomous vehicles, smart cities, advanced construction techniques and materials, and new approaches to governance. These tremendous challenges are not designed, built, operated, and maintained in a vacuum. They require experts from a myriad of disciplines to collaborate, communicate effectively, and make well-informed, ethical decisions in order to be successful. The American Society of Mechanical Engineers (ASME) also recognizes the importance of collaboration between disciplines as it "promotes the art, science, and practice of multidisciplinary engineering and allied sciences around the globe [2]." While political debate exists as to the dire or urgent need for investment in some of these areas, there is little debate that at some point, the need to address these challenges will come and will require skillsets from today's engineering students to tackle them.

While today's engineering faculty come from a wide range of different experiences and technical areas of discipline, the students of today are more diverse than ever before. Furthermore, graduates will be entering an increasingly diverse world and asked to interact with different stakeholders and experts to solve tough challenges during an uncertain tomorrow. Leadership at West Point has recognized this necessity and (as is common at most institutions) has developed a number of Academic Program Goals with supporting objectives that detail specific skills their graduates are expected to have at the time of graduation [3].

1. Graduates communicate effectively with all audiences.
2. Graduates think critically and creatively.
3. Graduates demonstrate the capability and desire to pursue progressive and continued intellectual development.
4. Graduates recognize the ethical issues and apply ethical perspectives and concepts in decision-making.
5. Graduates apply science, technology, engineering, and mathematics concepts and processes to solve complex problems.
6. Graduates apply concepts from the humanities and social sciences to understand and analyze the human condition.
7. Graduates integrate and apply knowledge and methodological approaches gained through in-depth study of an academic discipline.

This framework supports an overarching goal that "graduates integrate knowledge and skills from a variety of disciplines to anticipate and respond appropriately to opportunities and challenges in a changing world [3]." While not overtly stated in the overarching goal, it is important to note that there is an expectation of their graduates to win. After all, the American people expect West Point's graduates to fight and win their nation's wars. As recently stated by the 40th Chief of Staff of the Army, "Winning matters. There is no honorable mention in combat [4]!" The same can be said for graduates entering the workforce in an engineering discipline. The engineers of tomorrow must be able to apply concepts from STEM, the humanities, and the social sciences in order to win and remain competitive in the marketplace.

The unfortunate truth is that many college graduates enter the workforce without significant interdisciplinary experience. In fact, some professions have traditionally excluded populations from participation within their own community practices [5]. Even those college students that are exposed to a diverse curriculum often lack the ability to communicate effectively with audiences outside their discipline and to integrate their in-depth understanding of their area of expertise into a broader, multi-disciplinary context to solve problems. This is not primarily the fault of the students. Universities and educators must make the investment in pursuing opportunities to expose students to realistic interdisciplinary opportunities.

Understanding the importance of competition and providing students with interdisciplinary opportunities to develop, West Point's Civil Engineering Program has investigated the impacts of assembling an interdisciplinary team in a nation-wide competition, the AISC SSBC. While the SSBC rules change every year, the basic idea is that students are challenged with conceiving, designing, fabricating, erecting, and testing a steel bridge that best meets the specifications (fabrication, strength, and serviceability) demanded by a customer. Many teams, to include teams from West Point in the past, have taken a simplistic approach to this challenge and created teams consisting of only civil engineers. Real-world engineering issues such as project management were ignored, often to the detriment of the team. The last few years, the West Point SSBC team brought in different majors with different perspectives and areas of expertise. While positive qualitative results were clear, no attempt had been completed to assess student learning. This paper will provide a literature review that addresses the impact of competition and collaborative learning (both interdisciplinary and otherwise). Then, the authors will present their approaches for assessing the value of forming competition teams and interdisciplinary teams, as well as the results and subsequent findings that followed.

Literature Review

There's no debate that students have different motivations to learn and enter the workforce. Some students are solely focused on "getting an A" in every course. They are completely driven to do whatever it takes to earn the highest academic honors. Other students are fine with "getting by" academically and focus their time more on the social aspects of college. Yet others are driven by being part of a team. Their desire to compete with their brothers and sisters to their left and right, whether on athletic fields or as part of a club, takes up the majority of their time and effort. Student competitions such as the AISC SSBC and the ASCE Concrete Canoe Competition may serve as the melting pot for all of these students. A study of literature [6], [7], [8] suggests this to be true in that students' primary psychological needs are to compete, be a part of a team, and experience the sense of joy through accomplishment. Done correctly, administering these competitions as capstones can achieve these sources of student satisfaction while developing both student disciplinary depth and academic breadth.

The relationships and bonds that naturally form through competition teams motivate students to interact outside the competition and pursue success in other courses through collaboration [9]. Bringing students together to compete on one team within a university against other universities also generates a spirit of collaboration and enhanced learning in other courses. Students are required to demonstrate what they have learned through application even at the most prestigious universities. It could be homework, it could be a project, it could be an exam, or it could be a combination of all of them. The purpose of the student applying what they heard or read is to learn the material. Literature [10] is consistent in its conclusion that there is great value in the learners actively processing presented information. When students seek the assistance of other students to help with homework or to check answers, it opens up a student-teaching-student opportunity that lends itself to effective learning [11]. Literature [12], [13], [14] has consistently shown that cooperative learning has led to positive learning outcomes, higher performance and grades, and an improved ability to communicate effectively with others. This practice of explaining one's own work to someone else and checking the work of a peer gets students into the practice of what engineers do on a regular basis (check each other's work). Simultaneously, students are learning valuable lessons both specific to the technical discipline under review and in clear written and oral communications.

Analysis of scientific literature [15, 16] has led many to conclude interdisciplinary approaches in education are imperative for the next generation of leaders and problem-solvers to be successful. A study at Latvia University of Agriculture [15] divided students into groups in which they were challenged to work together, solve different engineering problems, and then share their findings with the group. This effort is consistent with the administrative structure of capstones. Researchers [15] observed student development in several competencies ranging from personal and social responsibilities, to integrating their work into a broader context, which requires both expanded learning and clear communication. Another study [16] involved interdisciplinary seminars at the University of Wisconsin-Madison and the University of Minnesota. In an interdisciplinary, graduate-level course, the authors posed real-world challenges focused on issues their students would likely face given an uncertain tomorrow. Course-end feedback from students indicated the interdisciplinary format of the course contributed to their abilities to communicate on a breadth of sustainability issues, which would prepare them for an environmentally constrained world.

Interdisciplinary capstones broaden perspectives, encourage individuals to use their imagination, and deter Groupthink. Coined by Irving Janis in 1971 [17], Groupthink is "a mode of thinking that people engage in when they are deeply involved in a cohesive in-group, when the members' strivings for unanimity override their motivation to realistically appraise alternative courses of action." According to the ASCE Civil Engineering Body of Knowledge [18], tomorrow's civil engineers must have the ability to generate creative and innovative solutions, lead multidisciplinary teams, and demonstrate proficiency in effective and persuasive communication. Groupthink is the antithesis of that charge. One of the more prominent examples of the disasters of Groupthink in engineering lies in the Space Shuttle Challenger disaster in 1986, resulting in the tragic death of seven U.S. crew members [19]. Even when not considering the loss of life, the financial costs of an inability to adequately partner and communicate effectively results in a financial price. A study from the National Institute of Standards [20] estimated the cost of inadequate interoperability in the U.S. commercial/institutional buildings and industrial facilities to be $15.8 billion per year! The literature review study shows tremendous value in encouraging interdisciplinary, competitive teams at the university level. Doing so prepares graduates to employ their education to help solve the tough, interdisciplinary challenges that await them.

Methods

Civil engineering capstones are completed at West Point over the course of two semesters for a total of 7 credit hours. Capstones must involve an open-ended design problem and involve the application of math, science, and engineering principles acquired in previous course work. Teams must use an iterative design process to define the problem, identify requirements, analyze alternatives, and select the ideal alternative to solve their problem. The structure of each capstone differs and is determined with the students and advisors for each project; however, each is graded in the context of a 2000-point course. Students input preferences regarding which capstone they would like to participate in, and the Capstone Design Course Director uses student preferences to formulate teams. Several capstone advisors will reach out to other Academic Departments within the Academy to develop interdisciplinary capstones. Students within other departments are then assigned to these capstones based on their preference. This is the third consecutive year that the West Point SSBC has formed an interdisciplinary team.

In their attempts to assess the effectiveness of interdisciplinary teams versus non-interdisciplinary teams and competition versus non-competition teams, the authors took both a quantitative and qualitative approach. Quantitatively, the authors sent out a Google Forms survey to 155 recent graduates from their university's engineering programs via e-mail. The intent of the survey was to assess their level of learning, as well as capture their experiences in, and attitudes towards, competition and interdisciplinary teams in an academic setting. The survey required respondents to provide information related to the nature of the capstone they had done and the quality of learning they gained from their capstone.

The survey asked a series of questions with many asking respondents to provide ratings on a 5-point Likert Scale for how much they agreed with provided statements ("1" was "I strongly disagree" while "5" was "I strongly agree"). The survey allowed for the partitioning of the data into competitive or non-competitive learning, as well as interdisciplinary or non-interdisciplinary learning, by asking the following questions:

1. *Did your team consist of members with different majors?*
2. *Non-competitive or Competitive Capstone?*

The second portion of the survey consisted of one question and several statements that were provided to all respondents in an attempt to assess student learning. Respondents were required to rate their level of agreement with the statements and sole question using the same 5-point Likert Scale. Based on the authors' literature review, it was determined that other factors influencing student learning should be investigated through the survey. Those factors included student motivation, the meaningfulness of work, and human interaction. Assessing student's perceived learning as well as factors that impact student learning allows for a more holistic approach towards assessing how much students are actually learning. In this study, increased student learning is defined as both the increase in self-perceived learning through their perspective capstones and their feelings pertaining to factors proven to positively impact student learning. The questions and statements asked within the survey included:

1. *How much do you feel you have learned by doing your Capstone?*
2. *My capstone motivated me to give 100%.*
3. *My capstone inspired me to interact with expertise outside my group.*
4. *My capstone inspired me to interact with my faculty members.*
5. *My capstone inspired me to interact with others within my group.*
6. *My capstone inspired me to pursue learning in topics of personal interest related to the competition.*
7. *I enjoyed my capstone experience.*
8. *My capstone led me to learn many practical aspects of engineering that I would not have learned in the classroom.*
9. *My capstone required student self-taught learning.*
10. *I feel like my capstone team accomplished a great deal.*
11. *I feel like my capstone played a significant role in my education.*
12. *I feel like my capstone provided a meaningful design opportunity for us to solve.*

Qualitatively, the authors conducted interviews and reviewed reports from two interdisciplinary SSBC teams, reviewed end-of-term reports for dozens of SSBC teams with only civil engineering majors, and assessed their own experience during the 2019-2020 academic year. While the authors were hoping to include their performance in the SSBC 2020 competition as part of their assessment for this paper, the competition will not occur prior to the submission of this paper.

Results

The survey received 34 responses, giving the authors a response rate of 21.9%. Due to the low response rate, response bias may be present in the survey's results meaning they are not a truly representative sample of recent engineering capstone participants. Of the responses, 14 were from graduates who had completed competitive capstone projects, and 20 were from graduates who had completed non-competitive capstone projects. In addition, eight of the respondents participated in an interdisciplinary capstone, while the other 26 did not. Of those eight respondents that participated in interdisciplinary capstones, the competitive versus non-competitive capstone breakdown was equally split. The results of the 5-point Likert survey are shown in Fig. 1.

The authors conducted a statistical analysis on the survey results to investigate if a capstone being competitive or non-competitive had a statistically significant impact on the survey responses provided. This was done by creating a linear model for each of the survey statements which respondents provided their level of agreement with. A linear model was also created for the question regarding how much graduates felt they had learned by completing their capstone. Each of the linear models followed the following format:

$$y_i = mx + b \text{ where}$$

y_i = *the Average Respondent Rating for Statement i*

m = *the impact of a capstone being competitive on the expected response to statement i*

x = *1 if a capstone was competitive and 0 if it was non-competitive*

b = *the Average Respondent Rating for Statement i among respondents who took part in non-competitive capstones*

This same process was used to investigate if a capstone being competitive or non-competitive had a statistically significant impact on the survey responses provided.

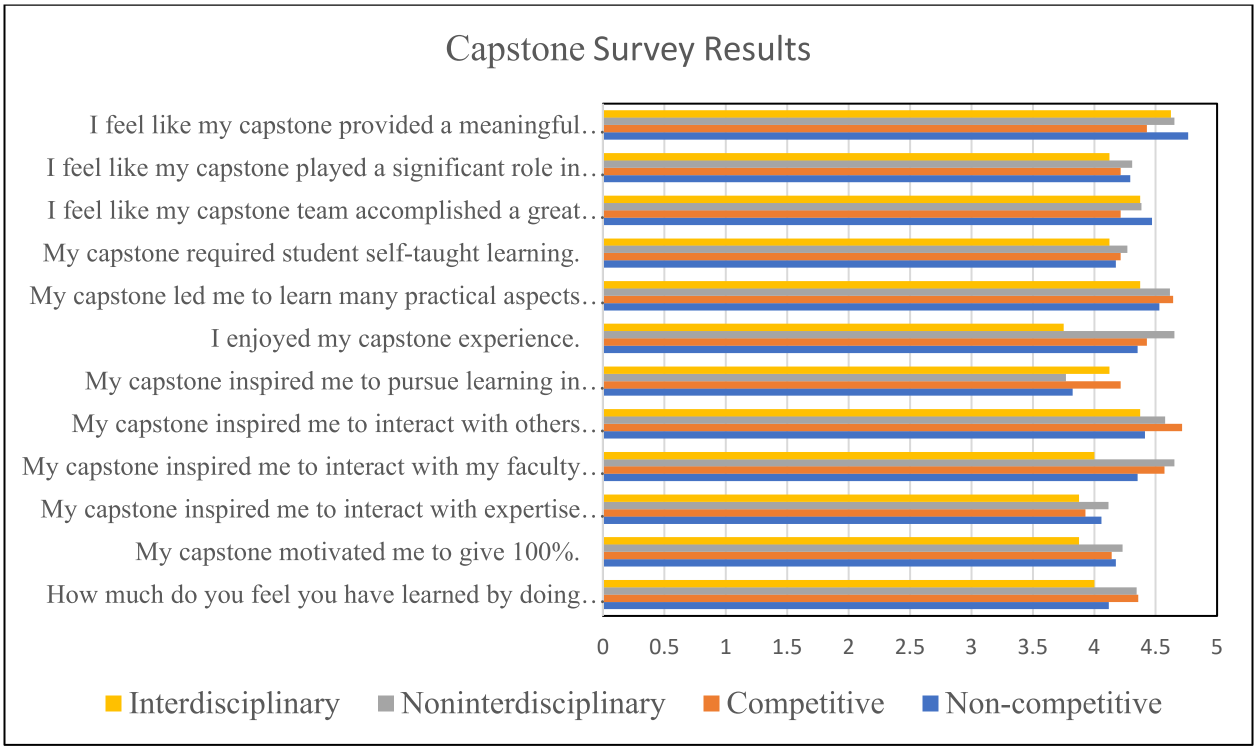

Fig 1. Capstone Survey Results

Once all of the linear models were created, the p-values (probability values) for "x" in each linear model was documented. P-values assist in assessing whether or not a null hypothesis should be accepted or rejected [21]. In the case of this study, the null hypothesis is that a capstone being competitive instead of non-competitive, or interdisciplinary instead of non-interdisciplinary, has no impact on survey responses. This study considered factors with p-values of less than 0.05 statistically significant. This is consistent with the standard practice of p-values of less than 0.05 being associated with statistical significance [21]. A factor being statistically significant indicates that the null hypothesis should be rejected.

The statistical analysis revealed that a capstone being competitive or non-competitive did not have a statistically significant impact on any of the responses provided. From a quantitative perspective, the null hypothesis that a capstone being competitive or non-competitive has no impact on survey responses was therefore accepted, as there is not enough statistical evidence to suggest the contrary.

However, whether a capstone team consisted of members with different majors did have a statistically significant impact on the responses given for two of the statements in the survey:

My capstone inspired me to interact with my faculty members.

I enjoyed my capstone experience.

In the case of each of the statements, graduates with non-interdisciplinary capstones averaged higher responses. For the first statement, the p-value for the impact of a team being interdisciplinary was .0284. This means that if the null hypothesis that student learning is not impacted by interdisciplinary teams is true, there is only a 2.84% chance that the responses to the first statement would be as extreme as they are. A student being on an interdisciplinary team reduced the expected response to the first statement by .6538. In the case of the second statement, the p-value for the impact of a team being interdisciplinary was .00291, and a student being on an interdisciplinary team reduced the expected response to the second statement by .9038. It is important to note that despite the difference in ratings, the ratings in both questions were still favorable. In addition, given the low population of eight respondents, further investigation is required.

Graduates who had completed interdisciplinary capstones were also asked:

How much do you feel the interdisciplinary nature of my capstone helped prevent GroupThink?

The average response to this question was 3.43. Meanwhile, graduates who did not complete an interdisciplinary capstone were asked:

How much do you feel the addition of a member from another discipline to your capstone would have helped prevent GroupThink?

The average response to this question was only 3.04, suggesting that students who have not been on interdisciplinary teams underestimate the positive impact that it can have in preventing Groupthink or are potentially unaware of Groupthink that existed within their group. This could also suggest that people lack interest in getting out of their comfort zone by integrating "outsiders" into their group. This also suggests that students who participate on interdisciplinary teams recognize its usefulness in creating more innovative solutions. Again, the sample size for this analysis warrants further investigation.

The p-values and t-statistics that were found for the linear models are shown in Fig. 2.

	Competitive/Non-competitive		Interdisciplinary/Non-interdisciplinary	
Question	p-value	t-statistic	p-value	t-statistic
How much do you feel you have learned by doing your Capstone?	0.507	0.672	0.196	-1.320
My capstone motivated me to give 100%.	0.979	-0.027	0.235	-1.209
My capstone inspired me to interact with expertise outside my group.	0.464	-0.742	0.486	-0.704
My capstone inspired me to interact with my faculty members.	0.649	0.460	0.026	-2.331
My capstone inspired me to interact with others within my group.	0.234	1.214	0.506	-0.672
My capstone inspired me to pursue learning in topics of personal interest related to the competiton.	0.130	1.554	0.449	0.767
I enjoyed my capstone experience.	0.939	-0.077	0.002	-3.274
My capstone led me to learn many practical aspects of engineering that I would not have learned in the classroom.	0.512	0.664	0.332	-0.985
My capstone required student self-taught learning.	0.910	-0.113	0.690	-0.402
I feel like my capstone team accomplished a great deal.	0.300	-1.054	0.976	-0.031
I feel like my capstone played a significant role in my education.	0.771	-0.293	0.587	-0.548
I feel like my capstone provided a meaningful design opportunity for us to solve.	0.074	-1.849	0.906	-0.120

Fig 2. P-values and T-statistics

Whereas the quantitative analysis was inconclusive and warrants further investigation over time, the qualitative analysis regarding the benefits of competitive capstones and interdisciplinary capstones is clear. Through the experiences of the students on the current West Point SSBC, it has been evident that the competition aspect of the capstone has enhanced learning. Over the past month, the team designed and fabricated machined connections, with the goal of developing an innovative solution to drastically reduce construction time during competition. After performing a tension test of the machined connection and understanding through observation the behavior of the connection, the team determined the connection was over designed to exceed nearly double the required force necessary. Promptly after this discovery the team initiated the redesign process to make the overall bridge design more competitive for the regional competition. A similar story could be said during the design process that took place during the first semester. The team conceived of dozens of different designs and conducted scores of analyses in an attempt to optimize their design. Stories like these are unlikely to be found in non-competitive capstone teams as design often stops after the initial feasible design is agreed upon. Competition provides a pressure on competitors to continuously revisit initial designs to maximize efficiency. As repetitions in the gym and on the athletic field enhance an athlete's performance, repetitions in the design, testing, and fabrication caused by competition improve the depth of knowledge of students. This is undoubtedly valuable as it promotes both creativity and knowledge within the engineering profession.

Interviews with former SSBC members and a review of their published literature reveal that interdisciplinary capstones promotes learning. For the last couple of years, the addition of a systems engineer on the team has led to significant learning for the civil engineering students in terms of defining activities, sequencing activities, scheduling, and allocating resources. Civil engineering students were given lectures designed by the systems engineering student on project management from the Project Management Body of Knowledge [22]. A few years ago, a law and legal studies major joined a group of civil engineers on the West Point SSBC. While his primary duties were to serve as a liaison between the rules committee and the team and as a "red team" to sharp shoot designs that might not conform completely to the rules, he also found himself educating his peers and making a significant contribution to the team by introducing a quantitative decision analysis to selection the optimized bridge design for the team [23]. Of course, all of the non-civil engineering majors learned a great deal about engineering statics, mechanics, and steel fabrication. These interdisciplinary teams competed well with highly functional and competitive steel bridges. In fact, innovative solutions from last year's team resulted in one of the fastest construction times in West Point history. These qualitative benefits have led the advisors to continue to seek an interdisciplinary approach to the West Point SSBC capstone. The advisors have already put in a request to the Systems Engineering Department for an Engineering Management major to join their team next year.

Conclusion

Given the importance of utilizing interdisciplinary approaches to solve engineering problems in the workforce, it is critical that academic institutions find a way to increase faculty and student participation in interdisciplinary learning. The benefits of interdisciplinary learning are essential to producing well-rounded engineers capable of communicating their perspectives and areas of expertise while listening and incorporating others areas of expertise towards innovative solutions. The failure of students to practice in interdisciplinary learning in a low-threat university environment could lead to a lack of adequate preparation when the stakes are highest. Students lacking interdisciplinary experience tend to underestimate the benefits of how helpful an interdisciplinary team member would be in improving performance by avoiding detractors such as Groupthink. The value of healthy competition lends itself to repetition, optimization, and enhanced learning. What is clear is that combining the value of competition with an interdisciplinary team composition brings the benefits of worlds into one student experience.

References

[1] https://www.futureworldvision.org/, site accessed 30 January 2020.

[2] https://www.asme.org/, site accessed 30 January 2020.

[3] C. Jebb, *Educating Army Leaders: Developing Intellect and Character to Navigate a Diverse and Dynamic World*. West Point, New York, 2017.

[4] J. McConville, Speech by the 40th Chief of Staff of the U.S. Army, 10 January 2020.

[5] C. Paguyo, R. Atadero, K. Rabo-Hernandez, J. Francis, *Creating Inclusive Environments in First-Year Engineering Classes to Support Student Retention and Learning*: Paper presented June 2015 at ASEE Annual Conference & Exposition, Seattle, Washington.

[6] J. Lowman, *Mastering the Techniques of Teaching*. San Francisco: Jossey-Bass Publishers, 1995.

[7] O. Milton, H. Pollio, and J. Eison, *Making Sense of College Grades: Why the Grading System Does Not Work and What Can Be Done About It*. San Francisco: Jossey-Bass Publishers, 1986.

[8] A. Bandura, "Human Agency in Social Cognitive Theory." *American Psychologist*, vol. 44, pp 1175-1184, Sep. 1989

[9] B. Barry, K. Meyer, K. Arnett, and B. Spittka, *Competition-Based Learning Activities within Civil Engineering Education*: Paper presented June 2013 at ASEE Annual Conference & Exposition, Atlanta, Georgia.

[10] M. Svinicki and W. McKeachie, *McKeachie's Teaching Tips: Strategies, Research, and Theory for College and University Teachers*. Belmont: Wadsworth Cengage Learning, 2014.

[11] R. Johnson, D. Johnson, and M. Taurer, "Effects of Cooperative, Competitive, and Individualistic Goal Structures on Achievement: A Meta-Analysis." *Psychological Bulletin*, vol. 89, pp 47-62, Jan. 1981.

[12] A. Hill and M. Campbell, *Student Mastery of Engineering with Design Review*: Paper presented 2018 at ASEE Gulf-Southwest Conference, Austin, Texas.

[13] A. Hill, *Student Mastery of Structural Analysis with Design Review*: Paper presented 2018 at ASCE/SEI Structures Congress, Dallas, Texas.

[14] J. Miller and J. Groccia, "Are four heads better than one? A comparison of cooperative and traditional teaching formats in an introductory biology course." *Innovative Higher Education*, vol. 21, pp 253-273, Summer 1997.

[15] A. Zeidmane and S. Cernajeva, "Interdisciplinary Approach in Engineering Education." *International Journal of Engineering Pedagogy*, vol. 1, pp 36-41, Apr. 2011.

[16] P. Eagan, T. Cook, E. Joeres, "Teaching the Importance of culture and interdisciplinary education for sustainable development." *International Journal of Sustainability in Higher Education*, vol. 3, pp 48-66, Mar. 2002.

[17] I. Janis, "Groupthink." *Psychology Today*, pp 43-46, Nov. 1971.

[18] Civil Engineering Body of Knowledge 3 Task Committee, *Civil Engineering Body of Knowledge: Preparing the Future Engineer*. Reston: American Society of Civil Engineers, 2019.

[19] I. Janis, *Groupthink: Psychological studies of policy decisions and fiascoes*. Boston: Houghton Mifflin, 1982.

[20] M. Gallaher, A. O'Conner, J. Dettbarn, and L. Gilday, "Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry." *National Institute of Standards Report NIST GCR 04-967*, Aug. 2004.

[21] R. Wasserstein and N. Lazar, "The ASA Statement on p-Values: Context, Process, and Purpose." *The American Statistician*, vol. 70:2, pp 129-133, 2016.

[22] A. Hill and M. Nelson, "Application of the Project Management Body of Knowledge (PMBOK) in an Interdisciplinary Capstone: The AISC Steel Bridge Competition." *International Journal of Engineering Management*, vol. 3, pp 17-24, 2019.

[23] J. Etringer, S. O'Brien, A. Updegraff, T. Langerhans, A. Nadjari, C. Kim, A. Hill, and M. Campbell, *Analyzing Multidisciplinary Team Effectiveness in an Engineering Environment: A*

Case Study of the West Point Steel Bridge Team: Paper presented 2018 at the ASEE Gulf-Southwest Section Annual Conference at The University of Texas at Austin.