Paper ID #23482

Continued Development of an Integrated Capstone Design Curriculum

Dr. Shayne Kelly McConomy, Florida A&M University/Florida State University

Shayne K. McConomy is the Senior Design Coordinator at in the Department of Mechanical Engineering at FAMU-FSU College of Engineering; He holds a PhD in Automotive Engineering from Clemson University. His focus is product development and design for the automotive industry.

Dr. Ruturaj Soman

Ruturaj Soman received his bachelor's in Mechanical Engineering from the University of Mumbai in 2006, followed by M.Sc. in Aerospace from the University of Glasgow in 2007. He did his Ph.D. from the department of Electronic and Electrical Engineering from University of Strathclyde also in Glasgow from 2007-2013. His research focused on using intelligent systems design methodologies, reliability analyses and risk assessment on finite inertia power systems particularly naval vessels. Currently he is a courtesy appointment at CAPS-FSU and was the instructor for Engineering Design Methods at the FSU-FAMU College of engineering.

Dr. Nikhil Gupta, Florida A&M University/Florida State University

Nikhil Gupta received his Bachelor of Technology degree from Y.M.C.A. Institute of Technology, Haryana, India in 2008, Master of Science degree from North Dakota State University, Fargo, ND, in 2010, and Ph.D from Florida State University, Tallahassee, FL, in 2014, all in Mechanical Engineering. He is currently an Adjunct Assistant Professor teaching Engineering Design Methods in the Department of Mechanical Engineering. He is also serving as Postdoctoral Research Associate at Center of Intelligent Systems, Control, and Robotics (CISCOR) at Florida State University. His research interests are primarily in the areas of dynamic system modeling, intelligent control, autonomous mobile wheeled and legged robotics, dynamic motion planning, and mechatronics.

Dr. Chiang Shih, Florida A&M University/Florida State University

Dr. Chiang Shih is a Professor of Mechanical Engineering Department, FAMU-FSU College of Engineering, Florida State University. He received his Ph.D. degree from the Aerospace Engineering Department at the University of Southern California in 1988. He has served as the department Chair from 2002 until 2011 and is currently the Director of the Aeropropulsion, Mechatronics and Energy Center established in 2012. He is the coordinator of the ME Senior Capstone Design Curriculum and the dual degree B.S.-M.S. program.

Continued Development of an Integrated Capstone Design Curriculum

The objective of this paper is to discuss the best practices for an integrated approach to teach project management and product design and development over three semesters, as opposed to the college's traditional two-semester curriculum. The integrated approach used collaboration between one semester of Engineering Design Methods (EDM) and two-semesters of the Senior Design Project (SDP). The integrated approach, modeled on the engineering design spine with roots in freshman courses, involved both the EDM and SDP cohorts. The interclass involvement includes participation in design review presentations, senior-to-junior mentorship, and multiclass workshops. Student feedback through periodic surveys and interviews provided insight into the students' progress and learning outcomes. This paper reports on efforts that would help an integrated Capstone Design curriculum succeed. The Department's surveys contribute to the current syllabus content related to learning outcomes and aimed at exploring the student mind-set. The Department expected the experiences gained through interclass collaborations and active feedback would enable a better EDM and SDP course structure. The integrated activities would also improve syllabus material drawn from surveys to afford the students' subject mastery.

I. Introduction

Across engineering departments in universities, the Capstone Design course is arguably the most influential course for engineering students. Fundamentally, the Capstone Design course is the summative assessment of the engineering curriculum, which pushes students to reach the *create* level in the revised Bloom's Taxonomy [1]. In addition, many universities engage with industry partners to provide project sponsorship and/or student mentorship. As a result the students are exposed to professional development by combining project-based learning and real-world practice. Early efforts stressed improving the overall Capstone Design experience for students with increased engagement from instructors. Specifically, Banios [2] outlines a two-semester Capstone Design curriculum making students work in teams to design projects first at a proposals stage followed by a second semester with a realization of a prototype model. Chung, Harmon [3], outline efforts to understand how students feel about their Capstone Design course. Chung, Harmon [3] used surveys that employ knowledge mapping and points out the following five important characteristics of a Capstone Design course:

1. Challenging design project done by students within teams.
2. Focuses on knowledge gained throughout the curriculum.
3. Encourages solving problems that represent real-life engineering.
4. Earns an understanding of the professional aspects and engineering culture.
5. Learns and practices project proposing, planning, and control.

Besides team-based projects, including a wider range of technical skills such as presentations, report writing, requirements analysis, and programming increases student the learning outcomes [4]. These technical skills serve to increase marketability for engineering graduates. Ideally introduction to the technical skills begins at the sophomore level is reinforced as juniors and executed as seniors in the Capstone Design course. The multi-semester approach to learning is already done with traditional subjects such as Dynamics and Thermal Fluids. However, multi-semester project based learning paired with multi-course years at the undergraduate level is uncommon if executed at all. The Automotive Engineering department at Clemson University has operated and demonstrated a similar curricula for Master's students since 2010 [5, 6]. The program at Clemson University is a two year project which utilizes cross curricular activities resulting in a functional concept vehicle. Ultimately, Capstone Design project strengthens the curriculum by closely following the Accreditation Board for Engineering and Technology (ABET) guidelines. Assessment of past efforts while developing the Capstone Design curriculum reveals important overall qualitative attributes which are summarized in Table 1. The work presented in this paper discusses the aspects listed in Table 1.

Table 1 Important qualitative attributes of a Capstone Design curriculum

No.	Qualitative attributes of design curriculum
1	Student-team based project solving.
2	Project topics in line with real-world applications.
3	Clear division of the design course including design theory and project implementation.
4	Emphasis on professionalism and ethics.
5	Ability to gauge student learning through surveys.
6	Adherence to ABET guidelines.

II. Background work

Over the years, the program has developed an integrated Capstone Design curriculum. A curriculum which starts with an introduction in freshman year and continues throughout the program of study and culminate in a two-semester Capstone Design class. The curriculum is modeled on the design-spine [7] and the approximate time line is shown in Figure 1. Note that the active integration efforts focus on the Junior and Senior class levels. The sections to follow reiterate the department's efforts to carry out effectively all important attributes listed in Table 1.

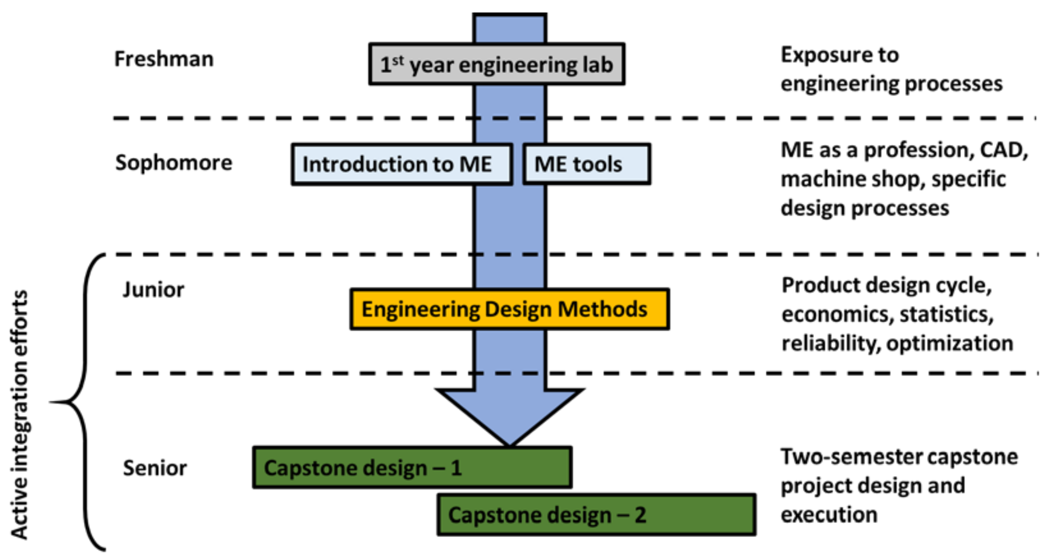

Figure 1. Integrated design curriculum in Mechanical Engineering

II.A. Design Theory and Project Management

This section describes the previous work that is the foundation for the efforts reported in this paper. Engineering Design Methods (EDM) forms the theory part of the overall design curriculum while Senior Design Project (SDP) focuses on the project execution. These two courses are explained briefly here focusing only on their more salient features.

1. **EDM** – A comprehensive syllabus, comprised of mechanical engineering design case studies, research work and applications, forms an integral part of EDM. Throughout the study, industry-relevant tools are introduced to students at various phases of the classical design cycle. Main topics with their respective focus areas are listed in Table 2. The class is divided into teams of 4-8 members (depending on class size) with assigned tasks working on mock projects defined early in the semester. The EDM projects are based on previous year's Capstone Design projects, and have been generalized to ensure consistency in the deliverables. Examples of the deliverables include House of Quality (HOQ), Failure Mode and Effects Analysis (FMEA), and Taguchi Design of Experiments (DOE). Typically, six team-presentation assignments in a semester encompass and provide a project related opportunity to students to use the theories and tools learned in lectures. Throughout the semester, a professional hierarchy that emphasizes ethical conduct is encouraged. Besides projects, other evaluations of students are done through tests, homework, and assignments similar to a regular course.

Table 2 Design relevant topics and tools covered in EDM

Subject	Topic/tool focused on
Engineering design cycle	Product development and design phases
Customer requirements assessment	Kano diagram, House of Quality
Risk, reliability and failure assessment	Failure mode and effects analysis (FMEA), fault tree analysis (FTA)
Economic decision making	Net present value (NPV), Internal rate of return (IRR), sinking funds etc.
Concept generation methods	Theory of inventive problem solving (TRIZ), morphological chart
Concept selection methods	Pugh matrix
Design assembly efficiency	Boothroyd-Dewhurst method
Project planning	Work breakdown structure (WBS), Gantt chart
Engineering ethics	Types of contracts, conflict of interest situations, laws and legalities
Robust design	Statistical tolerancing and Taguchi design of experiments (DOE)

2. **SDP** – This is a two-semester course which begins in the fall semester and ends in spring semester. The course usually comprises the full cohort of over 100 students and 20 or more projects. SDP focuses mostly on project implementation and frames in four years of engineering education where students will bring together their gained engineering knowledge and nontechnical professional skills such as teamwork, professionalism, communication, and project management. At the end of the second-semester, the Capstone Design course finishes with a whole-day open house event featuring team presentations, a poster session, and review session with panel judges. The audience is fellow students, faculty, external sponsors, and a panel of judges mostly comprised of the Mechanical Engineering Advisory Council (MEAC) members.

Throughout the school year, the EDM and SDP classes are required to interact thus encouraging exchange of experiences, self-reflection, and retrospective learning. The two main curricular activities that enable such interactive integration are:

1. **Project shadowing:** All EDM teams are required to "shadow" the current SDP teams. The expectation from the EDM team is to attend presentations, conduct a face-to-face interview, and combine their observations and critique of the SDP team's design methods. This shadow events is part of a graded shadow report at the end of the semester. Research has shown that involving students in assessment not only allows students obtain higher grades, but provides a deeper understanding with guided learning [8, 9]. Therefore, the grading rubrics used by EDM teams afford the students familiarity with the assessment process. The EDM students will also have the freedom to use their own judging criteria for the purpose of providing an unbiased evaluation in their shadow-reports.

2. **Peer review of EDM poster presentations:** EDM teams are required to take part in the end of the semester poster session showcasing the work done in their mock-projects. This session is attended by the current SDP students who are providing reciprocal feedback to EDM teams. This serves two purposes: EDM students gain an insight on poster presentations before they would become seniors and SDP students learn retroactively through self-reflection.

The interactive efforts show both a clear division between learning of design theory and managing project, while integrating simultaneously these two components through interaction between EDM and SDP. These opportunities enables students to self-reflect as well as gain insights into what to expect for a future course to form a feedback-feedforward system shown in Figure 2.

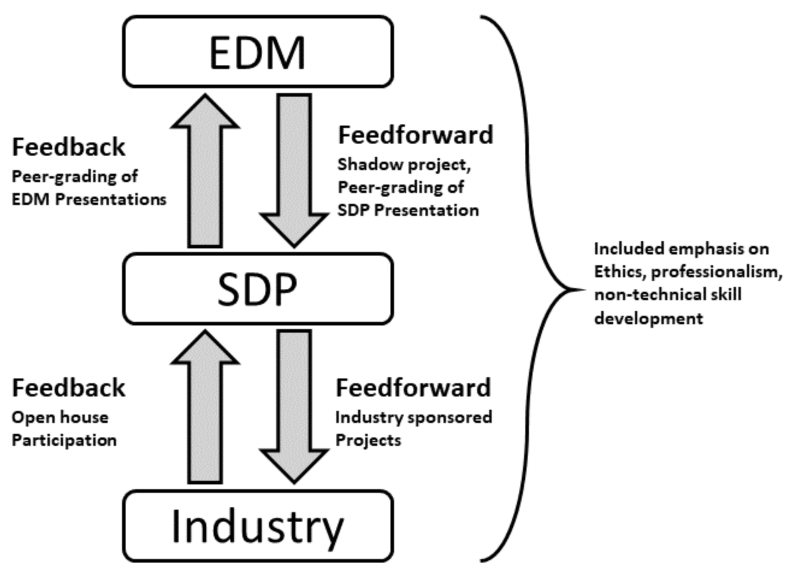

Figure 2. Interaction of classes and the feedback-feedforward system

Next, section II.B. focuses on the measures taken in both classes to learn from student feedback to improve the design curriculum thereby ensuring the aim of continual improvement adherent to ABET guidelines is met.

II.B. Continual improvement through student feedback

An important step towards successfully implementing an effective integrated design curriculum is the use of student feedback information. The authors have used several surveying techniques that measure different learning outcomes as summarized below and in Table 3:

1. General Beliefs (GB) – This survey pertains to the perceptions and thoughts of students from the learning point of view for the design curriculum. These surveys will be done with help from the College of Education.
2. Knowledge Retention (KR) – This survey assesses the level of knowledge retention of EDM topics when students pass EDM and enter SDP and to be conducted at the beginning of the school year (start of first semester for SDP).
3. Syllabus Focus (SF) – This survey deals with more syllabus-specific questions concerning the theoretical aspect of the design process, design tools as well as students' perception towards the efficacy of the teaching contents. As it is directly linked to specific topics based on EDM syllabus, this survey is conducted only in the EDM class and after the mid-semester.

Table 3 Survey types and timelines

Class	Previously used survey time	Survey type
EDM	Week 1-3	GB
	Week 9-10	SF
	Week 13-15	GB and SF
SDP	Week 1-3 (of fall)	KR and GB

Figure 3 shows the continual improvement cycle of measuring student feedback, providing qualitative and quantitative analysis, and integrating into the program's continual assessment loop for actionable plans and improvements. These surveys mentioned are analyzed at the end of every semester (for EDM) and end of each school year (SDP) to improve either course respectively based on student feedback of their course experiences. Section III summarizes the most important student feedback and the implemented changes in response to these suggestions. Furthermore, a comparison of student survey results with an added ABET-inspired performance scoring criteria are made to track the impact of improvements.

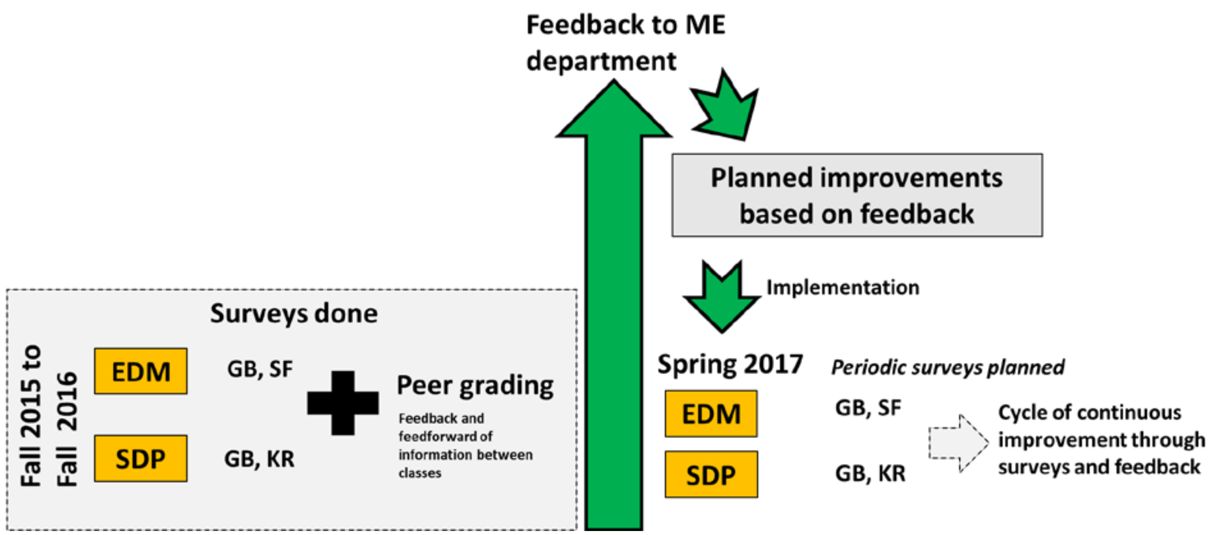

Figure 3. Continual improvement through student feedback

III. Current efforts to improve design experiences and learning outcomes

Building on the understanding gained from active student participation through surveys and feedback as well as interclass events, suitable changes were made to the course syllabus and delivery methods. These broadly classified changes fit into two categories as listed in table 4:

1. Evaluation methods – Adjustments to conducting class tests and other means of grading.
2. Syllabus contents – Core changes to course material.

In addition, Table 4 summarizes the "previously used" course structure versus the "current format" using baseline student feedback taken from the Fall 2015 and Spring 2016 cohorts. The results of these changes are shown through two quantitative metrics: (1) students' grade distribution in Table 5 and (2) the ABET-inspired learning outcome in Table 6. Grade distribution and ABET learning outcomes might not be the best indicators for overall improvement in learning; however, they can provide valuable measure if tracked for long-term development. Long-term development is the intention of the authors this can be seen in the multiyear tracking data in Table 5. To date the efforts in course integration and constant feedback has yielded improving grades. When mapped to student learning outcomes, Table 6 shows an improving self-perception learning outcomes as suggested in the most recent completed semester (Fall 2016). While the student performance has been, in general, better than previous semesters in 4 of the 7 surveyed results, the observations show some lower ratings as marked in greyed cells of Table 6.

Table 4 Summary of student feedback and actions taken

Course part		*General student Feedback*	*Previously Used*	*Current Format*
1. Evaluation methods	EDM tests	"test too long"	45min of test time	Increased to 75min
	Take home quiz	"highly research intensive"	1 week deadline	Removed and replaced by 15 min pop quizzes
	Team presentations	"peer review mechanism is unclear"	15% equal weight of peer reviews	Weight reduced to 5% and students exposed to more peer reviewing opportunities by including cross-class grading of presentations and posters
2. Syllabus	Scheduling tool: Critical Path Method	"never used"	Part of homework and tests	Removed from syllabus and more emphasis put on Gantt chart and Work Breakdown Structure.
	Linear programming optimization	"too complex and irrelevant"	Part of homework and tests	Removed from syllabus.
	Robust design: Taguchi method	"time consuming"	Part of homework, tests and presentations	Extent of taught material reduced to basic overview.

Table 5 Comparison of student performances

Semester (no. of students)	*Homework participation*	*Overall class average %*	*Student grade proportions*			
			A	***B***	***C***	***F***
Fall 2015 (24)	52.0%	77.2%	29.2%	54.2%	12.5%	4.2%
Spring 2016 (90)	86.5%	75.1%	34.8%	40.4%	20.2%	4.5%
Fall 2016 (57)	84.0%	84.6%	80.7%	17.5%	1.8%	0.0%

Table 6 Comparison of student performances mapped to ABET learning outcomes

ABET student outcome focused on	*Collective performance rated (max score = 5)*		
	Fall 2015	***Spring 2016***	***Fall 2016***
an ability to apply knowledge of mathematics, science, and engineering.	3.48	3.32	4.68
an ability to communicate effectively with written, oral, and visual means.	3.98	3.74	4.46
an ability to function on multi-disciplinary teams.	4.52	5.00	5.00
an ability to identify, formulate, and solve engineering problems.	3.43	4.76	4.56
an understanding of professional and ethical responsibility.	3.41	3.71	5.00
the broad education necessary to understand the impact of engineering solutions in a global and societal context, and a knowledge of contemporary issues.	2.83	4.55	4.04
a recognition of the need for, and the ability to engage in life-long learning.	2.9	3.94	3.32
Average (max score = 5)	3.51	4.15	4.44

IV. Planned work

Section IV.A. elaborates on the survey work planned for the Fall 2018 semester, and section IV.B. elaborates on the organized events work planned. The focus is on continuing the discussed practice of periodic surveys and assessments.

IV.A. Surveys

Continual improvements to the integrated design curriculum needs the gathering of more information from students. Data collection needs particular experience and background in educational psychology and thus, a need to collaborate with the College of Education. For the Fall 2018 semester, the following surveys with their expected outcomes are planned as shown in Table 7.

Table 7 Planned surveys and expected outcomes

Survey time	*Survey type and information required*	*Target class*	*Expected outcome*
Mid-semester	Learning beliefs and patterns (assisted through department of education)	EDM	Deeper understanding of student mindset to enable further evolution of the course and improvements.
Mid-semester	SF	EDM	Ability to compare two entire cohorts, the previous syllabus, and the modified one.
End-semester	KR and GB	EDM, SDP	Gauge the amount learned by both EDM and SDP classes. Which can be mapped to evaluated performance numbers.

Sample questions of the Knowledge Retention survey are shown in Table 8. The major focus of the Knowledge Retention survey is to include questions linked directly to material taught in the EDM class. SDP students need the EDM information for the SDP's project analyses hinges on retention after one year or more past their EDM course. On the other hand, EDM students answering this survey will help measure a similar retention amount after a single semester. These results, different over time; however, within the integrated design curriculum the differences will help to further assess efforts, and ensure students can retain knowledge, as well as provide meaningful data, correlations, and interpretations.

The subject domain assessments from the Syllabus Focus survey, shown in Table **9**, aims to link a student's perception of managing a project and its relevance to the syllabus. The Syllabus Focus survey is broken into two parts:

1. Learning outcome – Focuses on the student's self-perception of how much they have learned.
2. Coursework – Seeks information on adequacy of coursework and study materials given to students.

Understanding such a linkage at the middle of the semester, would further help with the results of assessing a General Belief survey held at the end of the semester (shown in Table 10). The Syllabus Focus survey tries to understand how students perceive relevance of a project in EDM to the syllabus content and given study materials. The General Belief survey strives to understand students' belief pattern about engineering studies. The General Belief survey is done with the help of the College of Education and is common to both EDM and SDP classes, while the Syllabus Focus survey is only for EDM students as it forms the basis of getting feedback to improve the teaching the design theory portion of the overall design curriculum. A plan to report the results from these surveys once collected and analyzed later in the Fall 2018 semester.

IV.B. Events

In addition to interclass interaction, the College of Engineering has organized some cross-department events such as the Engineering Design Day. Held in fall 2016, the Engineering Design Day was the first of its kind at this College of Engineering as it was attended by all five engineering departments: Civil & Environmental Engineering, Chemical & Biomedical Engineering, Electrical & Computer Engineering, Industrial & Manufacturing Engineering, and Mechanical Engineering. Over 48 teams gave oral presentations, poster presentations, and live demonstrations of the engineering prototypes developed over a two-semester time period. Advisory council members from these engineering departments served as external evaluators for the Capstone Design projects. The Engineering Design Day open house event provided a tremendous opportunity for seniors to showcase their engineering knowledge, teamwork, and leadership skills. Along with the Engineering Design Day, the college also hosted the first annual College of Engineering Technology Business Pitch Competition modeled as the Engineering "Shark Tank" event.

A summary of notable points from these event:

- Six parallel oral presentation sessions (30 minutes each) across four neighboring buildings on campus between 9 a.m. to 3 p.m., hosting 48 team presentations.
- Shark Tank competition held at the College of Engineering from 3 p.m. – 4:30 p.m. where six competing teams presented their business pitch for a total cash prize money of $2,500.
- Poster presentations and live demonstrations of the prototypes held from 4 p.m. to 6 p.m. at the College of Engineering.
- Award ceremony for IEEE student chapter winners, Engineering Shark Tank winners and Engineering Design Day event winners held at 6:30 p.m.
- The day ended with highly positive remarks from the judges' remarks.

Such an event was a unique opportunity to share with the entire College of Engineering faculty, staff and students at all levels and had showcased design outcomes from graduating seniors to many industrial partners and project sponsors. Such events are to be continued and greatly promoted by Mechanical Engineering department in the future to further strengthen the student experiences with the Capstone Design curriculum.

V. Discussion and conclusion

This paper provided the second phase of prior efforts that focus on integrating the design theory and project implementation of the Capstone Design curriculum. Results obtained from these efforts are summarized in section III and show promising outcomes which would include subject mastery, improved Capstone Design project results, and enhances student performance on ABET criteria. Specifically the increase in overall class average indicates student performance would improve with interclass integration. Overall, the foundation of the development originates from the six important attributes of the Capstone Design curriculum as outlined in Table 1. Gains were shown in three ABET learning outcomes. Further research is necessary to explore the results from the ABET student learning outcomes and student performance metric gains. To reiterate, that authors are keen on continuing the collaboration with the College of Education colleagues to further gain insight into students' learning beliefs and patterns, thereby helping improve both classes (EDM and SDP) of the design curriculum. The College of Education and College of Engineering collaboration is a vital aspect of this continual improvement effort and offers a better understanding of established strategies to improve the student learning experience.

In addition to reporting on current progress, this paper also outlines detailed plans for the Fall 2018 semester. The authors actively engage in preparing useful surveys to achieve meaningful insights and these are planned as shown in Table 7. Besides planned surveys, efforts are also made to develop cross-college events such as the Engineering Design Day to enhance students' participation in multidisciplinary collaboration as well as professional engagement with sponsors and industry practitioners.

It is expected that a comparative assessment would be made providing both qualitative and quantitative feedback to the Mechanical Engineering department for actionable plans integrating into the continual improvement loop. Last, the Syllabus Focus surveys, conducted in EDM classes of Fall 2018 and Spring 2019, will be compared to assess student perceptions in both classes to make syllabus-specific modifications to improve the teaching of EDM class.

VI. References

[1] Anderson, L.W., D.R. Kraathwohl, and B.S. Bloom, *A taxonomy for learning, teaching and assessing: a revision of Bllom's taxonomy of educational objectives*. 2001, New York: Longman.

[2] Banios, E.W., *An engineering practices course.* IEEE Transactions on Education, 1992. **35**(4): p. 286-293.

[3] Chung, G.K.W.K., T.C. Harmon, and E.L. Baker, *The impact of a simulation-based learning design project on student learning.* IEEE Transactions on Education, 2001. **44**(4): p. 390-398.

[4] Huizinga, D.M., *Four implementations of disconnected operation: a framework for a capstone project in operating systems.* IEEE Transactions on Education, 2002. **45**(1): p. 86-94.

[5] Qattawi, A., P.J. Venhovens, and J. Brooks, *Rethinking Automotive Engineering Education – Deep Orange as a Collaborative Innovation Framework for Project-Based Learning Incorporating Real-World Case Studies*, in *ASEE Annual Conference & Exposition*2014: Indianapolis, IN.

[6] Schmueser, D., et al., *Graduate Automotive Engineering Education Innovation – Deep Orange Program Collaborative Industry Partnerships Enable System Engineering Based Approach for Project-Focused Learning*, in *ASEE Annual Conference & Exposition*2017: Columbus OH. p. 11.

[7] Sheppard, K. and B. Gallios. *The Design Spine: Revision of the Engineering Curriculum to Include a Design Experience each Semester*. in *American Society for Engineering Education Annual Conference Proceedings*. 1999. Charlotte, North Carolina Session 3225.

[8] Falchikov, N., *Involving Students in Assessment.* Psychology Learning & Teaching, 2004. **3**(2): p. 102-108.

[9] Wickens, C.D. and J.G. Hollands, *Engineering Psychology and Human Performance*. 2000, Upper Saddle River: Prentice-Hall Inc.

Table 8 Sample Knowledge Retention survey to be used

Q. no.	*Question*	*Answer choices*	
1	When analyzing a product for potential risks due to faults and failures, I am aware of the following fundamental tools.	A	FMEA
		B	FTA
		C	Both A & B
		D	None of the above
		E	My project does not need risk analysis at all
2	In a House of Quality (HOQ), to better understand competitor's product(s), I am aware of two standard methods that could be employed.	A	Benchmarking
		B	Reverse Engineering
		C	Kano Diagram
		D	Either A or B
		E	Both A & B
3	To analyze a product and find performance related dependencies of various factors, a meticulous approach needs to be adopted. For this purpose, I am aware of the following tools at my disposal.	A	FMEA
		B	Taguchi DOE method
		C	Both A & B
		D	HOQ
		E	None of the above
4	If my project deals with an established product that needs to be modified using well understood fundamentals, I am aware of the appropriate technique to use to generate ideas.	A	Morphological method
		B	TRIZ
		C	FMEA
		D	HOQ
		E	Both A & B
5	To redesign a product and reduce assembly cost, I am aware of standard tools.	A	Boothroyd-Dewhurst method
		B	Hitachi method
		C	Lucas method
		D	Critical Path method
		E	All of the above

Table 9 Sample Syllabus Focus survey to be used in EDM

Q. no.	***Question***	***Question mapping***
1	How vital is customer assessment for the success of any project?	Learning outcome
2	How confident am I to successfully use customer assessment tools such as for information gathering and House of Quality?	Learning outcome
3	How confident am I to be able to use different types of concept generation tools?	Learning outcome
4	How confident am I when trying to select a concept using matrix based tools such as the Pugh method?	Learning outcome
5	How important do I think is failure or risk assessment at any stage of the design process?	Learning outcome
6	How confident am I to successfully use failure analysis tools such as FMEA and FTA?	Learning outcome
7	How well do I understand importance of scheduling tasks by means of Gantt Charts or CPM?	Learning outcome
8	How well do I understand the various parts of Embodiment Design as a whole?	Learning outcome
9	How confident am I in using the BDM to assess assembly efficiency and recommend any redesign exercises?	Learning outcome
10	How well do I understand the application of various steps, phases, and use of tools and methods for the engineering design process as a whole?	Learning outcome
11	How well has individual evaluations (homework, pop quiz, test etc.) helped me learn the course material?	Coursework
12	How well has team-based assignments helped me learn the course material?	Coursework
13	Individual student feedback was emailed as a PDF document, how much insight did that give me about my specific performance in the topics tested so far?	Coursework
14	How helpful were these in-class overall feedback for me to understand the material and perform better?	Coursework

Response Scale 1-10	***Interpretation table***
1 to 3	Irrelevant, or little to none
4 to 6	Marginal importance, or basic level of proficiency
7 to 9	Very important, or well above average level of proficiency
10	Extremely vital, or excellent proficiency

Table 10 Sample General Belief survey to be used in EDM

Q. no.	***Question***
1	I know the answers to questions in this field because I have figured them out for myself.
2	Sometimes you just have to accept answers from the experts in this field, even if you don't understand them.
3	The most important part of being an expert in this field is accumulating a lot of facts.
4	I am most confident that I know something when I know what the experts think.
5	One expert's opinion in this field is as good as another's.
6	Experts in this field can ultimately get to the truth.
7	All experts in this field understand the field in the same way.
Answer range	• Strongly agree • Somewhat agree • Neutral • Somewhat disagree • Strongly disagree