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Engaging Civil Engineering Students Through a "Capstone-like" Experience in their Sophomore Year

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Engaging Civil Engineering Students by Exposing them to a
"Capstone-like" Experience in their Sophomore Year: A Case Study

Abstract

As part of a National Science Foundation funded initiative to completely transform the civil engineering undergraduate program at Clemson University, a capstone-like course sequence is being incorporated into the curriculum during the sophomore year. Clemson's NSF Revolutionizing Engineering Departments (RED) program is called the Arch Initiative. Just as springers serve as the foundation stones of an arch, the new courses are called "Springers" because they serve as the foundations of the transformed curriculum. Through a project-based learning approach, Springer courses mimic the senior capstone experience by immersing students in a semester-long practical application of civil engineering , exposing them to concepts and tools in a way that challenges students to develop new knowledge that they will build on and use during their junior and senior years. In the 2019 spring semester, a pilot of the first Springer course introduced students to three civil engineering sub-disciplines: construction management, water resources, and transportation. The remaining sub-disciplines are covered in a follow-on Springer 2 pilot. The purpose of this paper is to describe all aspects of the Springer 1 course, including course content, teaching methods, faculty resources, and the design and results of a Student Assessment of Learning Gains (SALG) survey to assess students' learning outcomes. The feedback from the SALG indicated positive attitudes towards course activities and content. Challenges for full scale implementation of the Springer course sequence as a requirement in the transformed curriculum are also discussed.

Introduction

All ABET accredited civil engineering programs are required to have a "curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints" [1]. Such capstone experiences often engage students in projects outside of the classroom and are intended to equip students with the knowledge and skills needed to succeed after graduation. In many cases, the capstone project is a student's first significant practical endeavor that tries to replicate a real-world professional experience. As part of an initiative to completely transform the civil engineering undergraduate program at Clemson University, a capstone-like course sequence is being incorporated into the curriculum during the sophomore and junior years. Funded by a grant from the National Science Foundation's Revolutionizing Engineering Departments (RED) program [2], this departmental transformation (referred to as the Arch initiative) is aiming to develop a culture of adaptation and curriculum support for inclusive excellence and innovation to address the complex challenges faced by our society [3].

Just as springer blocks serve as the foundation stones of an arch, the new courses are called "Springers" because they serve as the foundations of the transformed curriculum. The goal of the Springer course sequence is to expose students to the "big picture" of civil engineering while developing student skills in professionalism, communication, and teamwork through real-world projects and hands-on activities. The expectation is that the Springer course sequence will allow faculty to better engage students at the beginning of their studies and help them understand how future courses contribute to the overall learning outcomes of a degree in civil engineering.

In the 2019 spring semester, a pilot of the first in the sequence of Springer courses introduced students to three civil engineering sub-disciplines: construction management, hydrology, and transportation. The remaining sub-disciplines were covered in a follow-on Springer 2 pilot in the fall of 2019. The purpose of this paper is to describe all aspects of the Springer 1 course, including course content, teaching methods, faculty resources, and the design and results of a Student Assessment of Learning Gains (SALG) survey to assess student learning outcomes. An overview of the Springer 2 course is also provided.

Clemson's NSF RED program

A combination of faculty from the Glenn Department of Civil Engineering, along with education researchers and social scientists, worked closely to create a low-cost, scalable, replicable academic change framework informed by Complexity Leadership Theory [4]. Guided by this framework, Clemson's RED program involves three tactics. Tactic 1, involves a curriculum transformation (including the new Springer course sequence) which fosters creativity and innovation to better meet the changing societal needs of the 21st century; Tactic 2 involves a transformation of departmental structure and culture to promote teamwork, inclusive teaching approaches and collective efficacy; and Tactic 3 aims to cultivate college-level impact by tactfully using discomfort and tension and leveraging our existing social network with all the chairs of engineering departments as well as promoting a shared vision for change with CE departments nationally.

The Clemson civil engineering curriculum transformation fosters interactions and interdependencies among heterogeneous teams of students and faculty creating a ripe environment for innovation. This is facilitated by creating a curricular scaffold that weaves coursework both vertically and horizontally through carefully designed, socially relevant, practically meaningful problem statements. The first problems students are exposed to are in the Springer course sequence.

Pilot Springer 1 Learning Objectives and Course Format

The RED curriculum plan calls for the Springer sequence to be team-taught by multiple faculty from civil engineering as well as a faculty member from the communication department, thus exposing students to multiple technical aspects of civil engineering and engaging them in professional skill development. While the purpose of the two Springer Courses is to provide a "big picture" foundation of civil engineering, the learning objectives vary somewhat based on course content. Springer 1 covers construction management, water resources, and transportation sub-disciplines and incorporates extensive content in oral communication while Springer 2 covers construction materials, geotechnical engineering, and structural engineering sub-disciplines and emphasizes written communication. Each Springer course is 2 semester credits. The curriculum plan for Springer I is for students to work in teams to develop preliminary and final designs for a site design project. As part of the team project, students will participate in a design charrette in which teams will present their conceptual designs to stakeholders. Based on stakeholder feedback, teams will complete a preliminary design. The incorporation of design charrettes in engineering classes have been shown to improve student engagement and provide a holistic design experience for students [5] [6] [7].

Based on this plan, learning objectives and a topical outline were developed for the Springer 1 course. The learning objectives are listed as follows:

- Identify and describe the roles of civil engineering professionals who focus on construction management, hydrology, and site/transportation disciplines of civil engineering.
- Produce conceptual civil engineering design plans, construction schedules and cost estimates that meet specified requirements.
- Demonstrate basic levels of competency with civil engineering tools that can help students to be successful in future classes including:
  - using CAD to create civil engineering drawings required for this course
  - using data analysis software for statistical and other engineering calculations
- Demonstrate basic levels of competency in professional skills that can help students to be successful in future classes including:
  - applying creative problem-solving skills
  - developing an acceptable project stakeholder assessment
  - producing an acceptable set of course project requirements
- Demonstrate a basic level of competency especially with regard to informative speeches and team presentations.
- Demonstrate an ability to conduct an audience analysis.
- Demonstrate an understanding of the purpose, format, and roles of participants of a design charrette.
- Demonstrate an ability to work in teams.

Note that the level of competency demonstrated in this course is predominantly at the basic or conceptual level. In most cases, students do not have any prior civil engineering experience, so the level of detail of designs or processes must remain high level. However, consider the newfound excitement that a student has when they encounter more detailed instruction on similar topics in future courses.

The format for Springer 1 is also unique as it is scheduled as two 2-hour laboratories but, in actuality, the length of the laboratory period is variable depending on what is being covered on a particular day. If the material coverage is predominantly lecture-based, then the time period used may be as little as 50 minutes. If most of the material coverage is active project-based learning with little instruction, then the full 2-hour period is used.

The first week of the course covers the civil engineering profession and sub-disciplines, history, and societal context as well as an overview of the project. About 30 minutes is allocated for introductory material on public speaking. The next 6 weeks of class focuses on fundamental skills including public speaking competencies related to informative speeches and group presentations, project definition skills, design and construction problem solving skills, and complementary technical and professional skills. The last 8 weeks of class are related to the design project and includes a design charrette with stakeholder interaction and feedback.

The grading rubric is based on the following breakdown. It is estimated that approximately 50% of the course evaluation is based on oral communication (comm) aspects.

- Short speeches—5% comm
- Mini projects 10% each (30% total with up to 5% comm)
- Informative speech 10% comm
- Final project 30% (10-15% is comm)
- Group presentation 10% comm
- Final Exam 10% (5% is comm)
- Other assignments, attendance, participation 5% (mostly comm)

The full integration of oral communication into the project-based course underscores to students the importance of communication skills in all aspects of an engineering career. Similarly, technical writing skills are emphasized in the Springer 2 course.

Teaching Methodology

In all teaching aspects of Springer 1, a significant emphasis on relevance is made throughout the course. This includes the relevance of material covered as well as the relevance of assignments. While a combination of teaching methods is used including lecture and flipped classrooms [8], the primary teaching methodology is project-based learning which is an active learning approach that allows students to retain what they learn longer as well as provide students with valuable practical experience in a classroom environment. Project-based learning is more engaging for students and can be an excellent way for a curriculum to allow students to use what they have learned in a practical application [9],[10],[11]. Further, researchers have found that this pedagogical method is more attractive to female and underrepresented students, thus providing an environment to support a more inclusive student body [12],[13],[14].

Pilot Springer 1 Course Logistics

A pilot Springer I course was taught for the first time during the 2019 Spring Semester. Students were invited to enroll in the course through various means including email, recommendation by their advisor, and in-class announcements. The incentive to take this class sequence was that it would replace one of the six required technical electives. Twelve students originally enrolled but one had to drop due to a scheduling conflict. Eleven students ultimately completed the course. The grade point ratio (GPR) of these students range from 1.48 to 3.64 out of 4.0 with a mean of 2.97 and median of 3.19. By comparison, the mean GPR of similar sophomore level students enrolled in Clemson's civil engineering department is 3.2. Student teams were assigned randomly with the exception for consideration of previous coursework completed. Many in-class exercises were done in teams as well as the semester-long project. Future offerings will utilize more sophisticated team assignment optimization algorithms such as ITP Metrics [15] or CATME [16] team maker modules. Further identification of students' strengths and skills through assessments and team feedback will help students determine their ideal roles and functions on teams and hopefully lead to greater individual success.

The classroom environment for the Springer 1 pilot course was a computer lab with large tables where students could gather in teams to work with large plans. The computers were placed below the tables and monitors were mounted on arms and were easily moved to maximize table space. The computers were equipped with a variety of practical and analytical software including CAD and land development modeling tools. The general feedback from faculty and students is that the classroom environment was adequate for the course. Future classroom renovations will enable more flexibility in furniture arrangement, supporting both lecture, individual, small group, and large group breakouts with and without technology.

Pilot Springer 1 Course Flow and Operations

During the first class, an introduction to the course was given by the professors such that students understood what to expect out of the course. An overview of each sub-discipline (i.e. construction management, water resources, and transportation) was given by the respective instructor as well as a discussion of oral communication competencies by the communication instructor. The first assignment was given during the first class which required students to make an introductory presentation of themselves. This first presentation was used by the communication instructor as a benchmark for comparison with later presentations. Other assignments early in the semester were discipline specific mini-projects and exercises that students were able to work on in and out of class. In-class exercises focused on developing critical thinking, creative problem solving, and team skills.

The main project is a hands-on, real-world experience assigned to the students as a culmination of all of the practice exercises, mini-projects, and presentation knowledge that they completed earlier in the course. The pilot course project involved designing a small parking lot for a church located adjacent to campus. Students worked in groups of 3 or 4 to complete the project and began by identifying project requirements in a round table discussion using techniques learned from the construction management faculty. Once project requirements were finalized, each student worked individually to create their own rough sketch parking lot design. Each of these designs were considered a sketch alternative and were discussed as a group. A final sketch design was created based on a consensus discussion and then the groups created an associated storm water management plan, and construction management plan. After initial feedback from the faculty, the groups prepared for and conducted the design charrette with community stakeholders.

In the week following the design charrette, the groups made 5-minute presentations of their site sketch and shared ideas collected at the charrette in a prioritized format along with a brief discussion of plans for the final project. At the end of the discussion, each group was asked to prioritize the most important and significant ideas for each topic. Using all the information collected, groups generated their own action plan for the final design. A final design project report and presentation were due during the last week of the semester (week 15).

Design Charrette Details

One of the most valued activities of the pilot course as indicated by student feedback was the design charrette involving community stakeholders. The design charrette occurred during week

12 of the 15-week semester. Several project stakeholders were invited, and all accepted the invitation. The stakeholders included city staff members (city planner and assistant engineer), a campus planner, church members, and nearby residents. Two students chosen by their peers provided stakeholders an overview of the project that included a discussion of the site, problem identification, the challenges faced, and discussion of the charrette process and the "rules". (Note: In a scaled-up classroom, groups could compete for this opportunity.)

After the overview presentation each group was assigned to a table with one or more stakeholders to begin Round 1 of the charrette. Charrette rounds were no more than 10 minutes followed by a 2-minute break. One team member was assigned the role of facilitator and presented their group's sketch design and then group members solicited ideas from the stakeholders. A second team member was the recorder and captured ideas and comments in notes and on post-its. The discussion included brainstorming, and questions and answers. When time was called, a two-minute break allowed the team members to help the recorder assimilate the ideas. At the end of the break, the students were sent to the next table.

In Round 2, the recorder became the facilitator and presented the design along with the ideas generated in round 1, and then solicited new ideas and comments from the stakeholders. The third team member became the recorder and collected and documented the ideas generated in round 2. The process was repeated in round 3 except the recorder from the previous round becomes the facilitator for the new round. During the design charrette, everyone in each group had a chance to be the facilitator and the recorder.

While this worked well during the pilot, the faculty realized that this level of engagement with stakeholders over multiple lab sections and increased numbers of groups would be cumbersome. Discussions have been ongoing about the best way to scale this process, but potential solutions involve have only 1-2 stakeholders per section, all students recording feedback, and groups sharing information from each stakeholder group with other sections. Thus, students would spend more facilitating sharing of information with other groups in other sections rather than with stakeholders. As with most project-based courses, these types of scale-up issues can seem insurmountable, but the value and benefit to students often necessitates faculty creativity and innovation.

Pilot Springer 1 Course Evaluation and Student Assessments

The grades for the Pilot Springer 1 course were calculated based on the grading rubric presented earlier. The culminating project represented 40% of each student's grade with a breakdown as follows: sketch plan 10%, conceptual design/design charrette 10%, final design 10%, and group presentation 10%. A peer evaluation was also considered in the project grade. The Springer 1 final grade distribution included 7 A's, 3 B's, and 1 C which equates to a 3.54 GPR. The student who received a C failed to turn in one of the mini projects. The grade distribution of the class equates to a 3.54 GPR which is nearly half a letter grade higher than the average GPR for the students in the class.

A Student Assessment of Learning Gains (SALG) survey was designed based on the Springer 1 learning objectives and distributed to students during the last week of the semester. The format of the web-based survey is shown in Table 1. The categorical questions ranged from 1 (no gains) to 5 (great gains) or 1 (no help) to 5 (great help) depending on the question. All 11 students completed the survey although none of the questions were required to be answered. Students were very conscientious in completing the survey because all the free response (long answer) questions received input from most of the students. Students provided constructive feedback which faculty have found to be very useful in modifying the course content for future offerings.

Table 2 gives a complete list of the categorical questions along with the response means. Over 90% of the questions had a response average of 4 or more and nearly 75% of the questions had a response average over 4.5 or higher. Three questions received 5's from all 11 students:

- How studying this subject area helps people address real world issues;
- How doing hands-on classroom activities helped learning; and
- How the Design Charrette helped learning.

Table 1 Springer 1 Course Student Assessment of Learning Gains (SALG) Web-based Survey Format

	Number of Questions:	
Question Grouping	Categorical	Long Answer
Understanding of course content	6	2
Increases in your skills	17	1
Class impact on your attitudes	7	1
Integration of your learning	4	1
The class overall	3	5
Class activities	8	2
Assignments, graded activities/tests	9	1
Class Resources	3	1
The information you were given	3	1
Support for you as an individual learner	6	1

Table 2 Springer 1 Course Student Assessment of Learning Gains (SALG) Survey Questions and Response Means

#	**Question**	**N**	**Mean**
Your understanding of class content			

1	As a result of your work in this class, what GAINS DID YOU MAKE in your UNDERSTANDING of each of the following?		
1.1	The main concepts explored in this class	11	4.5
1.2	The relationships between the main concepts (e.g. how site design can influence storm water)	10	4.7
1.3	The following concepts that have been explored in this class		
1.3.1	The roles of civil engineering professionals who focus on construction management, water resources, and site/transportation disciplines of civil engineering	11	4.7
1.3.2	Conceptual civil engineering design plans, construction schedules and cost estimates that meet specified requirements	11	4.5
1.3.3	The purpose, format, and roles of participants of a design charrette	11	4.9
1.4	How ideas from this class relate to ideas encountered in other classes within this subject area	11	4.8
1.5	How ideas from this class relate to ideas encountered in classes outside of this subject area	11	4.5
1.6	How studying this subject area helps people address real world issues	11	5.0
Increases in your skills			
2	As a result of your work in this class, what GAINS DID YOU MAKE in the following SKILLS?		
2.1	Developing a work breakdown structure (WBS) for the design and construction portions of the course project	11	4.5
2.2	Developing a milestone schedule for the design and construction of the course project	11	4.3
2.3	Developing a detailed estimate for one work package from the course project	11	4.5
2.4	Using CAD to create civil engineering drawings required for this course	11	4.7
2.5	Using data analysis software for statistical and other engineering calculations	10	3.7
2.6	Applying creative problem-solving skills	11	4.5

2.7	Applying the Clarify, Ideate, Develop, Implement model to the course project and explaining how they converged to their final solutions	11	4.5
2.8	Developing an acceptable project stakeholder assessment	11	4.7
2.9	Identifying the primary stakeholders for the course project and analyzing how to manage each identified stakeholder using the Power/Influence matrix	11	4.6
2.10	Developing a list of primary course project requirements based on appropriate stakeholder interactions	11	4.6
2.11	Working effectively with others on a team	11	4.8
2.12	Developing a basic understanding of site design concepts	11	4.7
2.13	Developing a basic understanding of storm water management related to site design	11	4.6
2.14	Preparing and delivering informative oral presentations	11	4.5
2.15	Conducting an audience analysis	11	4.0
2.16	Preparing and delivering a project team presentation	11	4.7
2.17	Using presentation software (Powerpoint) to give effective presentations	11	4.2
Class impact on your attitudes			
3	As a result of your work in this class, what GAINS DID YOU MAKE in the following?		
3.1	Enthusiasm for the subject	11	4.6
3.2	Interest in discussing the subject area with friends or family	11	4.7
3.3	Interest in taking or planning to take additional classes in this subject	11	4.8
3.4	Confidence that you understand the material	11	4.3
3.5	Confidence that you can do this subject area	11	4.5
3.6	Your comfort level in working with complex ideas	11	4.6
3.7	Willingness to seek help from others (teacher, peers, TA) when working on academic problems	11	4.7
Integration of your learning			

4	As a result of your work in this class, what GAINS DID YOU MAKE in INTEGRATING the following?		
4.1	Connecting key class ideas with other knowledge	11	4.7
4.2	Applying what I learned in this class in other situations	11	4.5
4.3	Using systematic reasoning in my approach to problems	11	4.5
4.4	Using a critical approach to analyzing data and arguments in my daily life	11	4.2
The Class Overall			
5	HOW MUCH did the following aspects of the class HELP YOUR LEARNING?		
5.1	The instructional approach taken in this class	11	4.3
5.2	How the class topics, activities, reading and assignments fit together	11	4.2
5.3	The pace of the class	11	4.2
Class Activities			
6	HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?		
6.1	Attending lectures	11	4.9
6.2	Participating in discussions during class	11	4.9
6.3	Listening to discussions during class	11	4.9
6.4	Participating in group work during class	11	4.9
6.5	Doing hands-on classroom activities	11	5.0
6.6	Specific Class Activities		
6.6.1	Team building activity	11	4.7
6.6.2	Creative problem solving activity	11	4.7
6.6.3	Design Charrette	11	5.0
	Assignments, graded activities and tests		
7	HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?		
7.1	Graded assignments (overall) in this class	11	4.4

7.2	Specific assignments		
7.2.1	Introductory Speech (baseline)	11	3.3
7.2.2	Informative Speech	11	3.7
7.2.3	Construction Management mini-project	11	4.1
7.2.4	Transportation Systems mini-project	11	4.1
7.2.5	water resources mini-project	11	4.1
7.3	Final project	11	4.9
7.4	The way the grading system helped me understand what I needed to work on	11	3.6
7.5	The feedback on my work received after assignments	11	3.6
	Class Resources		
8	HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?		
8.1	Online notes or presentations posted by instructor	11	4.6
8.2	Other online materials	10	4.7
8.3	Visual resources used in class (i.e. PowerPoint, demonstrations such as CAD, Excel, web resources)	11	4.5
	The information you were given		
9	HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?		
9.1	Explanation of how the class activities, and assignments related to each other	11	4.5
9.2	Explanation given by instructor of how to learn or study the materials	11	3.7
9.3	Explanation of why the class focused on the topics presented	11	4.6
	Support for you as an individual learner		
10	HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?		
10.1	Interacting with the instructors during class	11	4.7
10.2	Interacting with the instructors during office hours	10	4.2

10.3	Working with the teaching assistant during class	11	4.9
10.4	Working with the teaching assistant outside of class	11	4.8
10.5	Working with peers during class	11	4.9
10.6	Working with peers outside of class	11	4.8

The free response questions in the SALG were overwhelmingly positive. The sentiment of students regarding what they liked best about the class was the real-world project and interacting with stakeholders. Students were in general agreement that the class could be improved with better coordination between the four faculty members involved in the class; however, they also indicated that they liked having multiple faculty. For future semester, faculty will receive training on team-teaching and the department hopes to have dedicated faculty coordinating each of the courses in the Arch Initiative.

The following are a few sample responses from the long answer questions:

- Q 1.8 - Please comment on how THE WAY THIS CLASS WAS TAUGHT helps you REMEMBER key ideas.
  - "Being able to actually practice skills in a real-world project definitely solidified the concepts in my mind and made me feel more confident in my abilities."
  - "…Having projects instead of written exams was key to understanding what I was learning. Instead of just trying to memorize formulas for an exam, I would work a project and if it didn't work like I needed it to, I could go back and ask questions and understand what I did wrong."

- Q 2.18 - Please comment on what SKILLS you have gained as a result of this class.
  - "… I have learned how to trust members of my team fully instead of trying to do every aspect of an assignment myself and with that team. I have learned how to learn from my teammates things that I am not an expert in, but they are."
  - "I really liked the stakeholder involvement and having a chance to learn communication skills in a setting that is much more applicable to my future than a normal comm class."

- Q 3.8 - Please comment on how has this class CHANGED YOUR ATTITUDES toward this subject.
  - "Before taking this class, I just saw engineering as a bunch of equations and calculus that I was going to have to do. After taking this class, I am positive that I want to be involved in some aspect of Civil Engineering and I get excited to tell my family about my projects that I have done in Springer 1 because it is an actual design and a real life problem we were trying to fix instead of just a sheet

of calculations. After designing this parking lot, it makes me excited to see what I can do after I graduate and learn more."

- Q 4.5 - What will you CARRY WITH YOU into other classes or other aspects of your life?
    - "Understanding that the material we are learning throughout the curriculum has a purpose and will be useful in the future will help me be motivated to aim to excel in other courses."
    - "What I will carry out into another class or life is not having an ego. You cannot have an ego in anything because it will cause a person to not listen to others."

A teaching consultant from Clemson's Office of Teaching Effectiveness and Innovation (OTEI) came to observe the class on a few occasions and met with the class as a group to get feedback on three questions. The responses from students were similar in sentiment to the web-based survey and are summarized in Table 3.

Table 3 Clemson OTEI Class Interview Feedback Session Summary

Group Feedback	Compilation of comments from students:
Q1. What helps / supports your learning?	The group activities and student involvement; the discussions and team environment Projects > exams Real-world civil engineering problems are very insightful The design charette The essays and speeches The incorporation of water resources, construction management, transportation, and communication into the final projects Very helpful to have stakeholders/outsiders come to class for feedback; communication with the stakeholders The exposure to all of the sub-disciplines in civil engineering The size of the class allows for better relationships with the professors, and getting to know everyone to go through curriculum with them Its fun Having a TA who is always present and participating in projects

Q2. What could be done to improve your learning?	Some mini-projects feel off-topic Lectures can be long, so we have less time for the group work in class and missed out on "lab time" we should have had Professor presence and availability during class – for scheduled time that professor is asked to be there to answer questions and clarify expectations Work piles up onto major test weeks Course workload doesn't feel like just 2 credits of work Coordination between professors, which would help with the workload expectations of all 4 and what they are assigning; and overall organization
Q3. What can you do to improve your learning	Ask more questions Practice my presentations Study more outside of class Work ahead on this course while other course loads are lighter Connect with others in the class on projects Not be afraid to try new things

Challenges and Opportunities

The greatest challenge for permanent adoption and implementation of the Springer courses in a revised Clemson civil engineering required curriculum is meeting enrollment demand. Clemson's civil engineering department currently has roughly 150 sophomore students who would need to take both of the Springer courses. The independent design of the two sophomore courses allows flexibility because they can be taken in any order. The sentiment of the faculty involved in the Pilot Springer 1 is that the number of students for a section can easily increase two-fold (~20 students). While the format of two 2-hour flexible length classes per week worked well for the pilot, the scheduling and faculty resources needed to teach 4 sections of Springer 1 per semester may be too ambitious. The faculty involved in Springer 1 agree that reorienting the class as (1) 50-minute lecture and one 2.5-hour lab per week is achievable. Considering a semester in which 80 students register for the course, the workload would involve two lecture sections of 40 students each and four lab sections of 20 students. In-class exercises and computer usage are still possible in a lecture section with 40 students if students are required to bring notebook computers and there is adequate TA support to assist students.

Faculty resources are still a concern; however, Clemson plans to hire a full-time oral/written communication instructor to support instruction for both Springer classes as well as other undergraduate civil engineering classes. The current civil engineering curriculum requires that students take a communication and a technical writing class outside of the department. This will no longer be the case in the new curriculum where both oral and written communication will be integrated into Springer and other proposed civil engineering classes. Having a full-time in-house communication instructor is anticipated to improve the level of coordination among the instructors and provide consistency of instruction across entire curriculum.

The involvement of faculty from different sub-disciplines in the Springer series is resource intensive; however, the current format for the existing capstone course is taught in a similar fashion with one lead instructor and three consulting faculty. There is also TA support for capstone. In moving forward with the curriculum transformation, the Arch Courses are based on concepts of quality over quantity. Therefore, flexibility in workload assignment and additional weighting for project-based and team-taught courses is key. Department and college administrators must find solutions to replace simple teaching load models based on course credit. Four faculty teaching a 2-credit Springer course amounts to 0.5 credits per faculty in a standard workload system, but if we value this pedagogical approach and the benefits received by students' new models must emerge providing more credit for these faculty.

Another challenge is identifying an adequate number of appropriately scoped projects each semester. One significant finding of the pilot class is that the course design allowed the entire section to work on the same project. Thus, having a single project each semester that is worked on by four different sections will still achieve desired results from a student perspective. Having adequate stakeholder involvement may be of greater concern. Fortunately, in Clemson there is a significant pool of potential stakeholders that have already expressed interest in getting involved with future classes. A great opportunity exists to develop and strengthen our alumni involvement within the Arch Initiative.

Conclusion

This paper has described the incorporation of sophomore foundation classes in a redesigned civil engineering curriculum at Clemson. Through a project-based learning approach, Springer courses mimic capstone in that students work on a practical application of civil engineering concepts throughout the semester in a way that challenges students to incorporate tools that they will build on and use during their junior and senior years.

Goals for the Springer course sequence are to engage students in civil engineering projects earlier in their degree program, and to help them understand how future courses contribute to their overall learning in civil engineering. The SALG survey indicated that the design charrette and interaction with stakeholders was a favorite aspect of the Springer 1 pilot. A common format for civil engineering senior capstone courses is to have industry participants listen to final presentations but have little involvement in assisting students earlier in the semester [17]. Clemson's current civil engineering capstone follows this format. There is limited benefit to students from industry feedback so late in the semester. The student interaction with stakeholders including industry in a charrette format where students must use stakeholder feedback to complete final design makes this a positive experience for both the students and the stakeholders. It is anticipated that a design charrette with outside stakeholders will become part of the transformed curriculum's senior Keystone course that will replace the current capstone course.

The positive feedback from the Springer 1 pilot makes it clear that the course has helped reinforce student ambitions to be a future civil engineering professional ready to address the complex infrastructure challenges faced by our society. The springer sequence is just the beginning of the student's civil engineering journey at Clemson. Additional changes during the junior and senior years are designed to keep students engaged while reinforcing both oral and written communication concepts and use of civil engineering tools such as CAD.

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References

[1] *ABET CRITERIA FOR ACCREDITING ENGINEERING PROGRAMS*. ABET criterion 5D, 2017.

[2] *IUSE / Professional Formation of Engineers: Revolutionizing Engineering Departments (IUSE/PFE: RED)*. National Science Foundation. 2019.

[3] "CE-ARCH: ARCH Initiative." CEARCH, cecas.clemson.edu/ce-arch/arch-initiative/.

[4] R, Marion. *The edge of organization: Chaos and complexity theories of formal social systems*. Sage, 1999.

[5] M.R. Oswald. AC 2012-3084: INTEGRATING THE CHARRETTE PROCESS INTO ENGINEERING EDUCATION: A CASE STUDY ON A CIVIL ENGINEER- ING DESIGN CAPSTONE COURSE. (2012)

[6] S. Sanford, M.S, L.C. Benson, P. Alluri, W. Martin, L.E. Klotz, J. H. Ogle, N. Kaye, W. Sarasua, S. Schiff, "Evaluating Student and Faculty Outcomes for a Real-World Capstone Project with Sustainability Considerations", Journal of Professional Issues in engineering Education and Practice, ASCE, 139(2), April 2013, pp 123-133.

[7] W. Eagen, O. Ngwenyama, F. Prescod. The Design Charrette in the Classroom as a Method for Outcomes-based Action Learning in IS Design. Information Systems Education Journal, 6 (19). http://isedj.org/6/19/. ISSN: 1545-679X. (Also appears in The Proceedings of ISECON 2006: §3733. ISSN: 1542-7382.). 2008.

[8] J. Bergmann and A. Sams, *Flip Your Classroom: Reach Every Student in Every Class Every Day*. 1st ed., International Society for Technology in Education, 2012.

[9] M. W. Martin, "Implementing Active Learning Principles in an Engineering Technology Fluid Mechanics Course" [Online]. Available: http://www.asee.org/public/conferences/20/papers/6134/download [Accessed Jan. 15, 2020]

[10] P. C. Blumenfeld, E. Soloway, R. W. Marx, J. S. Krajcik, M. Guzdial, and A. Palincsar. "Motivating project-based learning: Sustaining the doing, supporting the learning." Educational psychologist 26, no. 3-4 (1991): 369-398.

[11] B. Stephanie. "Project-based learning for the 21st century: Skills for the future." The clearing house 83, no. 2 (2010): 39-43.

[12] S. Hurtado , NL. Cabrera, MH Lin , L. Arellano, LL. Espinosa. Diversifying science: underrepresented student experiences in structured research programs. Res High Educ. 2009;50:189–214.

[13] PW. Schultz, PR. Hernandez, A. Woodcock, M. Estrada, RC. Chance, M. Aguilar, RT. Serpe. Patching the pipeline: reducing educational disparities in the sciences through minority training programs. Educ Eval Policy Anal. 2011;33:95–114.

[14] Rodenbusch S, Hernandez PR, Dolan EL. Early engagement in course-based research increases graduation rates and completion of science, engineering, and mathematics degrees. CBE Life Sci Educ. 2016;15

[15] “ITP Metrics.” ITP Metrics, www.itpmetrics.com/.

[16] Layton, R. A., Loughry, M. L., Ohland, M. W., & Ricco, G. D. (2010). Design and validation of a web-based system for assigning members to teams using instructor-specified criteria. Advances in Engineering Education, 2 (1), 1-28.

[17] Yost, Scott A., and Derek R. Lane. "Implementing a problem-based multi-disciplinary civil engineering design capstone: Evolution, assessment and lessons learned with industry partners." In ASEE Southeast Section Conference. 2007.