

Restructuring VMI Civil and Environmental Engineering Labs: A move worth to explore!

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Abstract

Starting in Fall 2021, the Virginia Military Institute (VMI) Civil and Environmental Engineering Department restructured its lab courses, replacing the previous system with a two-lab sequence for third-year students. The change aimed to address scheduling challenges and cover additional core topics in civil engineering. After three years, the changes were assessed based on faculty and students' feedback. The new sequence has proven effective in reducing scheduling conflicts, enhancing coverage of engineering mechanics, structural engineering, and environmental engineering, and involving more faculty in the lab workload. Students appreciate the hands on experiences and find the labs beneficial in integrating knowledge across classes. However, challenges include stricter pre-requisite requirements and eliminating some previous lab content. This study highlights the positive outcomes and challenges observed in the restructuring from the perspectives of the department, faculty, and students.

Keywords

Civil Engineering, Laboratory restructuring, Experiential learning, Enhanced understanding, Continuous improvement, Scheduling

Introduction

Experiential learning through laboratory (lab) experiences has been a common practice in engineering programs for many years. A previous study demonstrated that most institutions still value the labs in civil engineering programs [1]. In addition, most universities also include labs in their science courses. The problem with labs is they take up a significant amount of time for both the students and professors and have a cost due to their resource demand, which can lead to scheduling problems and significant financial burdens on the university.

The following study reviewed the changes to the core civil engineering lab schedule in the civil engineering program at the Virginia Military Institute (VMI). The department decided to change the program's lab sequence by combining labs and topics taught in their labs to reduce the scheduling conflicts and give more professors the ability to present topics in the labs. This paper discusses the changes and the results, both good and bad, based on the perspectives of the students and faculty.

Background

The Virginia Military Institute (VMI) is a liberal arts university that offers undergraduate degrees in fourteen areas, including three in engineering. The institute focuses on providing a broad undergraduate education in a military environment with a strong core curriculum and leadership opportunities. Every student must take specific core courses covering English, history, speech, leadership, physical education, military training, math, and two electives in humanities. As part of the school's schedule, students have specific times during the day when they may take academic courses, limiting the flexibility to take courses and labs. VMI encourages a 4-year graduation for most students, so scheduling courses and staying on track is critical to meeting this goal.

The Civil and Environmental Engineering Department's (CEE) program is ABET (the Accreditation Board for Engineering and Technology) accredited. It provides a broad-based curriculum with required courses in 8 fundamental areas of civil engineering: water resources, materials, environmental, geotechnical, structures, transportation, surveying, and construction. Most of these courses are taken in sequence during the third year of study after passing statics and solid mechanics (mechanics of materials) courses with a minimum grade of a "C." Students who stay on track for a four-year graduation then take seven engineering elective courses, a capstone, and a seminar class in the department in their last year of study.

Many courses include required laboratory sections, typically one credit hour each. Most semesters require a military training course with an afternoon lab for four to six semesters (depending on commissioning status). During their first year of study, the students have labs in their two "Introduction to Civil Engineering" courses, a surveying course, and a chemistry course. In their second year, they have a lab in two physics courses and a basic science course (biology or geology). Historically, in their third year, they had labs in CEE materials, geotechnical, and water resources (Table 1). The last year of study has few labs because the department eliminated labs for electives (with only one exception in the curriculum) due to scheduling constraints in the academic day. However, the seminar and capstone courses are extended afternoon classes held during a laboratory period.

Faculty identified two main concerns with the CEE curriculum and lab organization three years ago. First, taking two civil engineering labs in addition to a military training lab, five core civil engineering classes, and a math class created very little flexibility for scheduling during the 3rd year in CEE. Any student who was not perfectly on track for a four-year graduation had difficulty planning their classes. Second, the labs only covered four of the eight core areas of civil engineering that were taught that year. Professors from other areas like environmental, structures, and transportation wanted an opportunity to have hands on learning. To try to solve this problem the civil engineering department decided to restructure their laboratory sequence for the classes during the 3rd year of study.

Description of Changes

The new CEE labs sequence established two semesters of one-credit laboratory courses typically taken in the 3rd Year. The first (fall) semester course covers mechanics, structures, and materials topics, whereas the second semester (spring) covers soil mechanics, fluid mechanics/water

resources, and environmental engineering topics (Table 2). This configuration closely aligns with the courses offered for that specific semester or courses taken the previous semester (solids mechanics, environmental engineering, fluid mechanics.)

Table 1: Required labs for a typical CEE student at VMI

| College Year | 1 st Year | 2 nd Year | 3 rd Year |
|---------------------------|---|---|----------------------|
| Laboratory Courses | Introduction to Civil Engineering I and II Surveying Intro to College Chemistry | General Physics I and II Natural Science (Biology/Geology) | Table 2 |

Table 2: Description of 3rd year courses for a typical CEE student at VMI

| Courses | Spring Semester (2 nd Year) | Fall Semester (3 rd Year) | Spring Semester (3 rd Year) |
|--------------------------------------|--|---|--|
| Laboratory Topics | | Solid Mechanics Structural Theory Materials | Fluid Mechanics/ Water Resources Soil Mechanics Environmental Engineering |
| Core Required Lecture Courses | Solid Mechanics Environmental Engineering | Structural Theory Materials Fluid Mechanics Dynamics | Reinforced Concrete Soil Mechanics Water Resources Project Management Transportation |

Before these changes, the faculty grew concerned about the lack of dedicated structural or environmental laboratory sections in the CEE curriculum. The reorganization into the two-semester lab sequence allowed both topics to be included in required CEE courses. The restructuring of the labs also alleviated some of the teaching load for CEE faculty. The new sequence allows two faculty members to share one laboratory course with one faculty member

teaching each topic. Although three topics are included in the spring, the course is still taught by two faculty members, one teaching soil mechanics and one teaching fluids/water resources and environmental engineering.

Merging these laboratory courses into a two-semester sequence has also allowed for better coordination between faculty and course material. The fall course includes an Excel basics and introduction to statistics and the spring course includes an advanced Excel and regression analysis session. These topics are also taught in an engineering statistics course in the math department, but many students take this class concurrently or after completing the CEE labs. These lessons complement the statistics material with lessons specific to civil engineering. Since the curriculum does not have a dedicated technical writing course, the fall and spring courses use a consistent laboratory report format to reinforce good technical writing skills. Both lab classes use a combination of group reports and individual reports to help students learn to work in groups while still expecting each individual to submit some individual assessments. The new sequence also provides an opportunity to organize field trips for every student in the 2nd class that would otherwise be nearly impossible to coordinate in a student's daily schedule.

Pros and Cons of this restructuring

As mentioned, the new sequence allows two faculty members to share one laboratory course. The CEE department typically offers six lab sections of 6-10 students per semester, so up to six faculty can be involved in the lab sequence each semester. Over an academic year, all tenure track faculty can be part of this lab sequence and teach topics in one of their areas of interest. After executing this restructuring for three years, the department and the faculty have gathered observations and monitored the students' reactions to the changes.

Faculty and Department Perspective:

A set of questions were asked to all full-time and part-time faculty in the civil engineering department (approximately 20 individuals). Their responses primarily focused on the positive outcomes of restructuring with some constructive feedback. Positive outcomes include the inclusion of a new lab portion for engineering mechanics, structures, and environmental engineering; labs more appropriate to help students transition to their first year on the job; student interaction with a broader spectrum of topics and more faculty; integration of different theories from multiple classes into one lab setting (i.e., statics, solid mechanics, and structural theory); and flexibility in terms of scheduling, workload sharing, and teaching relatively small classes. Many faculty enjoy working with students in small class sizes (7-8 per lab), a benefit that is not as common in lecture courses (10-15 per class). The small numbers in labs also help professors meet and recruit more students for student design projects and independent research. Additionally, by adding structures labs, students who choose to do projects for the American Society of Civil Engineers (ASCE) design projects (concrete canoe, steel bridge, etc.) are now trained in safety and equipment they otherwise would not have been exposed to.

One common concern with the restructured labs from the faculty perspective is the material does not line up directly with class instruction due to the rotating nature of the lab classes. Sometimes, especially with the soil mechanics topics, the labs are experienced before the material is presented in class. No specific area gets much time in the lab, and professors must share this

limited time. In addition, students rotate through the labs, and all sections do not do the labs the same week due to space limitations. It makes the real-time connection of the lab procedures with the current class offering difficult. Overall, it also affects the quality of work (primarily the lab reports). Another minor concern was these new lab sequences require pre- and co-requisite courses. For instance, in the fall, students must be enrolled in structural theory and materials; in the spring, they must be enrolled in water resources and soil mechanics. Off-sequence students (behind or ahead in the curriculum) may not have room to take all these courses during the semester the labs are offered, which can create further scheduling conflicts. For the first-time lab instructors, lab preparation and long afternoon time commitment were another concern; however, in the most recent iteration of the lab, a coordinator was assigned to help with organization and consistency. One last comment is that all eight areas of civil engineering with required courses are still not incorporated into the lab sequence. Construction and transportation are not represented, meaning six of the eight topic areas are now covered in a lab in the curriculum. At this point, additional material would need to be cut out of the labs to add additional lab material in transportation and construction. This could be the review of statistics and technical writing in order to gain two additional periods, however both topics have proven very important to the students success in the labs.

The faculty also made some excellent suggestions to improve the lab experience in the future. Since there is a lack of connection between the class material and lab sequences, a more comprehensive lab manual can help to make the connection. Another realization that has been made is the students are very weak in computer and technical writing skills. Additional practice and instruction may be needed in courses like the two-semester introduction to civil engineering courses (1st year) or other 2nd-year civil engineering courses. Also, to improve the engagement and make the lab experiments more personal, the idea of allowing the students to design and complete 1-2 labs at the end of the semester was suggested [2]. Because the labs are small and there are many faculty involved, making these additional adjustments is now a possibility. Improvement of these two lab sequences is a continuous process and CEE department is determined to make it better over the time.

Student Perspective:

A formal survey of previous students was not completed before these changes, but part of the stimulus to make the lab changes was the students' trouble scheduling their lab sections. This sequence reduced the number of labs they had to take by one. A survey was sent out to the students currently enrolled in the first lab of the sequence and students who had already completed both labs last year (See the Appendix). The participation rate was moderate. The survey included questions like how the labs were connected to the classes offered, rigorous co- and pre-requisite requirements, faculty involvement, and their overall experience with the labs. From their responses, it was clear that they could see the connection "moderately well" between the class lectures and the lab sequence and "strongly agree" that it helped them better understand the course content and the civil engineering concepts. They also mentioned labs increased their interaction time with faculty outside of the classroom, which aligned well with their tight academic schedule. For most participants, rigorous pre-requisites did not create any additional problems. Those who are off schedule already had to make up courses during summer school or take an extra semester to finish. These one-credit-hour labs did not add significant hardships for them beyond what they already had.

Summary/Conclusion

In conclusion, restructuring the Virginia Military Institute (VMI) Civil and Environmental Engineering (CEE) Department's lab sequence has yielded both positive outcomes and revealed the need for additional improvement. The shift to a two-semester lab sequence has successfully addressed scheduling conflicts, increased faculty involvement, and broadened the scope of hands-on learning in engineering mechanics, structural engineering, and environmental engineering in addition to materials, soil mechanics, and fluids/water resources engineering. Faculty members appreciate the flexibility in workload sharing, scheduling, and the opportunity to expose students to a broader range of materials and theories.

Concerns have been raised about the alignment of lab content with class instruction, the potential impact of recommended pre- and co-requisite courses on students not on track for a 4 year graduation, and not covering all eight required civil engineering sub areas with lab lessons. In addition, the labs have demonstrated to all faculty that students are weak in computing skills and technical writing. Faculty suggestions for improvement include developing a comprehensive lab manual, incorporating more computer and technical writing skills in introductory labs, and allowing students to design and complete labs at the end of the semester for a more engaging experience.

From the student perspective, there is a generally positive response, with students noting the moderate connection between class lectures and labs, increased understanding of course content, and beneficial interaction with faculty. Overall, this restructuring has enhanced flexibility, hands-on activities, and one-on-one time with students, providing a foundation for continued refinement and improvement in the future.

References

- [1] C. Newhouse and M. Swenty, "The Evolution of the Breadth and Depth in Civil Engineering Laboratory Classes," in *ASEE Southeastern Section Conference 2022, Washington D.C., USA*
- [2] D. Truax, "Restructuring the undergraduate laboratory instructional process." *Journal of Professional Issues in Engineering Education and Practice* 133.3 (2007): 192-198.

Appendix A: Survey Questions for the students

VMI CEE's lab restructuring-Students' perspective

Q1 Starting in the Fall of 2021, the Virginia Military Institute (VMI) Civil and Environmental Engineering (CEE) Department restructured its lab offerings. Previously, distinct lab courses were offered for Soil Mechanics, Material Science, and Water Resources. A new two-lab sequence was created for the third Year of the civil engineering curriculum; the same Year, students must take introductory courses in materials, structural, geotechnical, construction, transportation, and water resources engineering. Instead of having labs connected to each specific course, the restructuring connected labs with similar course content across the curriculum. Topics in materials, structural, and engineering mechanics were moved to the first-semester lab course, whereas topics in geotechnical, environmental, and water resources were combined into the second lab course. We would like to explore the benefits and downsides of this restructuring from the student perspectives.

Q2 Your graduation class-

- 2024
- 2025
- Other

Q3 How well do you feel the new two-lab sequence aligns with your academic schedule and workload?

- Not well at all
- Slightly well
- Moderately well
- Very well
- Extremely well

Q4 How would you rate the connectivity of lab content across different classes? 5 being the highest and 1 being the lowest?

- 1
- 2
- 3
- 4
- 5

Q5 Before restructuring the labs, we didn't have any lab materials for engineering mechanics, structural engineering, and environmental engineering. Have you found the restructuring to be beneficial in terms of covering additional material in engineering mechanics, structural engineering, and environmental engineering?

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

Q6 Do you believe the restructuring has improved faculty involvement in the labs? Why or why not?

Q7 To what extent do you feel the labs have helped you understand and apply concepts from your introductory courses in materials, structural, geotechnical, construction, transportation, and water resources engineering?

- Extremely dissatisfied
- Somewhat dissatisfied
- Neither satisfied nor dissatisfied
- Somewhat satisfied
- Extremely satisfied

Q8 Have you encountered any challenges or difficulties with the more rigorous pre-requisite requirements under the new lab sequence?

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

Q9 In your opinion, have the labs contributed to a better overall understanding of civil engineering concepts?

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

Q10 Would you recommend any further adjustments or improvements to the current lab structure? If yes, please provide suggestions.
