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Why Not Studios? – What Engineering Can Learn from Architecture and Art Programs

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Why Not Studios? – What Engineering Can Learn from Architecture and Art & Design Programs

Abstract

Engineering, like architecture and art & design, is well served by creativity. Architecture programs, both building and landscape, emphasize creativity and encourage exploration of the student's capacities for creative design through intensive immersion in "studio culture." Although art & design programs do not typically tout the benefits of studio culture to the degree that architecture programs do (e.g. [1]), studio classes also play an important role in most art & design programs. Studio inculcates an atmosphere of intellectual curiosity, cooperative learning, collaboration, and respectful consideration of new ideas and multiple points of view. Such attributes would contribute to the quality of teamwork encountered in the multidisciplinary design-team environment in which engineers typically function today.

The author teaches courses that primarily support a Landscape Architecture Accreditation Board (LAAB)-accredited [2] Landscape Architecture undergraduate program housed in the University of Delaware's College of Agriculture and Natural Resources. His courses, all cross-listed in landscape architecture and civil engineering, often have a mix of landscape architecture and engineering students simultaneously enrolled. Engineering students in civil, environmental, and construction engineering are represented. Data are examined that indicate the studio format promotes enhanced student learning in at least one important common element of the courses: mastery-based problem sets designed to improve student analytical abilities and technical skills. The data, gathered for two courses over 8 semesters and for 257 students clearly show that students master more of the problem set material under the studio/flipped classroom format.

This paper examines the typical structure of studios in architecture and landscape architecture programs and discusses some observations the author has had with use of the studio format in his courses. The complementary nature of studio and the flipped classroom are examined. The positive influence of studio culture on creativity, collaboration, cooperative learning, and the engineering design process are considered. Recommendations are proposed for incorporation of studio format courses in engineering programs beyond the obvious application in senior design courses.

Introduction and Literature Review

Programs in art & design, architecture, and landscape architecture have emphasized studio experiences (culture) since their inception. U.S. architectural education programs of the 1800s regarded European architectural programs epitomized by the prestigious *Ecole des Beaux-Arts* in Paris with its rich design problem and studio components as models to emulate [3]. Central to the concept of a studio is a physical space where students and faculty can gather to work and learn collaboratively. Studios meet for longer periods of time than the conventional 50-minute lecture with the studio room itself designed to support individual and group work in an active learning environment. Cornell's Department of Architecture provides this description as part of their studio culture policy statement [3]:

The architectural design studio today is unique in higher education, as it is at the same time a pedagogical method and a spatial concept. It is a group of people working together, generally in a large flexible space led by an instructor, wherein investigations take place, and students learn through doing, through making, and also through critique, through understanding, and through the recycling of ideas. The studio as a creative space is essential to architectural education.

The studio is intended to give students experience with the design process, enhance time management skills, and promote creativity through collaborative shared learning with fellow students and faculty [4]. Studio is meant to be a space where:

ideas are discussed and debated, and where contradictory viewpoints can co-exist.… The Studio is a laboratory for new ideas; one of the most productive aspects of studio culture is its variety and informality; many of the best ideas arise independent of a particular class, structure, or event, through an after-hours discussion or a chance encounter. [4]

An important aspect of studio culture is that it is a space for collaborative learning even outside of classroom hours. Students are given access to the studio and are expected to gather, make use of the space, and interact with one another (and faculty) in the studio outside of class time, and, indeed, occasionally into or through the night. It is expected that there may be occasions throughout the term when students may be in the studio for long after-hours work sessions, but time management and work-school-life-balance are taken into consideration. *Excessive* amounts of after-hours work are discouraged. The 2014 version of the National Architecture Accrediting Board (NAAB) Conditions for Accreditation [5] includes a passage under section I.1.2, Learning Culture, that requires a written studio culture policy that addresses "the values of time management, general health and well-being, work-school-life balance, and professional conduct."

In 2005, the National Architectural Accreditation Board (NAAB) required all accredited architecture programs to have written policies that address and shape their studio cultures [3]. NAAB "Conditions for Accreditation" documents for 2009 and 2014 contain requirements that accredited programs must have written policies regarding "studio culture" [5]. Curiously, the 2020 *Conditions for Accreditation* [5] document does not mention such requirements; however, a random inspection of numerous current NAAB-accredited architecture program web sites found studio culture policy statements published in all (e.g., [6], [4], or [3]). The Landscape Architecture Accreditation Board (LAAB) [2] requires students in accredited landscape architecture programs to "have assigned studio workspaces" and that student / faculty ratios in studios typically be no greater than 15:1 [7]. Landscape architecture programs, especially those housed within schools of architecture and/or design, may fall under blanket studio culture policy statements for all programs in the school (e.g., [8] and [9]).

There is some evidence that the use of studios in engineering programs has been considered before. In undergraduate engineering programs, much of the focus for studio use has been on single courses (e.g., [10]) or, understandably, on senior design courses (e.g., [11]). The Segal Design Institute, McCormick School of Engineering at Northwestern University [12] offers a master's degree in Engineering Design Innovation that emphasizes studio culture and "human centered design"[13], but it does not appear to be a true engineering program. An engineering undergraduate degree is not needed, and the curriculum does not appear to require any courses specifically in engineering. Instead, there are courses and studios focusing on design, product management, leadership, thesis work, a summer internship, and seven unspecified elective courses[14].

If ever there were an engineering discipline that would seem to be naturally aligned with studio culture, it would be architectural engineering. The EAC of ABET program criteria for Architectural Engineering curricula call for "employment of architectural theory and design in a design environment"; but, no mention of studio or studio culture *per se* is evident [15]. Random inspection of different undergraduate architectural engineering programs in the U.S. finds minimal use of studios in the programs. Web sites for architectural engineering programs at Pennsylvania State University [16] and University of Texas at Austin [17], for example, show no courses in the programs specifically identified as studios. For architectural engineering programs at Drexel University [18] and at Oklahoma State University [19], on the other hand, students take two courses identified as studios, but in both programs, the courses so identified are architecture courses, not engineering.

While engineering design creativity may be understood differently than creativity in architecture and the arts, it is certainly a related skill that should be encouraged along with the collaborative nature of the engineering design process. Given the role studio plays in art & design and architecture programs, the studio format should have much potential to foster growth for engineering students in engineering design creativity. Although specific implementations may differ somewhat in effectiveness, it is well recognized that use of active learning methods is an excellent strategy to promote student learning and retention of engineering concepts, skills, and information [20] [21] and that the modern practice of the "flipped classroom" lends itself especially well to such an approach [22]. Collaborative and cooperative learning can further enhance the student experience [10]. The studio format, long used in the architectural education world for its active and collaborative learning advantages, would seem to be the ideal setting in which to practice such methods in engineering education. Studio inculcates an atmosphere of intellectual curiosity, cooperative learning, collaboration, and respectful consideration of new ideas and multiple points of view [4]. Such attributes would contribute to the quality of teamwork encountered in the multidisciplinary design-team environment in which engineers typically function today.

Indeed, EAC of ABET student outcome 5 under "Criterion 3. Student Outcomes" [15] requires that students have "an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives." In view of the positive creative design experience and teamwork training that studio culture provides to architecture, landscape architecture, and art & design students, why not consider the use of studios in engineering programs?

Conversion of Lecture/Lab Format to Studio

The author has taught a variety of engineering, engineering technology, and landscape architecture courses in his nearly 40-year career. In 2014, the author's home Department of Bioresources Engineering, housed in the University of Delaware's College of Agriculture and Natural Resources was disbanded, and his faculty line was reassigned to the Department of Plant and Soil Sciences where he contributed to the creation of and has since taught courses in support of a professional undergraduate program in landscape architecture accredited by the Landscape Architecture Accreditation Board (LAAB) [2]. The four courses he has primarily taught are in surveying, site engineering, urban hydrology, and stormwater management. All four courses are cross listed between landscape architecture and civil and environmental engineering, and all were originally taught in a lecture/lab format. The surveying and urban hydrology courses serve primarily construction engineering and management students, civil engineering students, and environmental engineering students, while site engineering and stormwater management are required for landscape architecture students. Site engineering and stormwater management are technical electives for students in the civil engineering, environmental engineering, and construction engineering & management bachelor programs, and such engineering students are often enrolled in those courses alongside the landscape architecture students.

As described in [23] and [24], the author uses an online problem set system embedded within the online learning management software, LON-CAPA [25]. The online LON-CAPA problem sets are mastery-based with immediate feedback, and all students have individualized problems with unique numbers and sometimes unique circumstances [24]. The author wrote and coded nearly all the over 200 problems used in his classes. The problems were designed to promote understanding of core concepts and to help students develop analytical reasoning and technical abilities by giving them opportunities to work problems requiring the type of analysis, design, and reasoning skills they would typically encounter in real world situations. Problem sets are sequenced so that students hone the targeted skills just in time for application in other applications-based course assignments and design projects.

As noted in [26], the author has been gradually moving to a "flipped classroom" format in his courses whereby less time is devoted to passive learning lecture-type components and more time is allocated for active learning student tasks. In such a format the author spends most of the class period providing one-on-one student assistance or advising small groups working collaboratively on assignments [26]. Class time devoted to instructor-guided work on LON-CAPA problem sets has been a component of the author's classes since he started using the LON-CAPA system twenty years ago.

Before converting to the studio format, somewhat lengthier class times, which are advantageous for active learning, were obtained by combining lecture periods and using the longer meeting times of the associated labs. So, for example, a 4-credit lecture/lab course would be scheduled to meet once a week for a 2.5-hour lecture period and once a week for a two-hour lab period. The flipped classroom approach allows for easier dedication of class time for work on the LON-CAPA problem sets and more flexibility for including other individual and team-oriented active learning assignments. Use of the studio format enables full implementation of flipped classroom methods.

Appendix A is the calendar of events for the site engineering course as taught in spring semester 2022. The bold-font entries in the calendar are all the active-learning assignments or activities. Sufficient in-class time is devoted to these assignments so that they can be substantially completed during studio. Notice there is some type of active-learning opportunity scheduled for every class meeting. This includes a team assignment in weeks 8 and 9 and a major group project during the last four weeks of class in which NRCS hydrologic computer models are created for present and developed site conditions using information from CAD-file site plans and on-line resources. The longer studio meeting times also allow for incorporation of a class field trip (week 10) to an active construction site and stormwater management facilities where students can see the practices learned in class put to use. The emphasis on active learning is manifest in the grading scheme for the course. The two exams are worth only 40% of the overall grade while the before-class quizzes, problem sets, projects, and other active learning assignments are worth the balance.

The “studio” designation for classes organized in the longer class-time studio format provides students with a more accurate expectation for classroom activities than the conventional labels of “lecture” or “laboratory.” Additionally, the artificial segregation of active learning and other flipped classroom activities into conventional “lecture” and “laboratory” components is not propagated in the university’s system of confidential student course evaluations. The course evaluation system would have students complete separate and at least partly redundant (if not inapplicable) course evaluations for separate lecture and laboratory sessions, though, in practice, there might be little or no difference in how the “lecture” and “laboratory” components were delivered. With the studio designation, a single course evaluation for a studio is all that needs to be completed.

Because of his involvement with the newly created professional program in landscape architecture, the author became aware of the studio class format and its advantages. As noted previously, studio provides more contact hours per week per credit hour than does lecture. In architecture and landscape architecture programs, students typically enroll in just one major studio per term because the time demands would otherwise be excessive. Studio courses are assigned a commensurately larger number of credit hours. A major studio, for example, might meet twice a week for four to six hours per meeting time. Such a course would be assigned four to six credit hours. During the same term, students could also take a minor studio that might meet for, perhaps, two and a half or three hours twice per week that would be worth three credits.

Since the studio format is ideally adapted to the flipped classroom and the active learning measures the author has been increasingly using in his classes, starting in the 2018-19 academic year, he began to change his course formats to studio. The lecture/lab format of the site engineering, urban hydrology, and stormwater management courses was changed to studio. Because of the necessary and distinctive nature of the laboratory component of the surveying course, it was left unchanged. The stormwater management course was changed from a 4-credit lecture/lab course with 2.5 hours of lecture and 2 contact hours of laboratory to a 3-credit studio course with 5 contact hours of studio in two 2.5-hr sessions per week.

The first three years of data for the lecture/lab version of urban hydrology were for a 4-credit course configured the same as the original stormwater course described above: 2.5 hours of lecture and 2 hours of lab per week. In the fourth year of lecture/lab format urban hydrology was changed to 3-credit lecture/lab course having 1 hour and 40 minutes of lecture and 2 hours of lab per week. When converted to studio format the following 2018-19 academic year, urban hydrology was 3 credits with 5 contact hours per week in two 2.5-hour studio sessions. The site engineering course was changed from a 4-credit lecture lab course with 2.5 contact hours of lecture and 2 contact hours of laboratory per week to a 3-credit studio having 6 contact hours (two 3-hr sessions). Because of the change to studio format, it was possible to implement more completely the flipped classroom approach in these courses, which includes video lecture material to be viewed outside of class.

A major goal in the author's courses is to give students realistic experience with the types of applications of the course material they would encounter in practice. Consequently, hydraulic and hydrologic software, CAD, and online GIS resources are utilized heavily in the author's courses, so the studios are typically scheduled in an engineering computer lab. A studio session usually begins with a quick recap of material recently covered and how it relates to upcoming topics and assignments. An online quiz must be completed before most class meetings. Before-class quizzes are worth 5% of the course grade and are relatively straightforward being designed to encourage students to do the preparatory reading assignments and to review the videoed lecture material in time for class. The instructor typically reviews the quiz with the class to see if any points of confusion exist and to give students an opportunity to ask questions about any of the material. To give students another opportunity to ask questions and, perhaps, eliminate some confusion, the instructor will often discuss any particularly complicated or difficult material in the reading/viewing assignments. The instructor spends the remainder of the studio time working with students one-on-one or in small groups providing guidance about the assignments with which they are actively engaged.

Examination of Course Data

Because each of the courses taught by the author has a problem set component that accounts for approximately 25% of a student's grade, a significant common element is present that can be compared across class formats. Student success in completing the mastery-based problem sets is one measure of time spent on task and is indicative of student productivity and understanding of the material. Notably, the author found that online problem set completion rates had significant positive correlation with higher exam scores in his courses [24]. Problem set completion rate is by no means a perfect indicator of student learning, but as a major course component shared among different courses it can be used as a basis for comparison between lecture/lab and studio class formats. Because of the timing of course changes, two courses, site engineering and urban hydrology provided the clearest comparison of studio vs. lecture/lab formats. The stormwater course was newly created in 2017, and there were data from just a single year of lecture/lab format having only seven students for comparison with four years and 48 students worth of studio format data. The single year of lecture/lab format had a higher problem set (PS) completion percentage at $\alpha = 0.05$, but this finding is probably unreliable given the small number of students who took the course in the lecture/lab format.

Table 1. ANOVA data for mean problem set (PS) completion percents and sample standard deviations (STD) for Site Engineering and Urban Hydrology courses taught in lecture/lab and studio formats.

Course:	Site Engineering		Urban Hydrology	
Class Format:	Lecture/Lab	Studio	Lecture/Lab	Studio
PS Mean %	73.15[a]	85.69	90.58[c]	95.61
PS STD %	25.03[b]	13.75	10.16[d]	6.10
# of Semesters	4	4	4	4
# of Students	31	67	104	55
Degrees of Freedom	27	63	100	51
Footnotes:	[a] Lecture/Lab < Studio ($p<0.015$) [b] Var Lecture/Lab ≠ Var Studio ($p<0.0001$)		[c] Lecture/Lab < Studio ($p<0.001$) [b] Var Lecture/Lab ≠ Var Studio ($p<0.0002$)	

Table 1 summarizes the ANOVA data for the site engineering and urban hydrology courses. A standard F-test was used to determine that heteroscedasticity of model variances existed between the lecture/lab and studio versions of both classes (pg 126 of [27]). A one-sided test (H_0: lecture/lab PS% is not less than studio PS%) described on page 120 of [27] for unequal variances was used to test for differences between online PS completion % for the lecture/lab and studio class formats.

As indicated in Table 1, for both the Site Engineering and Urban Hydrology courses, PS completion percentages for the lecture/lab format were significantly less than the PS completion percentages for the studio format. Note that the instructor had begun to use flipped classroom techniques in both urban hydrology and site engineering before the courses were converted to studio, so that element is somewhat constant in both lecture/lab and studio formats. What the conversion to studio allowed was additional class meeting time that could be used for active learning opportunities during the studio period. Thus, the improved PS completion percentages for studio are no doubt largely attributable to the increased amount of class time devoted to student work on the PSs that is available in studio and the greater availability of the instructor for providing immediate individualized assistance to the students. Interestingly, the completion percentage for identical PSs increased in Site Engineering's move to studio format even though credit hours for the course decreased from 4 to 3. Apart from the evidence summarized in Table 1 about increases in PS completion percentages for studio, it has also been the author's observation that the quality of student work on group assignments and design projects in his studio classes has improved. The increased amount of time available for the instructor to act as a consultant or a guide during class meetings has likely been a factor along with improved opportunity for student collaborative learning.

Recommendations and Conclusions

The author realizes that full implementation of studio culture in engineering programs that emulates how studio is used in art & design, architecture, and landscape architecture programs may have some significant hurdles to overcome, not least of which is the cost in resources required to have dedicated studio space for each student as required in architecture and landscape architecture programs. Such a model might be impractical for engineering programs enrolling large numbers of students with class/cohort sizes that much exceed 30 or 40 unless the department is ready to devote necessary resources for student studio spaces and for additional instructors or TAs. An obvious starting point would be to reconfigure senior design project courses as studios. Beyond that, many engineering programs have freshmen design courses that would seem to be good places to implement the studio model.

At a minimum, programs should consider converting their senior design project class sequences to studio sequences. Given the range of material that needs to be taught in typical engineering programs, there may be an understandable reluctance to have major studio experiences (5 or more credits, 10 or more contact hours per week) in the curriculum for fear of crowding out technical electives that give a program breadth. Beyond major studio experiences in first year and senior design courses, it might be desirable, also, to identify one or two discipline-specific engineering courses each that could be taught each term in a minor studio format. Such courses could meet, perhaps, twice per week for 2.5 to three hours per meeting and could be used to promote comprehensively within the program the positive aspects of studio culture such as collaborative learning and creative design. Instructors could also be encouraged to convert technical electives to a minor studio format. Extended studio meeting times in such courses would allow instructors to experiment with a variety of active learning approaches and easily to introduce elements of the flipped classroom.

There is a huge variety of engineering programs available to students in the U.S., but examination of the curricula often reveals a large amount of curricular uniformity, especially among programs in the same or similar disciplines. Engineering programs in mainstream disciplines such as civil or mechanical engineering often struggle to differentiate themselves from their competitor peers. Use of studios and promotion of studio culture in undergraduate engineering programs as exemplified in art & design, architecture, and landscape architecture programs could be a way to enhance learning, improve the student experience, and truly make a program stand out in terms of offering a unique engineering educational product.

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Appendix A
LARC/CIEG 343 – Site Engineering, Schedule of Events, Spring 2022
Active Learning Exercises in **Bold**

Week # / Monday's date		Monday Studio (9:05 AM – 12:05 PM), SPL 010	Friday Studio (9:05 AM – 12:05 PM), SPL 010
1	Feb 07	Introduction to Course, Chapter 1: Site Engineering *Is* Design, Maps and Scale, **Problem Set: Maps & Scale**	Chapter 2: Grading Constraints, **Assignment 1: Locating Your Place on Earth**
2	Feb 14	Chapter 3: Contours and Form, **Assignment 2: Sections**	Chapter 4: Interpolation and Slope, **Assignment 3: Interpolation of Contours on a Grid and a 3-d Model, , Problem Set: Slope and Grading Calculations**
3	Feb 21	Chapter 5: Grading of Simple Design Elements – Linear Elements; **Assignment 4a: Grading a Swale**	Grading of Simple Design Elements – Area Elements, **Assignment 4b: Grading of Linear and Areal Elements**
4	Feb 28	Chapter 6: Grading Process, **Work on Assignment 4b**.	Chapter 7: Introduction to Soils and Soil Properties, Soil-Mass-Volume Relationships, **Problem Set: Soil-Mass-Volume Relations**
5	Mar 07	Chapter 7: Soils in Construction, Engineering Properties of Soils, **Problem Set: Soil-Mass-Volume Relations**	Chapter 7: Soils in Construction, Soil Classification Systems, **Assignment 5: Soil Classification Laboratory, Problem Set: Soil Grading and Classification**
6	Mar 14	Chapter 8: Earthwork Volumes for cross-sections, contours, and borrow pits, **Problem Set: Earthwork Volumes**	Chapter 8: Compaction, Cut and Fill Operations, Swell and Shrinkage Factors, **Problem Set: Earthworks Operations**
7	Mar 21	Introduction to Water Flow Concepts and Open-Channel Hydraulics, **Problem Set: Intro to Water Flow and Hydraulics Concepts**	Chapter 9: Stormwater Management, Chapter 10: Stormwater Management System Components, Watershed Delineation, **Assignment 6: Delineation of Watershed Boundaries**
	Mar 28	Spring Break	Spring Break
8	Apr 04	Chapter 11: Soil Erosion and Sediment (E&S) Control, E&S Plans, **Finish Assignment 6**, Exam Review	Exam 1: Covers from beginning of course through Introduction to Water Flow Concepts and Open-Channel Hydraulics. **Team Assignment 7: Examination of Erosion & Sediment Control Plans**
9	Apr 11	Introduction to Hydrology, Hydrologic Processes, Return Periods, **Finish Team Assignment 7, Problem Set: Intro to Hydrology and the Rational Method**	Chapter 12: Time of Concentration, The Rational Method for Peak Flow Estimation, **Problem Set: Intro to Hydrology and the Rational Method**
10	Apr 18	Chapter 13: NRCS TR-55 Hydrology: Curve Number, Rainfall, & Runoff Volume, Non-Standard CNs, **Problem Set: NRCS CN and Runoff Depth**	**Tour of Active Construction Sites and Stormwater Management Facilities.**
11	Apr 25	**Team Assignment 8: Present & Developed NRCS Hydrology from Site Plans, Group Work on Project**	NRCS TR-55 Hydrology: Time of Concentration, Graphical Peak Discharge (GPD) Method, and **Problem Set: NRCS TR-55 GPD, Group Work on Assignment 8, Group Work on Assignment 8**
12	May 02	Chapter 14, Elementary Swale Design, **Problem Set: Normal depth in swales, Group Work on Assignment 8**	Chapter 14: Designing & Sizing Piping Systems**, Problem Set: Swale Stability and Gravity-Flow Storm-Drain Design, Group Work on Assignment 8**
13	May 09	Chapter 16: Horizontal Road Alignment, **Problem Set: Horizontal Circular Curves, Group Work on Assignment 8**	Chapter 17: Vertical Road Alignment, **Problem Set: Equal Tangent Parabolic Vertical Curves, Exam Review, Group Work on Assignment 8**
14	May 16	**Group Work on Assignment 8**	Finals Begin
Finals Week – Exam 2 (TBD): Focuses on Material from Chapter 9, Stormwater Management through End of Course			