

Longitudinal Integration of the Same Design Project in Multiple Structural Engineering Courses

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Abstract

Civil engineering students may perceive that their course curriculum is composed of several isolated structural design classes that build expertise in separate areas that do not overlap. The objective of this research was to integrate the same design project longitudinally in steel and reinforced concrete design classes at multiple universities to introduce the ideas of iterative design, underscore design options, and reinforce common, key concepts.

Several questions were investigated using longitudinal integration of a common design project. First, how did students perform when completing the project for the first time in reinforced concrete design compared to those completing the project for the first time in steel design? Second, considering the same cohort of students, how did they perform on the project the second time in steel design compared to the first time in reinforced concrete design? Third, the students' knowledge on basic structural analysis and plan reading was measured at the beginning and end of each course. What level of knowledge did they have when entering the respective course? Were students' perceptions of their knowledge gains during the courses supported by assessed knowledge gains?

Student design project grades and pre- and post-surveys were used to answer the research questions. Students completing the project for the first time in steel design had slightly higher grades than those completing the project the first time in reinforced concrete design. Students completing the project for the second time had slightly higher average final grades compared to students completing the project for the first time. Survey results indicated that students' confidence in reading plans increased substantially the first time through the project regardless of which design class they took first, but remained similar the second time through. The students' ability to set up and solve free body diagrams from the structural plans continued to improve each time they completed the project, regardless of the course. Based on these results, students made the most knowledge gains the first time through the project, retained substantial knowledge after the first time through the project, but continued to gain confidence after completing the project the second time.

Introduction

Iterative design is an essential instrument in a practicing structural engineer's toolbox. Preliminary designs frequently look at different layouts, options, and materials during the decision-making stages. This process is not as common in an academic setting because topics covering similar design processes with different structural materials are taught in different courses (e.g., reinforced concrete design and steel design). In addition, the fundamental behavior of the separate materials must be presented prior to delving into the details of design alternatives. Thus, civil engineering students may perceive that their course curriculum is composed of several isolated classes that build expertise in separate areas that do not overlap. Capstone courses or projects are frequently used to combat this misperception. Providing an understanding of how topics covered in one course relate to previous courses in the curriculum allows students to see the overlap earlier and observe design options.

The objective of this research was to integrate the same design project longitudinally in two introductory structural design classes at multiple universities in order to introduce the ideas of iterative design and design options and reinforce common, key concepts. Longitudinal curriculum integration is frequently associated with freshman and sophomore level courses and often used to enhance student retention by maintaining interest in their field of study. Structural design courses are typically taught in a longitudinal order. Students first take a structural analysis course followed by one or more design courses (e.g., reinforced concrete design or steel design). There is some repetition among the design course topics, but they primarily cover their own unique material behavior. Students are often left to imagine or connect these topics on their own, in a capstone style course towards the end of their education or during their first years of employment. Unfortunately, some students graduate with a misunderstanding of the true processes used in structural design. Time restrictions and civil engineering program limitations lead to this quandary.

The goal of this project was to integrate the same design project in two upper level civil engineering structural design courses that were taught in a longitudinal manner: (1) reinforced concrete design and (2) steel design. Through the curricula in this study, students were required to take reinforced concrete design and had the option of taking steel design. Use of the same assignment allowed for the presentation of common design processes in each course. The students could also conceptualize the process of design alternatives for future use in capstone projects and employment.

Background

One of the goals of an engineering program is to teach students a body of knowledge that they are expected to master by graduation. In each program there are unique sets of topics and many of them have some degree of overlap and similarity. One common problem is teaching the students to recognize these connections and repetition among topics. There is a natural tendency for each class to be perceived as its own unique subject that does not integrate with other classes in the curriculum [1]. Historical methods of teaching focus on the details, but not the big picture [2]. The courses may be perceived as a set of independent stories rather than one continuous

story with a set of chapters contributed from each course. This fallacy has been identified for many years and continues to be addressed in a variety of ways [3], [4].

Part of the role of a professor is to provide opportunities and prompts to help students visualize engineering from a broad perspective. One way to do this has been to provide first year engineering courses that inspire and educate students as they pick a career path. Results have shown that making engineers more aware of the profession and connecting them on a humanistic level keeps students interested in the field of study and increases graduation rates [5], [6], [7]. Bernold et al. [8] studied learning styles to present material differently and improve retention during the first year of study in an engineering program. Palmer and Hall [9] converted their introduction course using problem based learning and case studies to excite the students. The case studies helped the students learn many challenges are interdisciplinary. Other programs have made strides in connecting basic math and science courses to the engineering curriculum. Froyd and Ohland accomplished this in introduction courses or learning communities during a student's first year of study [10].

One of the most comprehensive ideas for reform was suggested in an electrical engineering program [1]. The goal was to present connections across all core courses in the program. Math and practical engineering problems were integrated to help students see the repetition among topics. The goal was to remove topical barriers and teach to a set of collective goals throughout the degree program [1]. A similar plan was suggested for a series of engineering mechanics courses: statics, mechanics of materials, and engineering materials. A two course sequence was created that combined the concepts in order to help the students see the similarities and remove the barriers between classes [11]. One mechanical engineering program tracked student success in a series of critical topics. They saw the biggest gains occur after students took some of their upper level design courses [12].

In recent years, there has been a desire to integrate undergraduate research in courses. Undergraduate research has been documented to provide deeper study, more one-on-one attention, and the global understanding desired by many students. The challenge that many professors cannot overcome is the necessary time to maintain small class sizes and attend to each student on a personalized level [2].

In many curricula, there are a series of courses that build upon a core set of classes. These courses may or may not be electives, but they are commonly taken in sequence. For instance, a student may take a fluid mechanics course followed by hydraulics, water resources, and hydrology courses [13]. The goal would be for students to make connections across all of these courses because of their close connection and overlap in a design scenario. While combining courses may be effective, this is not always practical in curriculum development. The question is whether introducing a common iterative design project longitudinally throughout the sequence would help connect concepts across courses within the global curriculum.

Research Questions

The literature shows that a body of knowledge should be clearly connected across courses and throughout the curriculum. There are a variety of methods of doing this, but many require significant changes to introductory courses, the reorganization of course sequences, the introduction of undergraduate research and individualized attention, or the addition of a capstone style course. Few examples exist of programs making minor adjustments to existing courses to achieve the same desired connections.

A common design project was introduced longitudinally into two undergraduate structural engineering design courses. Completion of the project was iterative in nature and repetitive between the courses. The research study surrounding the project was implemented to investigate three questions:

1. First, how did students perform when completing the project for the first time in reinforced concrete design compared to those completing the project for the first time in steel design?
2. Second, considering the same cohort of students, how did they perform on the project the second time in steel design compared to the first time in reinforced concrete design?
3. Third, the students' knowledge on basic structural analysis and plan reading was measured at the beginning and end of each course. What level of knowledge did they have when entering the respective courses? Were students' perceptions of their knowledge gains during the courses supported by assessed knowledge gains?

Procedures

A common design project was created for use in the structural engineering design sequence. The project was longitudinally implemented in both a reinforced concrete design course and in a steel design course over five semesters. The project was designed to be a minor addition to an existing course syllabus and not an entire course rewrite or curriculum change. This integration was effectively completed at two different universities [14]. At one of the universities, both the steel and concrete design courses were taught by the same professor. At the second university, the steel and concrete design courses were taught by different professors. At both schools, all of the students were required to take the reinforced concrete design course, and many students chose to take steel design even though it was not required. Reinforced concrete is often taken during the students' junior year or first semester senior year. The steel design course is frequently completed after the concrete design course. In these design courses, students have their first in-depth assignments related to reading structural engineering design plans, although a few may have been exposed to the topic in a previous engineering drawing course, construction course, or internship. In this study, 46 students were exposed to the design project for the first time in the concrete course, 28 students were exposed to the project for the first time in the steel course, and 37 students were exposed to the project a second time in the steel course after completing the concrete course. The students who completed the project for the first time in the steel course previously had taken concrete in a course section that did not require the project. No students took the steel course before the concrete course in this study, although this was technically a curriculum option. Data do not exist to compare how this group of students

introduced to the longitudinally integrated project performed compared to a control group of students that did not complete the project.

The design projects were completed in three submittals over the length of the semester by small groups of students (e.g., two or three students) and the technical content of each submission aligned with the content presented in class. The groups were not selected by the professors and students in steel design could have paired themselves with a colleague who had previously completed the design project in the concrete course. The design project was introduced during the second week of the course and the final project was submitted on the last day of instruction. Students received feedback on the first two submittals regarding issues that needed to be addressed before the end of the semester. Feedback to students ranged from incorrectly completing technical calculations to a lack of professionalism in their submitted task report. Students were encouraged to fix these issues prior to the next submittal and make note of their changes in a memo in order to improve their final project grade. The project was graded using the same rubric for all of the classes at both universities. Consistency of grading was achieved between the courses and over various semesters through the use of the rubric and because the authors were the only faculty teaching the courses. In all of the courses, students were required to complete individual homework problems in addition to the project. The project was weighted to be approximately 10-15% of the overall course grade and the homework was weighted to be approximately 20-25% of the overall course grade.

The processes used to approach the design project were implemented similarly in both classes and at both universities with a common starting point. An industry partner provided a set of plans for a precast concrete parking garage. The students were then challenged to perform an alternative design of basic components of the garage with reinforced concrete and steel in the respective classes. The project in both classes was based on the same set of plans, the same column grid and spacing, and the design of the same structural members (e.g., interior beam/girder, exterior beam, interior column, and exterior column). The design procedure was very similar in both the concrete and steel classes because the applied loads, load paths, and member free body diagrams were similar. Completion of these tasks was required in the first project submittal. Hence, these tasks were designed to be highly repetitive for students who were experiencing the design project for a second time. Students were expected to submit their design calculations and drawings in a professional manner, utilizing AutoCAD and Mathcad software to create a professional product, automate repetitive tasks, and efficiently redesign components as the project progressed. The final project submittal included an overall set of design calculations and a set of drawings corresponding to each of the individual members the students designed.

To help answer the research questions, the authors collected survey data at the beginning and end of the semester using 16 questions to help assess students' knowledge gains and the perceptions of their knowledge gains related to the project. These questions included ten related to specifically finding information on a set of plans, three related to their confidence reading a set of plans, and three related to their ability to use concepts from statics and structural analysis on this project. The survey was administered to each student individually prior to starting the project and then after concluding the project the last week of the semester. In both cases, the students were given 15 minutes and a participation grade for the respective course if they

finished the survey. The students were not given the correct answers to the survey at any point in the longitudinal integration process.

Grades on the final project submittals were used to analyze how students performed when completing the project for the first time in reinforced concrete compared to those completing the project for the first time in steel design. A comparison was then made between the project grades for students who performed the project a second time in steel design after completing it for the first time in concrete design.

Results

Project Grades

The final project grades were subdivided by the class students were completing (e.g., steel or concrete) and the number of times they attempted the project. The categories included: completing the project for the first time in reinforced concrete (1st Time Concrete), completing the project for the first time in steel design (1st Time Steel), or completing the project for the second time in steel design after initially being exposed to it in reinforced concrete design (2nd Time Steel, 1st Time Concrete). Students completing the project for the first time in steel design (28 students) had higher grades by approximately 1.5% compared to those completing the project the first time in reinforced concrete design (46 students). The average final project score was a 93.9% in steel design compared to an average final project score of 92.5% in concrete design. Results from this comparison are shown in Figure 1, which shows the final project grade vs. the normalized student population (i.e., a unitless number generated by dividing the student number by the maximum number of students in each group). The final grades were relatively close, and a *t*-test indicated that the difference was not statistically significant (i.e., *p*-values were greater than an α of 0.05). Differences in the average grades were attributed to previous experience in design courses or the nature of the design process for each material. Students may have completed other design courses prior to taking steel design, which provided them with some background design experience. Alternately, the final project grades may have been higher in the steel design course due to the tabulated nature of design in an introductory steel course compared to the variability in introductory concrete design related to selecting dimensions and checking spacing/detailing requirements.

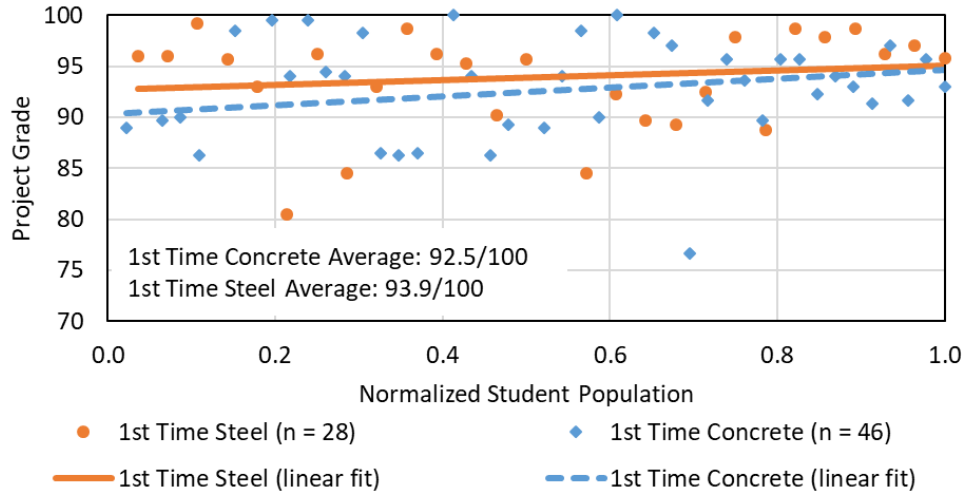


Figure 1. A comparison of final project grades for students exposed to the project for the first time in steel and for the first time in concrete.

Students completing the project for the second time (37 students) had higher average final grades by approximately 1% compared to students completing the project for the first time (74 students) as shown in Figure 2. Results from a *t*-test indicated that the difference was not statistically significant (i.e., *p*-values were greater than an α of 0.05). Higher grades were attributed to design repetition and familiarity with the design project, which had a common starting point in both courses. Students exposed to the project for the first time in steel design (28 students) did not perform statistically different compared to students exposed to the project the second time in the same steel design class (37 students) as shown in Figure 3. This may have been because the professors did not control whom students selected for their colleagues in the group project. Students completing the project for the second time could have worked with students who had not previously completed the project.

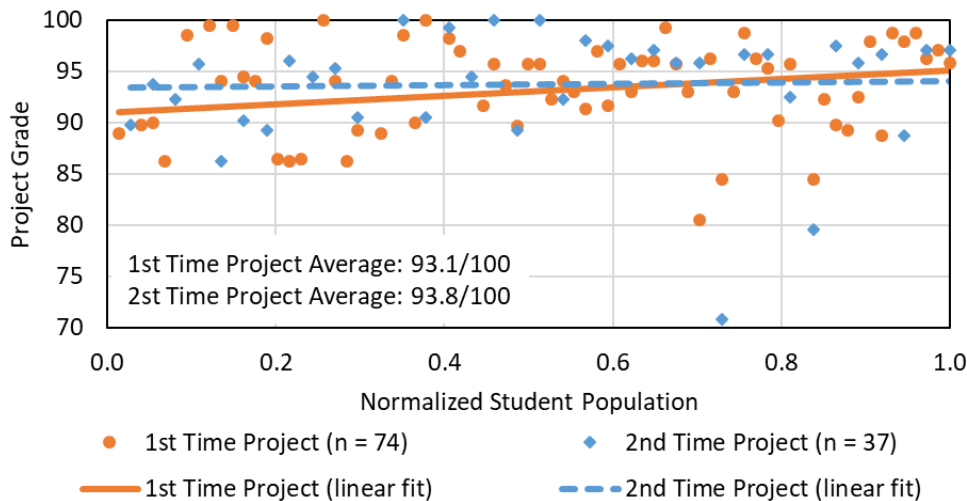


Figure 2. A comparison of final project grades for students exposed to the project for the first time in concrete and for the second time in steel.

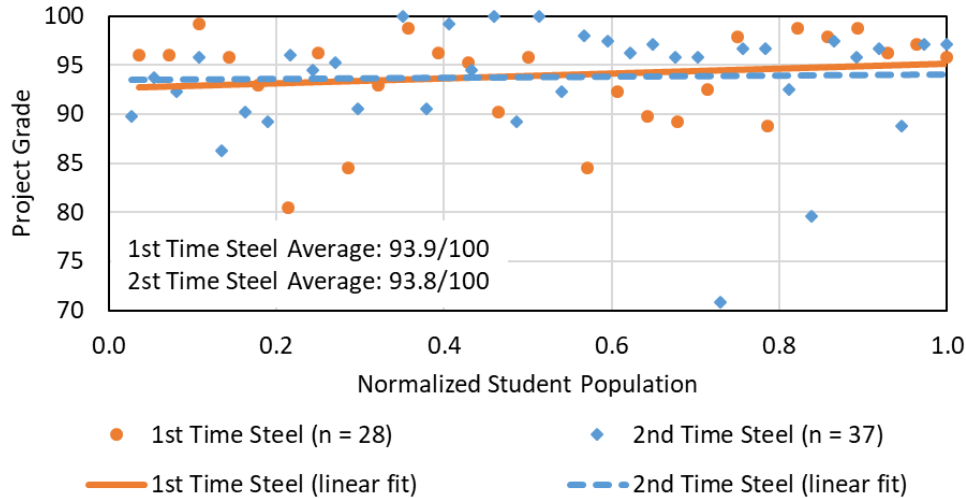


Figure 3. A comparison of final project grades for students exposed to the project for the first time in steel and for the second time in steel (after concrete).

Surveys

The ten questions on plan reading were answered by each student prior to introducing the project. Table 1 shows the number of students who took the initial survey prior to working on the project (beginning of the semester) and who took the final survey after completing the project (end of the semester). The number of students surveyed were similarly subdivided by course and how many times they encountered the project. The total participation rate on the surveys was 81% for those who took it at the beginning of the semester and 94% for those that took it at the end of the semester. Most students took the survey both times, but they were given the choice to take it each time per the IRB agreement.

Table 1. The number of students surveyed before and after completing the project.

Project Iteration	Number of Students Surveyed	
	Initial	Final
1st Time Concrete	26	30
1st Time Steel	15	21
2nd Time Steel, 1st Time Concrete	21	21

The percentage of students who correctly answered each question was computed for all of the students who took the initial and final surveys as shown in Figure 4. A few questions had much different results on the final survey that might be explained by the question asked. For example, question #5 asked students to identify a steel member on the plans, which is a topic that very few would have known initially and only those who were in steel would know at the end of the course. Question #3 asked students to count the number of stairwells, however many answered by counting the number of stairs in the structure.

The students who had already completed the project (2nd Time Steel, 1st Time Concrete) answered more questions correctly than those completing the survey for the first time on six of the ten questions and scored higher than 70% on eight questions. Those taking reinforced concrete for the first time (1st Time Concrete) answered the most correct on the remaining four

questions and scored higher than 70% on six questions. Those taking steel for the first time (1st Time Steel) did not have the highest percent on any question and scored over 70% on two of the ten questions. When reviewing the percentage of correct answers on the initial survey for students taking either class for the first time, the students taking reinforced concrete did better on all ten questions.

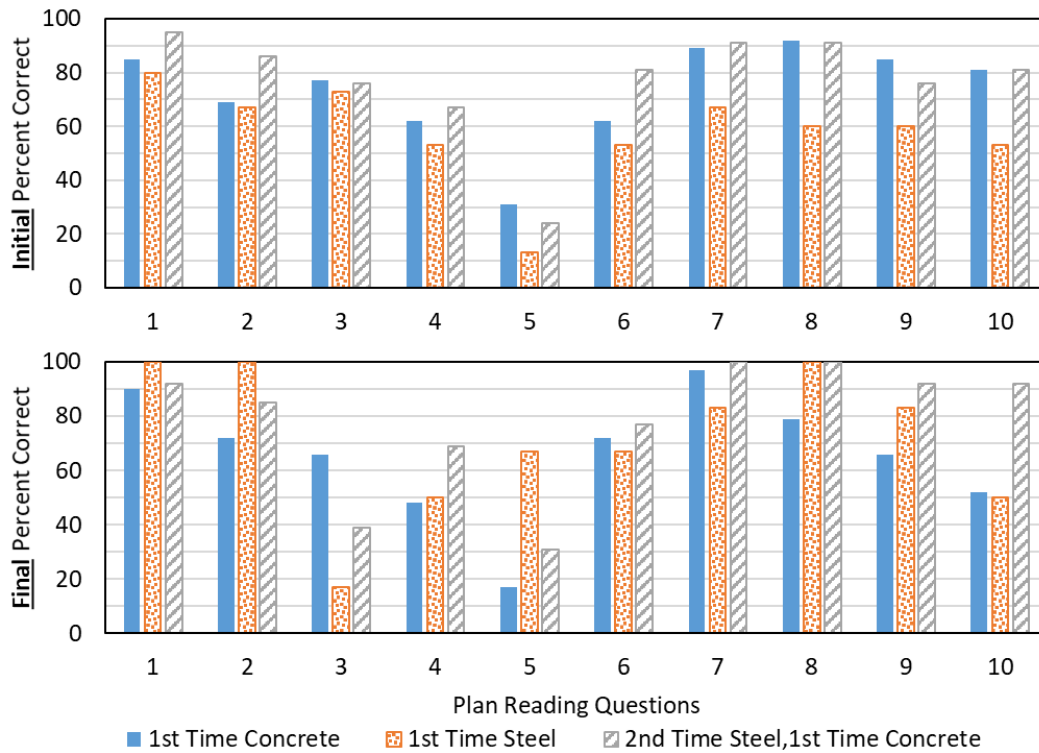


Figure 4. Results from the initial (top) and final (bottom) plan reading questions.

The students who had already completed the project (2nd Time Steel, 1st Time Concrete) answered more questions correctly than those taking it for the first time on six of the ten questions and they scored higher than 70% on seven questions. Of the remaining four questions, those taking steel design for the first time (1st Time Steel) answered the question correctly the most four times and scored over 70% on five questions. Those taking reinforced concrete answered correctly the most one time and scored over 70% on five questions. On question 8, all of the students answered correct in two different classes. When reviewing only the final survey results for students taking either class for the first time, the results were mixed. Students taking reinforced concrete first did better on four of the ten questions while those in steel first did better on six of the ten questions.

When comparing the initial versus final survey results, those who had already taken the project (2nd Time Steel, 1st Time Concrete) did not show an increase or decrease in score of more than 15% in nine of the ten questions. Those taking steel for the first time had final results that were 20% or higher in five of the ten categories. Those taking concrete for the first time had final results higher in four of ten categories, but none of the gains were more than 11%. Another comparison was made using the survey results for students taking concrete for the first time (1st

Time Concrete) and those completing the project for the second time in steel (2nd Time Steel, 1st Time Concrete). All of these students went directly from the reinforced concrete course to the steel course. Of the survey questions, nine were higher on the initial survey the second time students were exposed to the projects compared to the final survey the first time completing the project. This indicated that students retained knowledge from the first time through the project to the point in time when they started the project the second time.

Three survey questions were given to the students at the beginning of the course on structural analysis review topics (Figure 5). On two of the three questions, those who had already completed the project (2nd Time Steel, 1st Time Concrete) answered the questions correctly more often and scored higher than 70% correct. Those taking reinforced concrete for the first time correctly answered one question more frequently and the score was higher than 70% correct. Those taking steel for the first time did not answer any of these questions above 70% correct, but they performed higher than those taking reinforced concrete for the first time on one question.

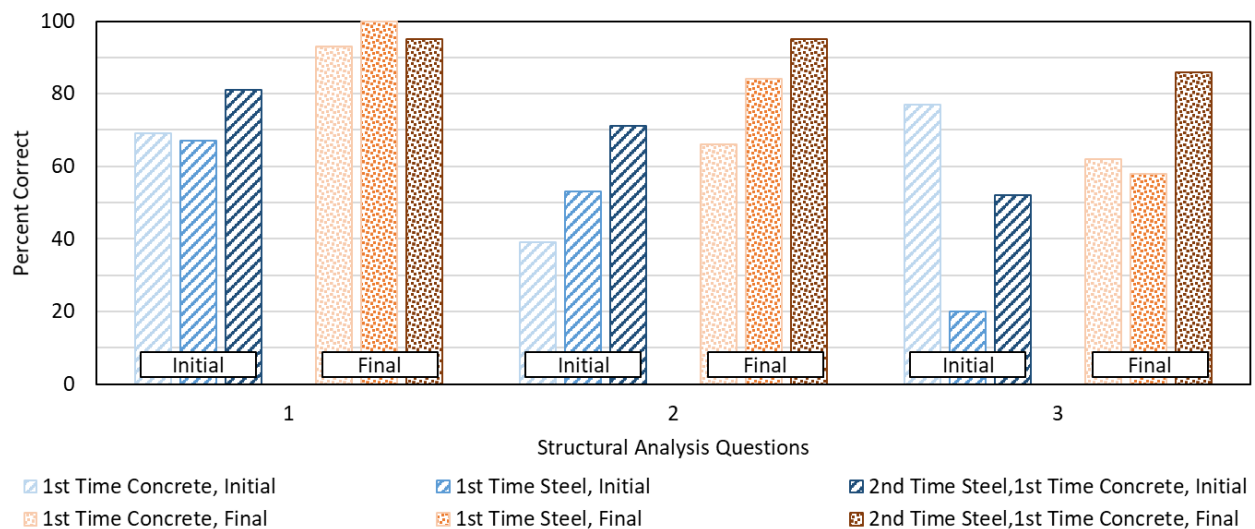


Figure 5. Results from the structural analysis survey questions.

The same three questions related to structural analysis were given to the students on the final survey at the end of the course as shown in Figure 5. On two of the three questions, those who had already completed the project (2nd Time Steel, 1st Time Concrete) correctly answered the questions more often, and on all three questions, the scores were higher than 70%. Those taking steel for the first time correctly answered one question more often and scored higher than 70% on two questions. Those taking reinforced concrete for the first time answered one question above 70% correct and performed better than those taking steel for the first time on one question.

There was a clear pattern in the structural analysis survey results; improved survey scores at the end of the semester indicated that skills related to structural analysis increased while completing the project. On all of the final survey questions for those performing the project a second time (2nd Time Steel, 1st Time Concrete), the scores improved by 14-33%. Those taking steel for the first time had final survey scores that improved by over 30% on every question.

Those taking reinforced concrete for the first time had final survey scores that improved by at least 30% on two questions but scores that dropped by 19% on one question. A comparison of those who had taken the final survey at the end of the concrete class (1st Time Concrete) and the initial survey at the beginning of the steel course (2nd Time Steel, 1st Time Concrete) showed that the students answered the questions correctly about the same amount (within 12%). Many students retained their structural analysis abilities from the first time through the project to the point in time when they started the project the second time.

Three questions related to confidence in plan reading were given on the initial survey at the beginning of the course (Figure 6). The scores were measured on a scale from 1 (Not at All) to 5 (A Great Deal). Students seeing the project for the second time (2nd Time Steel, 1st Time Concrete) had a score of at least 3.90 (between A Lot and A Great Deal) on all three questions. Students seeing the project a second time were clearly the most confident on all of the questions. Students experiencing the project for the first time in steel (1st Time Steel) had lesser confidence, but at least a value of 3.0 (Somewhat) on each question. Those starting the project for the first time in reinforced concrete (1st Time Concrete), had the least confidence on all questions ranging from 2.31 to 2.88 (between Just a Little and Somewhat).

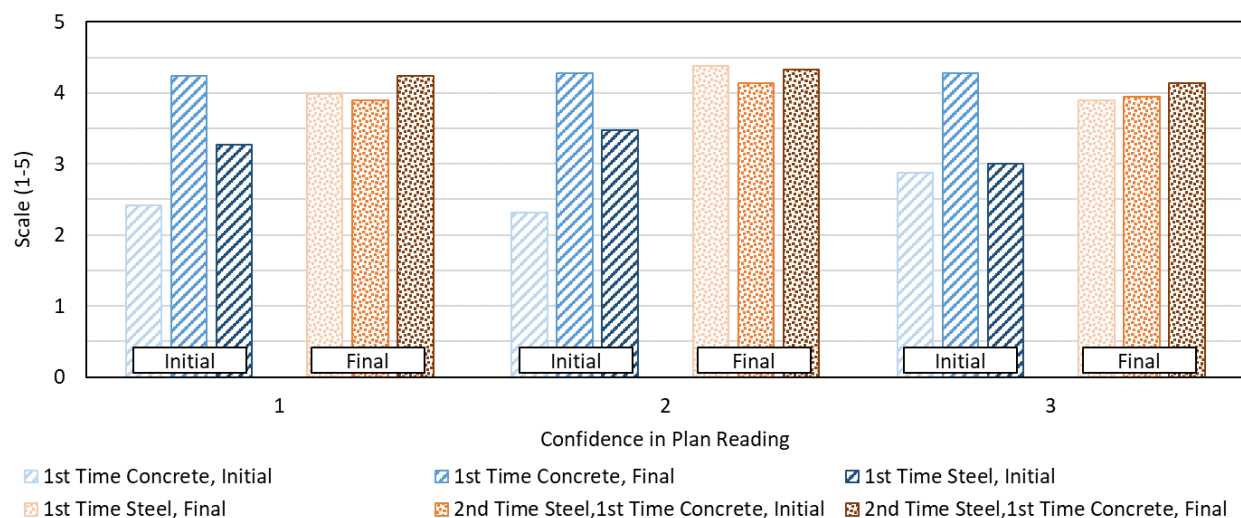


Figure 6. Results from the confidence in plan reading questions.

The same three questions related to confidence in plan reading were also given on the final survey at the end of the semester as shown in Figure 6. Students completing the project for the second time (2nd Time Steel, 1st Time Concrete) had scores ranging from 4.14 to 4.33 (between A Lot and A Great Deal). Those seeing the project for the first time in steel (1st Time Steel) had similar confidence, with answers ranging from 3.90 to 4.38. Students seeing the project for the first time in reinforced concrete (1st Time Concrete) had the highest confidence, with answers ranging from 4.24 to 4.28 (between A Lot and A Great Deal). In all three cases the confidence in plan reading went up over the semester, but it was most drastic for those who were going through the project the first time regardless of which class.

When comparing the results of the final survey in reinforced concrete (1st Time Concrete) to the initial survey results on the second time in steel (2nd Time Steel, 1st Time

Concrete), there was a clear retention in confidence of plan reading. There was a drop of 0.34 or less on all three questions. The first time through the project increased confidence significantly, but re-exposure to the project maintained approximately the same confidence level from the start to finish of the course.

Professor Observations

In both classes, the project was an addition to courses that had already been developed and taught for many years without a project. No additional course load credits were given for adding a project to the course. Both concrete and steel design were three credit courses. The following observations were made related to longitudinal project implementation.

The projects were administered throughout the entire semester. Most students worked in groups of two, but a few groups were composed of three students. Groups of two students had a more even distribution of workload. Most groups of two divided the computer software work evenly because two computer programs were required to finish the project, AutoCAD and Mathcad. In the end, half of the class had a higher proficiency with Mathcad while the other half became more proficient at AutoCAD. Learning and reviewing the computer software packages was beneficial to both groups of students, but it also required a large learning curve. Most students had not used the programs extensively since introduction to engineering or engineering drawing courses. Based on student feedback, groups composed of three students typically did not work as well because the design process was not as easily split among three individuals. The impact of group teamwork on the project was not specifically assessed in this study.

The students who had previously completed the project used their first project as a reference. The structural analysis components (e.g., shear and moment diagrams or load factors) were much better on their initial submissions when completing the project a second time. Students understood the process of factoring loads and finding design values better. This was expected since this phase of the project was the same regardless of the design material and course. The only downside to having previously completed the structural analysis was discovered in groups where one person had done the project and one had not. In the future, it may be better to pair students who have not done the project together, so they have to each think through the analysis process at least one time.

In general, the project submittals were much harder and more time consuming to grade than a traditional homework. Even though the building loads and design process was the same throughout both courses, there was a lot of variation in the final solutions. Additionally, the students were allowed two intermediate submissions prior to the final submission. This improved the final report quality for most students as exhibited by the average scores over 90% in Figures 1 - 3, but it required more grading time from the professors. The final product was much more professional and the student feedback related to the project was very positive. Most students quickly learned what was required and strove to make improvements and better their grades. Students understood the benefits of correcting their work and seemed to understand the process better by the end of the course.

A project integrated into the course allowed students that work very hard, but are still bad test takers, to demonstrate their knowledge and professionalism more effectively. Numerous

students who performed poorly on tests did very well on the project and showed a great deal of pride in their final product. The feedback indicated students enjoyed the project and appreciated being able to show what they know. The progression of the project also worked well as a review for in-class exams. Coordinating the due dates for the project submissions and exams required the students to finish the project prior to each exam.

Conclusions

A parking garage design project was longitudinally implemented in two structural engineering design courses over five semesters: (1) reinforced concrete design and (2) steel design. This integration was completed separately at two different universities using the same design project. Part of the project was implemented to review previous material from structural analysis and construction courses. Other parts of the project asked students to design the same structure out of two different materials. Responses from initial and final surveys revealed students' perceived gains related to their structural design abilities. Final project grades and professor observations provided additional evidence when assessing the three research questions in this study.

The first research question was related to how students performed on the project for the first time in either course. The project grade data indicated that students completing the project for the first time in steel design had slightly higher grades than those completing the project the first time in reinforced concrete design, however the sample sizes were relatively small and the results were not statistically different. The final project grades may have been higher in the steel design course due to the tabulated nature of design in an introductory steel course compared to the design variability in an introductory concrete design course. Students had also all completed other design courses prior to taking steel design, so they likely understood the design process better upon entering the course. Because the results were similar regardless of the course, the order of presenting the project likely did not make a difference. The survey results indicated that students had the least confidence related to structural analysis and plan reading at the beginning of the concrete course compared to the steel course. However, the confidence in plan reading went up over the semester and the increase was most drastic for those who were going through the project the first time in the concrete course (i.e., likely their first civil engineering design course).

The second research question was interested in the performance of the same group of students who completed the project for the second time, longitudinally. Students completing the project for the second time had slightly higher average final grades compared to students completing the project for the first time, however the sample sizes were relatively small and the results were not statistically different. Higher grades were attributed to repetition and familiarity with the design project, which had a common starting point in both courses and incorporated many of the same preliminary structural analysis skills (e.g., shear/moment diagram creation or application of load factors). However, much like research question one, the project results were similar for those completing the project the first or second time. While this was not anticipated, these results do not clearly show that performing the project a second time helps the students make significant knowledge gains. The survey results indicated that students retained knowledge from the first time through the project to the point in time when they started the

project the second time. These results were corroborated by observations from the professors over the length of each semester, as students were more comfortable with and performed better on the structural analysis components.

The final research question was related to the students' knowledge on basic structural analysis and plan reading, which was measured at the beginning and end of each course. The survey results indicated that students continued to improve their skills related to structural analysis while completing the project, regardless of how many times and in what class they were exposed to the project. The first time through the project increased confidence in reading plans significantly, and re-exposure to the project maintained approximately the same confidence level from start to finish of the second course.

The results confirmed many of the patterns seen in the literature. A common project with the same introductory problems presented an opportunity for students to see similarities among subjects. The students successfully completed these repetitive portions regardless of the course as exhibited by their project grades. The students' confidence increased on repetitive topics in plan reading demonstrating that seeing the same topics across the curriculum helped them become more familiar with the topic. Unlike much of the literature, the project did not promote a complete rewrite of the curriculum or implementation of undergraduate research in the course in order to meld topics together. However, the positive outcomes from this study demonstrate that a minor addition of a common project across a course series (structural design in this case) may be all that is needed to help connect topics across the curriculum.

Based on these results, students made the most knowledge gains the first time through the project, retained substantial knowledge after the first time through the project, but continued to gain confidence after completing the project the second time. While there were numerous lessons learned on effective project implementation, overall the project was viewed as a success at introducing longitudinal design in a structural engineering course sequence.

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