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Competition Based Learning in the Classroom

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Competition Based Learning in the Classroom

Introduction

Traditional engineering courses at most universities have been taught for decades with a 3-hour lecture format, usually meeting for either three 50-minute lectures, or two 75-minute lectures each week. In both formats, the course is generally taught with passive, abstract (theoretical), verbal, and sequential teaching styles, in other words, the instructor presents the material with little time for experimentation or reflection, generally spending a significant amount of class time discussing theory, using chalk or dry erase markers and other forms of verbal communication, in a very step-by-step progression, where preceding topics are built upon throughout the duration of the course. Engineering education researchers have shown these styles of teaching to contradict the learning styles of most engineering students, who are generally active, sensory, visual, and sequential learners [1]. As a result, the awareness in the engineering community has risen in recent years and a number of techniques have been introduced to help instructors tailor their courses to incorporate most, if not all learning styles of the students.

Within the past decade, a push for learner-centered teaching environments [2] has become more and more prevalent throughout all of academia. Learner-centered teaching approaches encourage instructors to relent some control of their respective courses, allowing students the opportunity to be more interactive during class. It can be intimidating to both young and experienced instructors, who likely took those traditional engineering lecture-based courses during their education. In the modern classroom, instructors familiar with some of the newer techniques are now more likely to use a quick, in-class problem, or a three-dimensional figure, or a prop, spend less time on theoretical discussion and more time on application, and attempt to showcase the end goal prior to beginning the step-by-step process of presenting the material. In addition to the subtle changes an instructor can make in class, a number of other options exist taking the learner-centered teaching approach to another level. The most common methods are problem and project-based learning techniques. Both provide more open-ended types of experiences for students, but also require more upfront organization from the instructor. Problem-based learning exercises are generally open-ended, real-world problems worked out in teams where the instructor simply facilitates and monitors progress. Project-based learning exercises are similar, but usually include more than one task that leads to a final product, also worked out in teams [3]. In most cases project-based learning exercises are lengthier and are evaluated by some form of a final report.

In the traditional civil engineering curriculum, undergraduate students take courses with both lecture and laboratory formats. While the lecture courses provide the opportunity for students to absorb new information, the purpose of a laboratory is to expose students to the physical problems associated with a course and reinforce course content. The traditional type of laboratory has well-planned experiments, typically containing step-by-step guides leading the students through each experiment. Generally in groups of four or five, students in-turn conduct the experiment, regurgitate the results, and prepare a laboratory report, arguably fulfilling ABET student outcome (b) “an ability to design and conduct experiments, as well as analyze and interpret data.” It is possible, however, that these “cookie cutter” laboratory experiments, in fact, may not be that effective. The two primary downfalls to the traditional laboratory format are the size of laboratory groups and the amount of information the students are provided during the experiment. Using such large groups can result in students divvying up the responsibilities or worse, some students having little to no contribution at all. Giving students too much information can result in a lack of effort to investigate things on their own, providing a false sense of security that they will always be provided with all the required information. In either case, the primary objective of the laboratory is not being met. Another option, contrary to the traditional laboratory format, is to use *Competition Based Learning* in the course.

Competition Based Learning is essentially project-based learning, still involving teams of students in an open-ended assignment resembling a scaled down version of a problem they may encounter in their career; the added twist is accounting for the performance of the resulting specimen during final project testing with respect to other groups in the course. The hope is to generate motivation in the students to have the best overall project and eliminate the tendency of just doing enough to get by. This paper highlights the use of a project similar to the American Concrete Institute (ACI) Egg Protection Device (EPD) Competition in lieu of a traditional laboratory format in a Reinforced Concrete Design course. The project includes design, analysis, and laboratory components and eliminates the two primary downfalls of a traditional laboratory course by using teams of two students and minimizing the amount of information given on the front end. Like most design courses, ABET student outcomes (c) and (e) are addressed. On the contrary, unlike most design courses, this format also encompasses ABET student outcomes (b), (g), (i), and (k). Descriptions of all outcomes are listed later in Table 4. At the beginning of each semester, students enrolled in the Reinforced Concrete Design course were asked to take a learning styles survey, and following the completion of the project a post survey was given to students from the two courses that have done the project. A brief summary of the learning styles results are presented with some quantitative data for justification, while the results of the post survey provide some qualitative data on the effectiveness of the project.

Review of Existing Literature

The methods used in the presentation of material in an engineering course and the general organization of assignments and projects can be critical to a student's ability to absorb and retain the information. In addition to the presentation and organization of a course, a number of additional factors can also be attributed to a student's ability to learn. For example, the teaching style of most university professors contradicts the typical learning styles of most students in a wide range of disciplines. And in regard to curriculum, the vast majority of university systems across the United States have managed to squeeze more and more theoretical information into engineering curricula, while limiting the contact of undergraduate students with physical, hands-on projects, through laboratories and design projects.

In 1988, a paper was published by Richard Felder and Linda Silverman entitled *Learning and Teaching Styles in Engineering Education* which has become one of the most referenced documents in the field of Engineering Education [1]. In that paper, Felder and Silverman describe the discrepancies that exist between the teaching styles of most instructors and the learning styles of most students within the various fields of engineering at the college level. They state that most college courses are taught using passive, abstract, verbal, and sequential styles of teaching.

On the contrary the preferred learning style for most students is active, sensory, visual, and sequential. Other than the latter, each teaching style contradicts the learning style of the vast majority. And after nearly 25 years, contrary to what should be, the majority of courses in programs across the country are still being taught with the traditional approach despite the continual accumulation of data regarding students' preferred learning styles.

While learning styles are important, they are not the sole basis for how an instructor should prepare a course and there are appropriate uses for data gathered on learning styles. Felder and Spurlin [4] discuss the applications, reliability, and validity of the *Index of Learning Styles* questionnaire [5]. They begin by stating that when the contradiction is present, most students become bored and inattentive in class, which will likely lead to poor academic performance [1] [6]. They quickly point out that the intention is not to modify instructional techniques to fit individual students but rather use a balanced approach encompassing the whole. A number of studies [7] [8] [9] [10] [11] [12] [13] [14] [15] are cited and summarized by Felder and Spurlin, which consistently show most engineering students to have predominately active, sensory, visual, and sequential learning styles. They do note that researchers would do well to only examine students with moderate or strong preferences, as students with mild preferences would likely be able to adapt between categories fairly easily.

In traditional engineering courses, the style of material presentation is, for the most part, classified as deductive. Instructors begin with theory and derive equations and eventually explain the application of said theory and equation, often towards the end of a lecture or during the next class. Students leave the class likely more confused than when they walked in, seeing very little application. Conversely, an alternative is to use an inductive approach presenting existing data, a case study, or a quick problem to solve that could potentially lead to summarizing a general theory. Prince and Felder [3] summarize a number of these inductive methods available for use by instructors, including inquiry learning, problem-based learning, project-based learning, case-based teaching, discovery learning, and just-in-time teaching, all of which are considered to be active learning activities and learner-centered [2]. The inductive methods Prince and Felder mention are not meant to replace the traditional lecture format as a whole, but for instructors to simply relent some control of their course, still guiding, encouraging, and making clarifications on problems and projects. Additionally, motivation can be key to a successful format. Bransford et al. [16] state, "Motivation to learn affects the amount of time students are willing to devote to learning…" Motivation of the students to learn can easily be accomplished through *Competition Based Learning*.

To anyone with any knowledge of the field of engineering education, active learning would seem to be a logical form of instruction. To most instructors it can be incredibly intimidating and quite a challenge. And in some cases, active learning is viewed with a skeptical perception by more experienced faculty that have "always taught this way." Active learning is defined as an instructional method that engages students in the learning process, using meaningful learning activities that require a deeper thought process [17]. The primary objectives of active learning are to promote student activity and to engage them in the learning process [18]. The most extreme version of active learning, also an inductive method as previously mentioned, is project-based learning, which provides an open-ended project with a variety of problems to solve over the course of an extended period of time. One advantage of project-based learning is it teaches students to make adjustments when uncertainties arise. Another advantage is the introduction of students to the concept of life-long learning, which falls under the ABET Student Outcomes.

In 2004, a paper by Prince [18] reviewed the research regarding active learning and its effectiveness. Prince cites various studies showing positive results from in-class activities. Di Vesta and Smith [19] noted that test scores were significantly higher when three two-minute breaks were introduced in a class, compared to test scores when no pause was introduced in class. Wankat [20] mentions that the attention span of students in a lecture is roughly 15 minutes, which is likely attributed to the results by Di Vesta and Smith. Studies by Hake [21], Redish et al. [22], and Laws et al. [23] also support the effectiveness of active engagement. On a larger scale, such as problem and project-based learning, the effectiveness is much more difficult to measure. Vernon and Blake [24] and Albanese and Mitchell [25] found that students and faculty prefer problem-based learning while Norman and Schmidt [26] note, "Problem-based learning does provide a more challenging, motivating and enjoyable approach to education." Although it is difficult to measure, Prince also notes that evidence exists that the use of problem-based learning activities improves the long-term retention of knowledge [27] [28] [29] and promotes better study habits [24] [25] [29] [30].

In summary, research has shown countless discrepancies between how college courses are taught in comparison to the preferred learning styles of most students. Numerous active learning techniques have been presented over the years aiding in the development of learner-centered teaching environments through in-class activities and problem and project-based learning activities. However, the vast majority of engineering courses taught across the country still fail to utilize these available resources, likely as a result of intimidation or skepticism. Beyond the classroom, there do exist a number of extracurricular projects and competitions available to students, but few students take advantage of those opportunities and in most cases there is no direct link between those projects and competitions with the classroom. Thus, there is a need for the development and dissemination of projects shown to be successful and easily implemented in a standard engineering course.

Learning Styles and Academic Performance

Over the course of the past six years, the *Index of Learning Styles* questionnaire [5] was given seven times to 181 students at Virginia Tech and the University of Louisiana at Lafayette (UL Lafayette). The survey results were used to determine the learning profiles of students enrolled in the Reinforced Concrete Design course taught by the author. Students scoring -5 to -11 or +5 to +11 in each dimension were considered to be moderate-strong based on the recommendations of Felder and Spurlin [4], while students scoring -3 to +3 were considered to be mild and could easily shift or adapt to either learning style. The results of the questionnaire are shown in Table 1 along with a visual representation in Figure 1. Consistent with previous studies [7] [8] [9] [10] [11] [12] [13] [14] [15], the students surveyed had predominately Active, Sensory, Visual, and Sequential learning styles. The Active-Reflective dimension showed that about half of the students were mild and could adapt either way, but 40 percent had a moderate-strong active learning style with only 13 percent having a moderate-strong preference for reflective learning. The Sensory-Intuitive dimension showed a stronger preference for the Sensory learning style with 58 percent, but only 5 percent leaned towards the Intuitive learning style. The Visual-Verbal dimension showed a very definitive trend with nearly three-fourths of the students surveyed having a moderate-strong visual learning style, while almost none leaned toward the moderate-strong verbal learning style. Lastly, the Sequential-Global dimension was shown to be more wide-spread across the population. Over half the students surveyed were mild, but still more leaned toward the sequential side than the global.

Table 1. Learning Styles Results

	Active-Reflective			Sensory-Intuitive			Visual-Verbal			Sequential-Global			
Sample	Mod-Str Active	Mild	Mod-Str Ref	Mod-Str Sensory	Mild	Mod-Str Intuitive	Mod-Str Visual	Mild	Mod-Str Verbal	Mod-Str Seq	Mild	Mod-Str Global	N
Fall 2007^{VT}	31%	54%	15%	46%	50%	4%	85%	12%	4%	65%	31%	4%	26
Spring 2008^{VT}	42%	48%	10%	58%	39%	3%	68%	26%	6%	19%	61%	19%	31
Fall 2008^{VT}	39%	44%	17%	59%	37%	4%	72%	26%	2%	37%	52%	11%	54
Spring 2009^{VT}	27%	67%	7%	47%	47%	7%	67%	33%	0%	40%	47%	13%	15
Fall 2010^{UL}	48%	48%	5%	71%	24%	5%	67%	33%	0%	19%	71%	10%	21
Fall 2011^{UL}	53%	29%	18%	59%	29%	12%	65%	35%	0%	24%	76%	0%	17
Fall 2012^{UL}	41%	47%	12%	65%	29%	6%	76%	24%	0%	24%	65%	12%	17
Total	40%	48%	13%	58%	37%	5%	72%	26%	2%	34%	56%	10%	181
Std. Dev.	9%	11%	5%	9%	10%	3%	7%	8%	3%	17%	16%	6%	

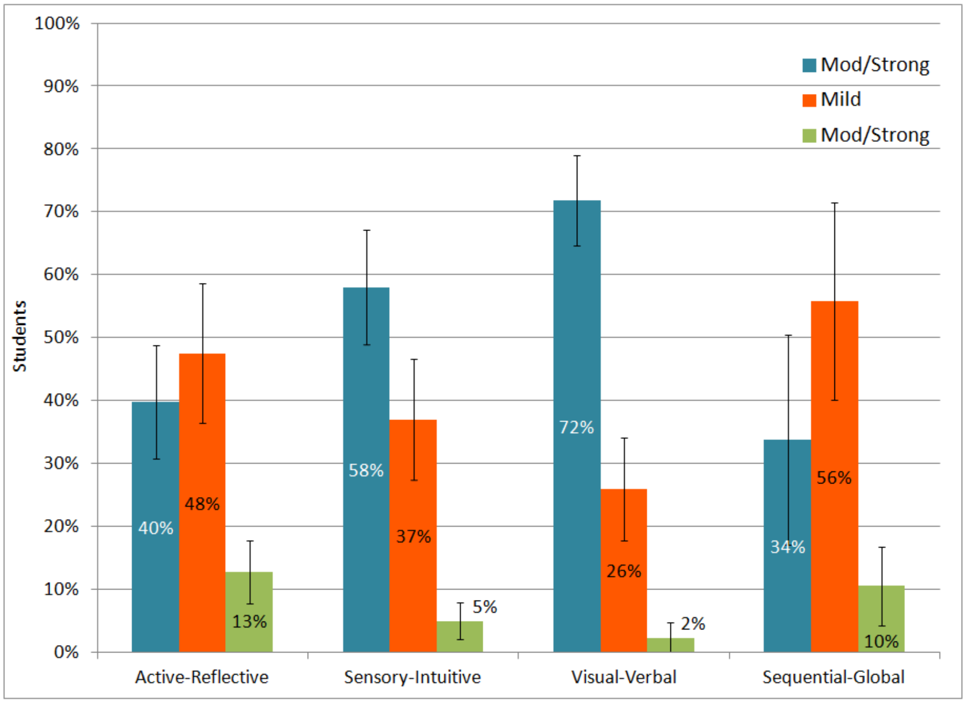


Figure 1. Learning Styles Results

The GPA's of the students at UL Lafayette were evaluated with respect to the magnitude of each student's score on the *Index of Learning Styles* Questionnaire [5]. As recommended by Felder and Spurlin [4], the results were analyzed based on the Moderate-Strong and Mild ranges for each dimension as previously discussed. Five versions of each student's GPA were evaluated as shown in Table 2. The first, "total", is the total GPA including all core civil engineering courses, including Statics, Dynamics, Mechanics of Materials, Fluid Mechanics, Environmental Engineering, Structural Analysis, Geotechnical, Environmental Engineering II, Steel Design, Reinforced Concrete Design, Hydrology, Hydraulics, Transportation, Foundations, Highway Design, and Construction. The second, "lecture", is the GPA only including the aforementioned courses that do not contain a laboratory section, while the third, "laboratory", is the GPA including the aforementioned courses that do contain a laboratory section. The fourth, adjusted, is the total GPA for the students for all courses taken at UL Lafayette, adjusted for any retakes and lastly, CIVE 427, is the equivalent GPA as a result of linear interpolation of the students' final average in the Reinforced Concrete Design course. It is interesting to note the different averages in GPA's with respect to learning style preference.

With respect to the Active-Reflective dimension, students with a moderate-strong preference for an active learning style had an average GPA about two-tenths less than students with a moderate-strong preference for a reflective learning style. For the Sensory-Intuitive dimension, the students with a mild preference had much better GPA's, while the only time students with a moderate-strong preference for a sensory learning style had a higher average GPA than those with a moderate-strong preference for an intuitive learning style was in the Reinforced Concrete Design course. This is not surprising, as that course is taught with much practicality in mind. The Visual-Verbal dimension was, for the most part, inconclusive with regard to a student's GPA being dependent on learning style preference, although at UL Lafayette, there have been no students with a preference for a moderate-strong verbal learning style. Lastly, and maybe with the most notable differences, students with a preference for a moderate-strong global learning style had an average GPA four-tenths lower than students having a preference for a moderate-strong sequential learning style in their engineering classes, except the Reinforced Concrete Design course, where the difference was over one full point.

Table 2. Average Student GPAs

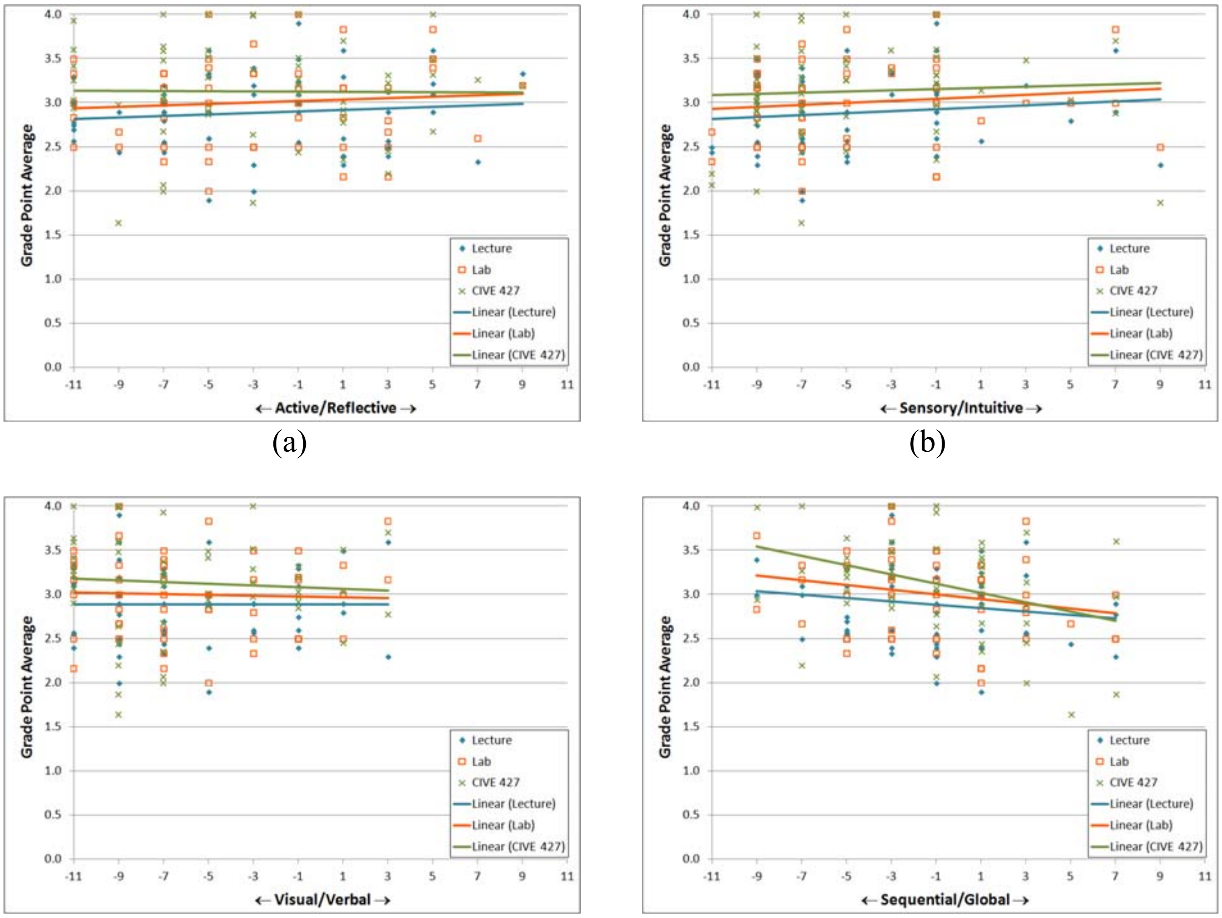
	Active-Reflective			Sensory-Intuitive			Visual-Verbal			Sequential-Global		
GPA Type	Mod-Str Active	Mild	Mod-Str Ref	Mod-Str Sensory	Mild	Mod-Str Intuitive	Mod-Str Visual	Mild	Mod-Str Verbal	Mod-Str Seq	Mild	Mod-Str Global
Total	2.84	2.89	3.02	2.79	3.03	2.85	2.92	2.97	NA	3.00	2.96	2.60
Lecture	2.81	2.86	2.96	2.74	3.01	2.78	2.87	2.93	NA	2.95	2.92	2.55
Laboratory	2.89	2.95	3.12	2.87	3.07	2.97	3.00	3.05	NA	3.08	3.03	2.67
Adjusted	2.92	2.92	3.15	2.87	3.08	2.87	2.96	2.99	NA	3.04	3.00	2.83
CIVE 427	3.00	3.06	3.28	2.90	3.35	2.73	3.12	3.17	NA	3.29	3.11	2.23

In addition to evaluating the average GPA's with respect to learning style dimension the correlation coefficient, sometimes referred to as the Pearson Product Moment Correlation Coefficient (PCC), was also calculated for each GPA type with respect to learning style dimension. Correlation coefficients are used to describe how closely two sets of data are to having a linear relationship, with values ranging between -1 and 1. A value of 1 indicates a strong positive linear relationship, while a value of -1 indicates a strong negative linear relationship. On the other hand, values approaching zero indicate a poor correlation to a linear relationship. The values from the data presented herein, are shown in Table 3. Each learning style dimension, excluding the Visual-Verbal dimension, was shown to have a somewhat linear relationship based on the PCC values. It was interesting to note the differences of the PCC values for the CIVE 427 grades compared to all other GPA's. Although the linear trend does appear to disappear for the Active-Reflective and Sensory-Intuitive dimensions with regard to the CIVE 427 course, it should be noted when examined the data did appear to favor those with active and sensory preferences. The most interesting observation was the significant change in the Sequential-Global PCC value for the CIVE 427 course compared to all others. In retrospect, it is not surprising with the structure of the course. Unfortunately, the structure of the course appears to be a significant disadvantage to those students with a global learning style and warrants further investigation. More effort on the front end will likely be made in the future to address this issue, with more focus on the end result.

Table 3. Correlation Coefficients

GPA Type	Act/Ref	Sen/Int	Vis/Ver	Seq/Glo
Total	0.101	0.124	-0.018	-0.195
Lecture	0.101	0.122	-0.001	-0.173
Laboratory	0.088	0.112	-0.039	-0.211
Adjusted	0.120	0.105	-0.008	-0.143
CIVE 427	-0.010	0.056	-0.066	-0.348

Complementary to the calculated correlation coefficients, three GPA's (Lecture, Laboratory, CIVE 427) of each student were plotted against the score for each dimension of the *Index of Learning Styles* Questionnaire [5], shown in Figures 2 (a), (b), (c), and (d), respectively. Figures 2 (a) and (b) show a slight positive linear trend for the Lecture and Laboratory GPA's with respect to score, which indicates students with reflective and intuitive learning style preferences tend to perform better. On the contrary, Figure 2 (c) shows a relatively level linear trend, while Figure 2 (d) shows a strong negative linear trend. These trends can be linked to aforementioned correlation coefficients. As a result of the teaching methods used in the Reinforced Concrete Design Course, the students with historically less favorable learning style preferences appear to be improving. Figures 2 (a), (b), and (c) all show improvement by those with active, sensory, and visual learning style preferences. Unfortunately, the organization of the course may not be as helpful to those with a global learning style preference, but those with a sequential learning style preference show a significant improvement. The data shown regarding student performance with respect to learning style preferences is presented herein to illustrate the need for alternative teaching styles contrary to the traditional approach. While a thorough evaluation of student performance with regard to learning style dimensions is beyond the scope of this paper, the differences presented are noteworthy and highlight the effects of using alternative teaching styles.



(a) (b)

(c) (d)

Figure 2. Grade Point Average versus Learning Styles

ABET Outcomes

Throughout the country, engineering programs are evaluated by the Accreditation Board for Engineering and Technology (ABET) every six years based on a number of factors, one of which is successfully meeting a list of 11 student outcomes (a) through (k), also acknowledged in the ASCE Body of Knowledge (BOK) from 1 to 11. In order to verify successful completion of each outcome a program is required to verify how and to what capacity each outcome is being met. This is generally done through individual courses using course evaluations, student surveys, and copies of students' exams and other pertinent projects. While some of the ABET Student Outcomes are easily covered others are not. For example, most design courses cover ABET outcomes (c) and (e), and if they are taught in the traditional three 50-minute lecture format, it is likely a stretch that other outcomes are also being addressed. The lecture portion of the Reinforced Concrete Design course at UL Lafayette has traditionally covered ABET outcomes (c) and (e), but through the addition of the EPD project, four additional outcomes are also being addressed, (b), (g), (i), and (k). Table 4 lists the ABET Student Outcomes as worded in the ASCE BOK with those covered through the CIVE 427 course shaded in, which are later evaluated.

Table 4. ABET Outcomes

Outcome	Description
(a)	Graduates can solve problems in mathematics through differential equations, calculus-based physics, chemistry, and one additional area of science.
(b)	Graduates can design a civil engineering experiment to meet a need; conduct the experiment, and analyze and interpret the resulting data.
(c)	Graduates can design a complex system or process to meet desired needs, within realistic constraints such as economic, environmental, social, political, ethical, health, and safety, manufacturability, and sustainability.
(d)	Graduates can function effectively as a member of a multi-disciplinary team.
(e)	Graduates can solve well-defined engineering problems in four technical areas appropriate to civil engineering.
(f)	Graduates can analyze a complex situation involving multiple conflicting professional and ethical interests, to determine an appropriate course of action.
(g)	Graduates can organize and deliver effective verbal, written, and graphical communications.
(h)	Drawing upon a broad education, graduates can determine the global, economic, environmental, and societal impacts of a specific, relatively constrained engineering solution.
(i)	Graduates can demonstrate the ability to learn on their own, without the aid of formal instruction.
(j)	Graduates can incorporate specific contemporary issues into the identification, formulation, and solution of a specific engineering problem.
(k)	Graduates can apply relevant techniques, skills, and modern engineering tools to solve a simple problem.

Many design courses claim to cover ABET Student Outcomes (c) and (e) (BOK Outcomes 3 and 5). Depending on the course, how well are students prepared to design a "system," in the case of reinforced concrete, a structural system? While it is likely students who have completed a reinforced concrete design course can design a beam and a column, it is not guaranteed they would be able to design a full structural system with the basic concepts covered in a typical undergraduate reinforced concrete course. Thus, there is a need for a more holistic activity that ties together all the concepts presented throughout the course.

Project Overview

In a traditional laboratory, a series of well-structured experiments are pre-planned prior to the start of the semester covering specific topics in more depth at the instructor's discretion. These experiments typically contain step-by-step guides leading the students through each experiment. Students are either assigned to groups or allowed to choose their own, generally resulting in groups of four or five in engineering laboratories. The first primary downfall to this format is the size of the laboratory groups, which can influence student responsibilities. The second primary downfall is the amount of information the students are provided with during the experiment, which can provide a false sense of security to always be provided with all the required information. Additionally, many labs are just assumed to be active learning activities as well as problem/project-based learning activities, and while most laboratories may classify as an active learning activity, large laboratory groups and too much structure coupled with excessive given information can essentially eliminate the problem/project-based learning atmosphere.

In the traditional curriculum, the first exposure to a true open-ended project for most students is the capstone, senior design project, which to a student can be immensely overwhelming. At UL Lafayette an exit interview is given to each graduating senior. Included in the exit interview are opportunities for students to comment on program weaknesses and make general comments for improvements. Multiple times, students have made comments such as "limited open-ended projects before the senior design course", "not well prepared for open-ended senior design project", and "need introduction to small projects in all civil courses…" The purpose of this project is to provide the students with a project-based experience, addressing the issues previously mentioned, while still meeting the traditional laboratory needs. The objectives of the project are listed as follows:

1. Become familiar with concrete mix design.
2. Design a reinforced concrete frame.
3. Fabricate a reinforced concrete frame.
4. Perform a structural analysis of a reinforced concrete frame.
5. Perform standard tests on fresh concrete.
6. Monitor the strength gain of concrete over time.
7. Learn the influence of impact loads on material behavior.
8. Prepare a professional project report.

The American Concrete Institute (ACI) sponsors a variety of student competitions at each of its biannual conventions. One of those competitions is the Egg Protection Device (EPD), which requires student teams to design and fabricate a small reinforced concrete frame. The frame is tested by dropping a small mass from various heights until ultimate failure. The project used in the Reinforced Concrete Design course is similar to the ACI EPD Competition and requires each team to cast two identical concrete frames. Each group is responsible for the design of the concrete mix, determining the shape of the structure, mixing and casting the concrete, and completing standard fresh and hardened concrete tests. One frame is tested under static load, while the second frame is tested under impact load.

Each group is given a copy of ACI 211.1-91 – Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete [31] and ACI 211.2-98 – Standard Practice for Selecting Proportions for Structural Lightweight Concrete [32] and are expected to complete a full mix design, which is due one week prior to specimen casting. The concrete mix may only consist of the four primary constituents: Type I/II Portland cement, coarse aggregate, fine aggregate, and water. The coarse aggregate may be limestone or river rock, but should be no larger than ⅜ in. Lightweight aggregate may be used but it must be considered a sand lightweight aggregate. The students are provided with absorption values for each aggregate available for use, but are expected to make any necessary adjustments to water proportions accounting for moisture content and absorptions.

The shape of the structure is limited to a given envelope as shown in Figure 3. The thickness of the structure (into the page) is limited to 2 in. and must be 2 in. at the top, 1 in. to the left and right of the centerline (4 in.^{2} impact area). In addition to the dimension limitations, the maximum weight of the structure is limited to 9 lbs. The reinforcement used in the project is limited to 0.06 in. diameter (approximately 16 gauge) like the ACI competition for use as both longitudinal "bars" and stirrups. Limits of 15 and 8 each are placed on the longitudinal bars and stirrups, respectively. Soldering and welding are not permitted, but the reinforcement may be constructed using small gauge tie wire or glue. Contrary to the ACI competition, the students are also allowed to use macro and/or micro fibers in addition to the standard reinforcement. A representative reinforcement cage is shown in Figure 4 (a).

Subsequent to successful mix design, design of the structure, and fabrication of the reinforcement cage, each team met with the instructor during a scheduled period of time to mix and cast the structures. The formwork for the structures was made from 2 in. thick blue board insulation with the shape of the structure cut out via jigsaw. The students were then guided by the instructor during the mixing process and during the fresh concrete tests, which included slump, unit weight, and cylinder casting. During this time, the students also cast their two structures, with the concrete typically placed in two layers and the reinforcement cage pushed in place in between the placement of each layer. The forms were tapped with rubber mallets to ensure consolidation and were covered with wet burlap and left to cure. Shown in Figure 4 (b) are two students performing a slump test, while Figure 4 (c) shows the first layer of concrete placed in the formwork along with the reinforcement cage.

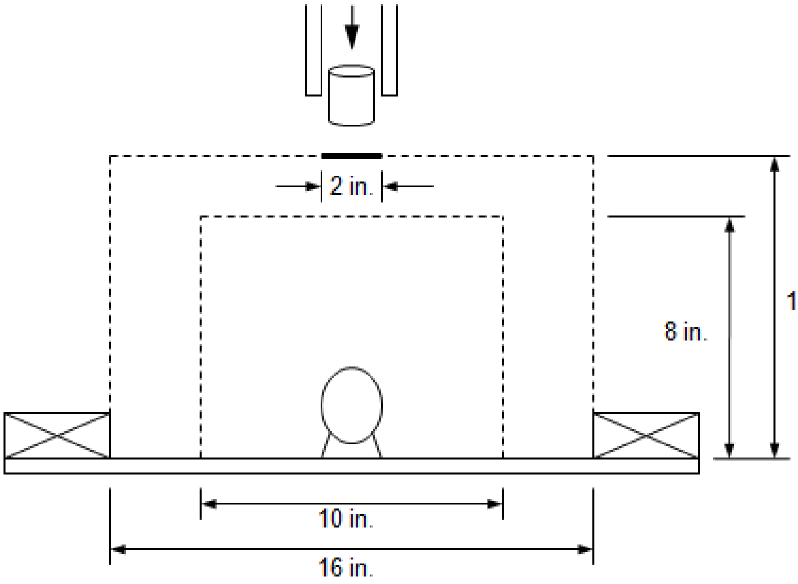
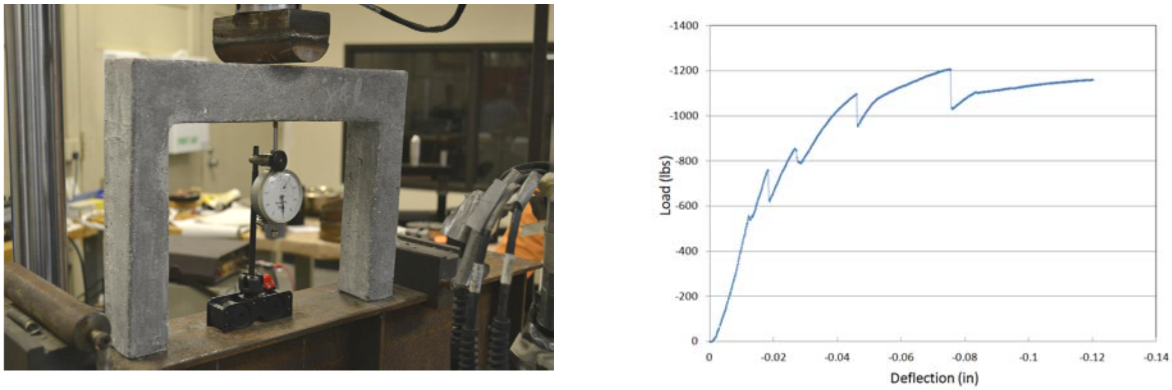


Figure 3. Project Envelope


(a) (b) (c)

Figure 4. Casting Process

Over the course of the 28 days following casting, each team was responsible for monitoring the strength gain of the concrete, breaking cylinders on days 1, 4, 7, 14, 21, and 28, along with split cylinder tensile tests on day 28. Subsequent to the determination of compressive and tensile strengths on day 28, a static test was performed on one of the two structures. However, prior to static testing, each team was required to calculate the estimated cracking load and vertical deflection at cracking using virtual work. One structure for each team was tested using an MTS universal testing machine, during which the load and displacement was continuously monitored. Figure 5 (a) shows the test setup used for each of the static tests. A dial gauge was used to measure the deflection up to cracking, but was then removed during the application of the loading beyond cracking up to failure. Figure 5 (b) shows a typical load vs. displacement curve for a static test, which was used after the test to visually describe to each group the progression of cracks during load application as well as the redistribution of stresses as a result of the mechanical bond between the concrete and reinforcement. Additionally, Figure 6 shows the failure progression of one EPD during static testing.



(a) (b)

Figure 5. Static Testing

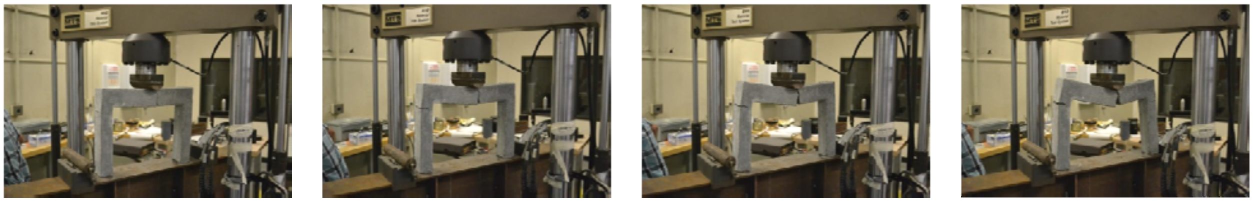

(a) (b) (c) (d)

Figure 6. Failure Progression

Following the completion of all static tests, the impact tests were conducted successively in conjunction with an ASCE/ACI student chapter meeting at the end of the fall semester. Each EPD was placed in the impact test apparatus as shown in Figure 7 (a) and subjected to a falling mass (approximately 10 lbs) at increasing heights of 1.5 ft, 3 ft, 4.5 ft, and up to five times from the maximum height of 6 ft. The winning EPD was determined based on most impacts from the highest point. In the event of a tie, the EPD's were ranked based on the most efficient structure (i.e. lightest structure). Figure 7 (b) shows an EPD just after impact, surviving, while the next hit resulted in complete failure. Following the completion of the impact competition, each team submitted a full report based on specific guidelines, worth 70 percent of the project grade. The remaining portion of the grade was based on the mix design (5%), virtual work calculation (10%), virtual work efficiency (5%), and impact load class rank (10%).


(a) **(b)**

Figure 7. Impact Testing

Results

In addition to the final project report, students from each class that participated in the EPD project were asked to complete a ten question survey at the conclusion of the semester. The survey was broken into two sections, the first of which was focused on ABET Applicability and included the five questions shown below. Similar to surveys seeking students' opinion to evaluate the successful coverage of course objectives, the students were given five potential selections: (1) not at all, (2) not very well, (3) in part, (4) mostly, and (5) completely. Based on previous experience with such evaluations by the author, any objective or outcome with at least 85 percent of responses indicating (4) mostly and (5) completely were considered to be successfully covered. Questions (2), (3), and (5) had at least 90 percent of responses indicating mostly or completely, while questions (1) and (4) both had 87 percent of responses indicating mostly or completely. Table 5 shows the results in their entirety for the questions pertaining to ABET Applicability.

1. How comfortable would you be selecting a series of fresh and hardened concrete tests (i.e. slump, unit weight, compressive strength, tensile strength), conducting the tests, then analyzing the data? (ABET Outcome b)
2. How well do you feel the EPD project introduced the design process of a complex system to meet a desired need with a variety of constraints? (ABET Outcome c)

3. How well do you feel the EPD Report Guidelines helped you to organize and deliver effective verbal, written, and graphical communication? (ABET Outcome g)
4. How well do you feel the EPD project helped you to develop the ability to research and learn on your own, without the aid of formal instruction? (ABET Outcome i)
5. Were you able to apply relevant techniques and skills from the Reinforced Concrete course and other courses you have previously taken? (ABET Outcome k)

Table 5. ABET Applicability

	Q1	Q2	Q3	Q4	Q5
(1) not at all	0%	0%	0%	0%	0%
(2) not very well	0%	0%	0%	0%	0%
(3) in part	13%	0%	10%	13%	10%
(4) mostly	53%	60%	33%	43%	57%
(5) completely	33%	40%	57%	43%	33%

The second section of the survey was focused on Project Effectiveness and included an additional five questions as shown below. As before, the students were given five potential selections: (1) not at all, (2) not very well, (3) in part, (4) mostly, and (5) completely for the first three questions. The fourth question was seeking a response based on a comparison to other laboratory courses taken in civil engineering, given five different potential selections: (1) much less, (2) less, (3) about the same, (4) more, and (5) much more, while the fifth question was simply looking for the "entertainment value" of the project. Eighty-six percent of the students felt the EPD project reinforced the concepts taught in the lecture portion of the course and 80 percent felt the EPD project also reinforced concepts taught in previous structural engineering courses, namely Structural Analysis. It was not expected that all students would feel an open-ended project would help them better learn and retain the material, but 83 percent felt that it did, which the author believes is a result of the required "self-learning" involved with the project. Complementarily, 73 percent felt they learned the material better in this format in comparison to other laboratories having a traditional format. Table 6 shows the results in their entirety for the questions pertaining to Project Effectiveness. Lastly, 94 percent of the students felt the project was engaging based on ratings of 8 and higher as shown in Figure 8.

1. How well did this project reinforce the concepts taught in the Reinforced Concrete course?
2. How well did this project reinforce the concepts taught in previous structural engineering courses you have taken?
3. This project was set-up completely different than other laboratories in the curriculum. How effective do you feel this type of laboratory (open-ended projects) was in helping you to learn and retain the material?
4. In comparison to other laboratories you have taken (i.e. Geotechnical, Hydraulics, Environmental, Highways), how well do you feel you learned the material through this laboratory?
5. On a scale of 1 to 10 (10 being very and 1 being not at all), how engaging (i.e. interactive, entertaining, etc.) do you feel this project was?

Table 6. Project Effectiveness

	Q1	Q2	Q3	Q4*
(1) not at all	0%	0%	3%	3%
(2) not very well	0%	0%	7%	3%
(3) in part	13%	20%	7%	20%
(4) mostly	53%	57%	33%	33%
(5) completely	33%	23%	50%	40%

*(1) much less, (2) less, (3) about the same, (4) more, (5) much more

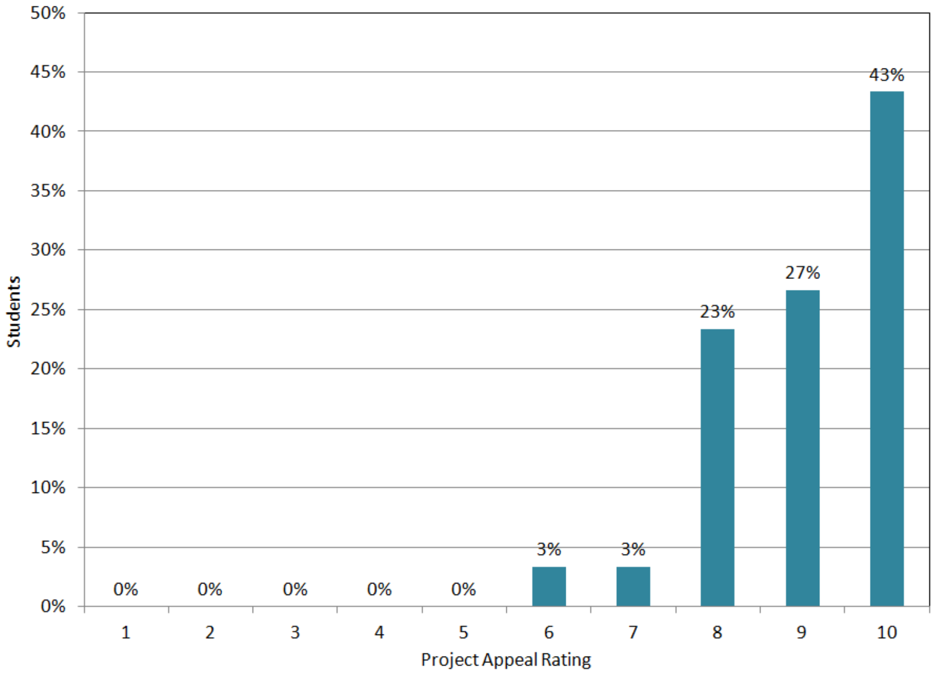


Figure 8. Project Appeal

In addition to the ten multiple choice survey questions, the students were also given an opportunity to comment on other aspects of the project whether it be positive or negative, two of which are listed below. The first comment was made in regard to the students' ability to calculate the cracking load using virtual work. While the student surveys did indicate they were able to apply relevant techniques and skills from other courses they had previously taken and that this project reinforced those concepts, the actual calculations of the cracking load did not reflect that success. Through those calculations, it became evident that, although they may have mastered the individual concepts, they struggle when it involves multiple concepts used in succession. This observation is similar to the same problems students incur during their capstone, senior design project, and again reinforces the need for more open-ended projects, just as graduating seniors have noted on their exit interviews at UL Lafayette. On the other hand, the second comment highlights the students' desire to not be "spoon fed." This particular student has been very observant in regard to "excessive information" given on the front end of a project and feels the effectiveness of the labs is hindered as a result. Additionally, the student mentions "bragging rights" and the motivation to do well, which aligns with the previous quote by Bransford et al. [16].

> "The concept of how to determine cracking load should be an entire class lecture. No one knew how to do it. Some people just got lucky."

> "The effectiveness of many labs is often hindered by the professor's 'hints, advice, or knowledge of the outcome'. It is just as important that students get a chance to get things wrong and learn from their mistakes as it is for them to learn from strict direction of what to do and what not to do. The professor directing the EPD was adamant about enforcing this philosophy of learning and I think this encouraged the students to try to do well. Also, this lab was the only one in which students competed against each other. Most of the students enjoyed having something else to motivate them (bragging rights), other than trying not to get less than a 'C' in the course."

The Reinforced Concrete Design course at UL Lafayette is only offered once every fall semester and to date, the course has been taught by the author four times (fall 2009, 2010, 2011, 2012), the latter two times including the EPD project. It would be beneficial to have more quantitative data using control groups. However, the project implementation is still in its infancy and unfortunately control groups are not available at UL Lafayette. The author does anticipate tailoring the final exam in future semesters to further evaluate student retention of the material based on the EPD project and hopes to compare student performance at UL Lafayette with student performance in a similar course taught with the traditional approach at a peer institution. Furthermore, the passage rates of students on the Structural Design section of the FE Exam were also evaluated in comparison to the national average and other peer Carnegie II institutions dating back to the fall semester of 2006 and are shown in Figure 9, but are likely inconclusive regarding the EPD project. The first offering applicable for evaluation based on the teaching styles discussed herein is the spring 2010 semester. The results do show an improvement in student performance in regard to the Structural Design section. However, a large percentage of the students that have completed the EPD project, have yet to take the FE Exam. The overall improvement is likely a result of the teaching styles used in the course as a whole, rather than just the EPD project, which is beyond the scope of this paper.

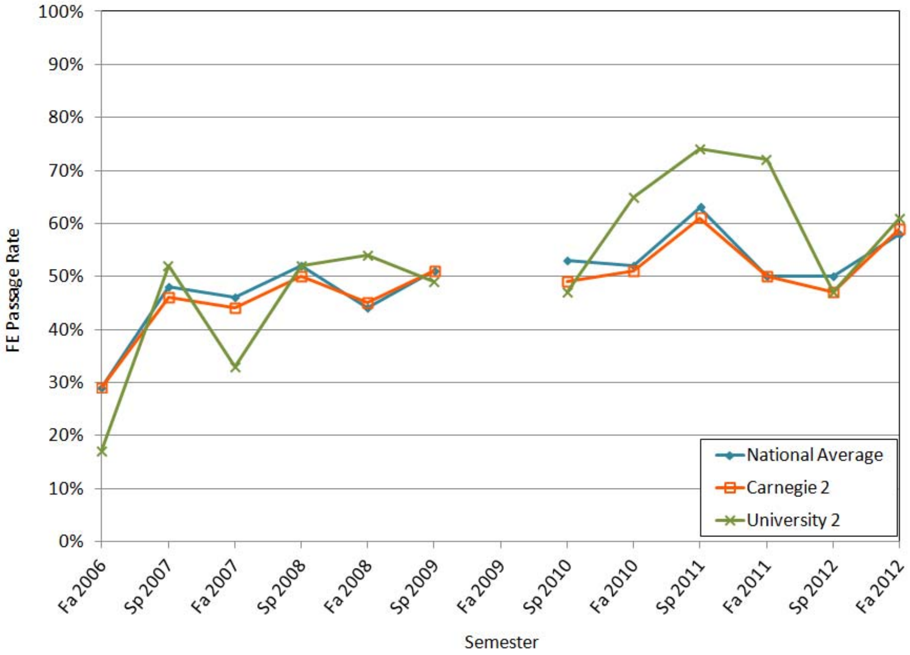


Figure 9. FE Passage Rates

Conclusions

Over the course of the past six years a compilation of learning styles data has been gathered at both Virginia Tech and UL Lafayette, providing consistent results in comparison to previous studies. Differences in student GPA's have been observed with respect to learning style preferences and while more analysis is needed in regard to those relationships, the data does verify the need for alternative learning activities within standard engineering courses. A review of the existing literature further verifies that need and provides some insight to the level of success that is attainable. In an effort to continually better the Reinforced Concrete Design course beyond the smaller learning activities, the author incorporated a modified version of the ACI EPD Competition into the course at UL Lafayette. Contrary to the larger extracurricular projects such as the ASCE/AISC Steel Bridge and ASCE Concrete Canoe, the EPD Competition was easily incorporated into the existing curriculum.

The project was well-structured, but was still open-ended, requiring a substantial amount of self-learning on the part of the students. With the exception of the detailed virtual work calculations, the surveys by the students indicated successful completion of the project objectives as well as meeting the related ABET and ASCE BOK student outcomes, of which the author fully concurs. The students as a whole seemed to thoroughly enjoy the project and would prefer to have more classes with this format. Although this project has been mostly successful throughout its two offerings, its use as an in-class project is in its infancy and needs additional modifications. In the past, student teams have been limited to two members, the author recommends three members per team in the future to (1) reduce the workload on each student and (2) reduce the number of groups per class. Additionally, more structure is needed in regard to calculating the cracking load for comparison during the static tests. While some students do make solid efforts to learn on their own, there have been very few that have successfully mastered the complexity of that calculation, considering the number of unknowns and the support configurations of the EPD. Lastly, having tested individual EPD's under impact load on separate days the first year and holding a competition night at the end of the semester the second year, the author also recommends the competition night type of event, which drastically increased the excitement and anticipation of the entire project.

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