An Alternative Approach for Practical Experience in Undergraduate Engineering Curricula

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***Abstract*— In this paper we present an alternative approach for providing students with practical experiences within the undergraduate curriculum. In contrast to conventional internships and co-op programs, the Field Experience is a full-fledged academic course that combines both in-class and on-site activities taken at the end of junior year. The course starts with 18 hours of in-class lectures and activities intended to prepare the students for on-site work through a combination of technical and non-technical skills. The students then work in engineering design and construction for a minimum duration of 240 hours under the direct supervision of practicing engineers. Specific activities and outcomes of the field component are directly mapped to the course learning outcomes, and are defined prior to commencing the fieldwork. The student's work is continuously monitored by the academic instructor through a journal or daily logs submitted periodically. Multiple assessment tools are used throughout the course, including homework assignments, in-class activities, an oral presentation, a detailed final report, and direct observation by the supervisor. A letter grade is earned at the end of the course, which affects the student's GPA. Compared to conventional internships, this approach has resulted in measurable increase in students' engagement and better attainment of the program-wide learning outcomes.**

Keywords—experiential learning; project-based learning; internship; practical training; field experience.

I. Introduction

The value of experiential learning in engineering education has been always recognized through special projects, field trips, industry seminars, and similar activities within individual courses. Systematic integration of experiential learning within conventional engineering curricula in the USA started to take place in the early 1970s, when the Engineers' Council for Professional Development, currently known as ABET, revised the accreditation criteria to emphasize the role of design and practice in undergraduate engineering studies [1]. Early experiential learning components were introduced at the University of Cincinnati, Harvey Mudd College, Kansas State University, and the University of Massachusetts among others.

In countries where emphasis is placed on science and technology education, compulsory internships are part of the undergraduate engineering curricula, and as mandated by governments or accrediting bodies. For example, the Council of Higher Education in Turkey enacted rules in 2002 to make internships a mandatory element in undergraduate education [2]. Compulsory internships have also been a tradition in many engineering programs at European universities, although not necessarily mandated by accreditation agencies. In Russia, mandatory internships at engineering companies allow students a faster transition into the workplace upon completion of their studies [3], [4]. In India, the All India Council on Technical Education (AICTE) enacted new requirements in 2017 that make it mandatory for engineering students to complete the equivalent of six to eight weeks of internship as part of their degree completion requirements. It is interesting to note that in many cases where internships are mandatory, the class sizes are relatively large. Appropriate monitoring and evaluation of the internship activities becomes a burden on the faculty members. Meaningful assessment on the type of internship, the student's work, and the extent of learning is difficult. In addition, finding suitable placement for large numbers of students is a persisting challenge.

One of the key challenges facing the wide implementation of compulsory internships is ensuring the integrity, quality, and relevance of the activities to the student's education. In addition, because of the challenges surrounding fair assessment of the student's activities, these internships are graded on a Pass/Fail basis. In many instances, the evidence of completion of the internship activities is limited to a certificate of attendance or a letter from the employer confirming that the student has actually reported to work as scheduled. Additional evidence may include an evaluation or a completion survey completed by the internship supervisor, but using such evaluations as a basis for student performance is questionable since they come from different supervisors. Universities are almost always bound to give the student a grade of "Pass", unless there is ample evidence of negligence, or serious issues with performance on the part of the student.

Only a few programs in the USA have implemented compulsory internships in the undergraduate engineering curriculum, although the cooperative education model, adopted by a number of universities, integrates study and work in an alternating fashion over the program duration. Outside the scope of cooperative education, California Polytechnic State University at San Luis Obispo (Cal Poly) and Seton Hall University are among the few universities that require students to complete internships before graduation [5]. The importance of mandatory practical experience as part of certain disciplines, such as construction engineering and management, has also been established and implemented at the individual program levels [6].

In this paper, we present a new model, the Field Experience in Civil Engineering, which is part of a broader compulsory Field Experience adopted at our university across all engineering programs. The word "Field Experience" originated in the domain of Teachers Education. Field Experiences have been an essential component of teacher education and development since the early 1970s [7]. Unlike conventional engineering internships, the Field Experience entails a comprehensive set of activities that are interlinked, measurable, and conducive to proper attainment of learning outcomes. Student placement in a real workplace environment is part of the process, and constitutes what we define as "the internship component" of the Field Experience.

II. Background and Course Structure

The Field Experience across all undergraduate engineering programs at our university has been implemented in the form of a two-credit course for ten years. The course is part of the major core courses, and is incorporated within the curriculum at the end of the junior (third) year of studies. When the idea of implementing a compulsory Field Experience in the undergraduate engineering curricula was conceived, a key aspect was the necessity to issue a letter grade instead of treating it as a Pass/Fail graduation requirement. As such, it was deemed essential to base the letter grade not on qualitative assessment by an external party (internship/field supervisor), but rather on specific learning outcomes that are demonstrated through direct assessment of the student's work.

In terms of workload on the faculty member (course instructor), the students are divided into sections, each capped at 15 students. Because the burden is on the student to demonstrate what they have learned, as opposed to simply providing documentation that they completed an internship, grading and course administration by the course instructor is manageable. The course includes common lectures for all sections that are taught jointly in a large classroom/auditorium, as well as separate classes for each section. The total workload on the faculty member teaching each section is equivalent to that of a three-credit course in a typical semester system.

The course prerequisites include successful completion of key junior year core courses in the discipline. In the case of Civil Engineering, introductory courses in transportation engineering, geotechnical engineering, environmental engineering, and/or reinforced concrete design fulfill the purpose. In addition, students must have completed a communication course, Public Speaking, which is part of the university-wide liberal arts core. Completion of the Field Experience is a prerequisite to registering in the capstone senior design course.

In terms of course structure and administration, we will first introduce the terminology used throughout the paper with respect to various stakeholders. The "*student*" is the main stakeholder and beneficiary, and is responsible for ensuring attainment of the learning outcomes. The "*course instructor*" is a full-time faculty member, responsible for preparing the students academically prior to starting the field activities, assessing the student's work, and issuing the course grade. The Course Instructor also works with each student on defining the field activities, reviews and approves the student placement, and resolves any issues encountered by the student during the field activities. The "*field supervisor*" is a practicing engineer who is responsible for supervising the student on site, assigning engineering-related tasks and activities, and evaluating the performance of the student upon completion of the field activities.

A. Course Components and Outcomes

The course includes three main components: 1) lectures and classroom activities, 2) an internship with an engineering company, and 3) a final report and short presentation. The course learning outcomes are mapped onto ABET Student Outcomes a-k [8].

B. Lectures and Classroom Activities

The course starts with eighteen contact hours of in-class lectures and classroom activities over a duration of two or three weeks. These are intended to prepare students through in-class activities relevant to the workplace. They include lectures, discussions, multimedia presentations, and in-class group exercises. The topics covered include:

1. Business communication and business etiquette
2. Ethics in the workplace
3. Technical writing and documentation
4. Public speaking and oral presentation
5. Effective teamwork and conflict resolution.
6. Project management processes and software
7. Data analysis and information presentation
8. Preparation and interpretation of design drawings

Five homework assignments are given to the students, and are graded in preparation for the internship.

C. Internship

Following completion of the lectures and classroom activities, each student spends a minimum of six weeks full time (240 hours) at an internship with an engineering company or organization. The majority of students end up spending eight weeks spanning over the summer break. A standard-form "*agreement*" is prepared jointly by the student, the course instructor, and the field supervisor prior to commencing the internship activities. The agreement establishes the specific learning objectives and activities, as they pertain to the nature of the workplace (e.g., design vs site work). Normally, students are not expected to receive compensation from the company for the internship, which plays a major advantage in finding suitable placements for all students. However, work for pay is allowed, provided such information is shared with the course instructor.

The agreement includes three components that depend on the nature of the internship. First, the field of sub-specialty within civil engineering is identified (e.g., structural design; transportation planning; construction engineering). Second, specific learning objectives for the student are defined (e.g., acquire skills in design of post-tensioned slabs; gain proficiency in traffic impact assessment; learn about construction methods for pile foundations). Third, relevant field experience activities that support the learning objectives are established (e.g., model post-tensioned slabs using commercial software; perform traffic impact studies for a new development; assist with quality control, monitoring, and testing of pile foundations). Students document their activities in daily logs that are assessed periodically by the Course Instructor.

D. Final Report and Presentation

Students are required to submit a 3000-word report summarizing all activities undertaken during the internship period. The relevance of the activities to the course learning outcomes is an integral part of the report. The report is submitted to the course instructor one week after the internship activities are completed. Students are also required to give a 10-minute presentation, followed by a Q&A session, which is assessed by a panel of faculty members.

III. Assessment

A. Assessment Tools

Multiple assessment tools are used in the course to ensure attainment of the course learning outcomes. These assessment tools are:

<u>Assignments:</u> five homework assignments are given on the following topics: technical writing, teamwork, ethics, project management, and communication through drafting. Each homework assignment is designed with the main objective of addressing at least one learning outcome. For example, case studies involving ethics in a design or construction context are provided. Students are then expected to analyze, critique, and decide a course of action based on relevant fundamental canons and professional obligations described in relevant engineers' codes of ethics. On one hand, this exercise addresses one of the learning outcomes of the course, but more importantly, it prepares the Student to deal with potential ethical conflicts that often arise during the internship. Assignments on the other four topics are also given with the same objectives in mind.

<u>Daily logs:</u> the students are expected to keep a daily log for each activity undertaken during the day. Each student is expected to send the daily log to the course instructor for feedback on a bi-weekly basis, or at 80 work-hour intervals. The course instructor reviews the daily logs and sends the student constructive feedback. The daily log plays an important part of the assessment process because it can easily indicate whether the student is performing meaningful activities. Students who spend most of the time on basic office work, passive learning activities, or non-engineering tasks are easily identified and advised to shift their focus toward active learning type activities.

<u>Final report:</u> one of the most important assessment tools of the course is the final report, which is handed to the course instructor within a week following the last day of the internship. The final report, which includes a narrative and appendices, is the culmination of all work done during the internship. The main body of the report describes the activities and lessons learned, and links them to the course learning outcomes. Evidence and examples of work done such as calculations, tables, reports, memos, email messages, drawings, and photographs taken are included in the appendices. Both the quality and the quantity of the information provided in the final report play an important role in the assessment process.

<u>Final presentation:</u> the final presentation is also a key assessment tool because it complements the final report and provides much more insight regarding the depth and breadth of the work carried out by the student during the internship. In addition to the course instructor, members of the faculty attend the final presentation, ask questions that directly map to the course learning outcomes, and provide their own assessment of the presentation in the form of a survey. The final presentation was, in more than one occasion, a key reason for failing the course because the student was unable to demonstrate substantial work performed by them, especially when asked specific questions. In other cases, the presentation was a key determinant in passing the course for students who performed sufficient engineering tasks, but were lacked the proficiency required to document all their activities in writing.

<u>Field supervisor evaluation:</u> In addition to direct assessment of student work by the course instructor and other faculty members, evaluation of the student's performance during the internship is collected from the field supervisor. The evaluation is designed in such a way to minimize subjectivity on the part of the field supervisor. Specifically, the supervisor is asked to compare our student's performance in relation to interns from other universities. The feedback obtained from the field supervisors in the form of written comments and scores was a catalyst for many changes in the course, as part of the continuous improvement process.

B. Grading Scheme

One of the unique aspects of the Field Experience, in contrast with a regular internship, is that a letter grade is issued. Our hypothesis is that the grading scheme motivates students to do their best throughout the course. The letter grade is based on the A, B, C, D, and F grading system. A grade of "A" corresponds to a score of 90% and above, while "F" corresponds to less than 60%. Grades of "A" through "D" are passing grades, with "D" indicating marginal performance. The details of the grading scheme are shown in Table I.

TABLE I. Course Grade Distribution

Component	Percentage
Assignments	25%
Daily logs	15%
Final report	40%
Final presentation	10%
Supervisor evaluation	10%

The course grade distribution was balanced to ensure that the student puts effort in every component. In other words, submitting the final report only will not earn the student a passing grade of 60%. On the other hand, although the supervisor evaluation is only worth 10% of the course grade, it can be a determinant in passing the course for marginally performing students.

C. Results

Fig. 1 shows the level of attainment of each of ABET Student Outcomes a-k, as assessed by field supervisors. The data shown span over a period of five years, starting with summer 2013. The number of students enrolled from 2013 to 2017 were 11, 22, 33, 24, and 23, respectively.

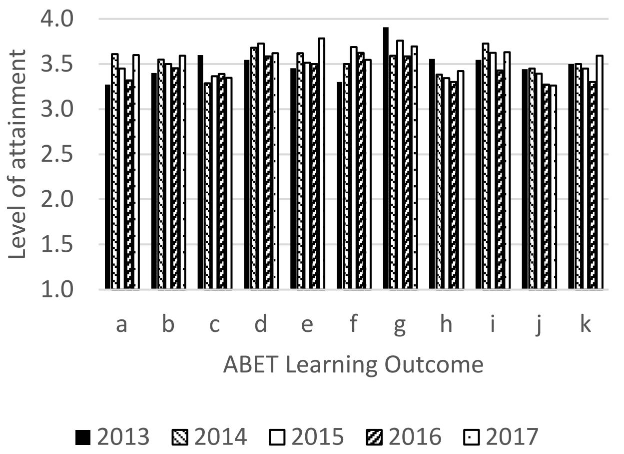

Fig. 1. Level of attainment of ABET learning outcomes assessed by field supervsiors

D. Data Analysis

According to Zeichner [9], Field Experiences are characterized by three key elements that define the scope and extent of learning: 1) structure of the Field Experience program, 2) relevance and characteristics of the workplace, and 3) skills and preparation of the students and other stakeholders to ensure successful completion. These three key elements, which are addressed in our model, have proven to be an essential part of the success of the experiment.

First, the course grading scheme in the form of a letter grade rather then Pass/Fail, and the specificity of the tasks and outcomes spelled out in the agreement, along with their relevance to the course learning outcomes, provide a clear structure for the internship before it starts. In fact, students often voluntarily report any deviations in tasks and outcomes to the course instructor as they occur, in order to ensure that the changes are properly documented, and are not affecting the learning experience in a negative way.

The relevance and characteristics of the workplace are inherently guaranteed, in part because the student plays a role in selecting their placement. Students tend to look for placement based on their technical interests and future employment preferences. For instance, the student's affinity to work with a contractor vs a consultant, or with a construction firm vs an environmental regulator, ensures that the needs and interests of the student are compatible with the workplace.

Preparation of the students through the six in-class sessions also carries an important role in the success of the Field Experience. Assignment of homework and in-class activities that are relevant to what the student will encounter in the workplace ensures a smooth transition, especially for those students who do not have any prior work experience. The requirement that the student be supervised by a practicing engineer in the discipline guarantees a minimum level of rigor in technical work, and ensures quality and integrity of the process.

Field supervisors are briefed by the students and/or the course instructor at the time of signing the agreement. In some cases, direct communication between the course instructor and the field supervisor is necessary before the agreement is signed, in order to ensure goal alignment and to manage expectations. At the end of the internship, the field supervisor rates the performance of our students against other interns they have supervised from other institutions. A score of 1 to 4 is assigned to each of the learning outcomes, according to the rubric shown in Table II. An option of "*unable to judge*" is also given on the form to avoid any bias in cases where questions are irrelevant to the nature of the work done.

TABLE II. FIELD SUPERVISOR EVALUATION RUBRIC

Score	Performance
4	Our student is better prepared than other interns
3	Our student and other interns are equally prepared
2	Our student is weaker than other interns
1	Our student's performance is unacceptable

The average level of attainment for each ABET Student Outcome was calculated for each year, as shown in Fig. 1. Three targets were set as indicators of a satisfactory level of attainment:

1. An average level of achievement of 3.0 provided a minimum benchmark in terms of comparison between our students and interns from other universities;
2. A maximum of 10% of students receiving a score of 2.0 to ensure that our students have the minimum level of preparation and work ethic required; and
3. None of our passing students earning a score of 1.0 on any of the outcomes.

The data in Fig. 1 clearly demonstrates that, across the years, all outcomes were attained with an average score that is well above 3.0. The other two targets related to scores of 2.0 and 1.0 were always met. However, we found that outcomes *c*, *h*, and *j* were systematically scoring lower than other outcomes. Outcome "*c*" relates to design of engineering systems and components within realistic constraints; outcome "*h*" relates to the student's appreciation for the economic and environmental impacts of engineering solutions; and outcome "*j*" relates to the student's knowledge of contemporary issues. This was attributed in part to the large number of students who choose to work on site, which gives them limited opportunity to appreciate design constraints, as well as the economic and environmental impact of engineering solutions. In addition, it is not necessarily expected from a junior year student to be knowledgeable in contemporary issues. However, assessment data for the whole program at the end of the fourth year shows that the Field Experience course had a positive impact on these learning outcomes in specific. Outcome "*g*" which relates to effective communication, shows the highest level of attainment, and is consistent with the emphasis placed at the university level on oral and written communication. Completion of all composition and rhetoric courses, as well as a course in public speaking as a prerequisite to the Field Experience also plays a major role in relation to the level of attainment of outcome "*g*".

IV. Continuous Improvement

Several changes were made to the course over the past ten years, as part of the program's continuous improvement cycle. Some of the changes made were driven by the course instructor observations, while others were the result of feedback from the field supervisors or suggestions by students after finishing the course. A number of key changes that had a positive impact on achieving the course learning outcomes are discussed in the following sections.

<u>Development of the agreement document:</u> although the main content of the agreement has remained unchanged throughout the years, student-specific tasks, objectives, and outcomes were explicitly added to the agreement. Students are now asked to plan for, and document, specific tasks that will help accomplish the learning outcomes during the internship. These tasks are the basis for discussion and detailed documentation in the final report. Description of the tasks must follow Bloom's taxonomy, and must be specific and measurable. Examples include "*to develop a spreadsheet to automate the design of columns*", or "*to compare the progress of work on site to that on the project schedule, and to revise the schedule using Primavera software*".

The tasks must be also mapped to the learning objectives of the internship, which are, in turn, mapped to the course learning outcomes. The agreement is not approved by the course instructor until clear and specific tasks are outlined, taking into consideration that the tasks can be reasonably accomplished within the internship timeframe. Such specificity has proven to help students focus from the onset of the internship onward on what they need to accomplish. In terms of assessment and grading, comparison between the tasks planned and the tasks achieved at the end of the internship provides the course instructor with the necessary information needed to evaluate the student's planning skills. The student's ability to report any deviations from the planned as they happen is a business habit that is best developed during the internship.

<u>Allowing the students to choose their placement:</u> when the course was first developed, finding suitable placement for the students was the responsibility of the course instructor and the department chair. Even in cases where students proposed specific companies, the course instructor had the upper hand in the final selection. This intervention prevented students from working abroad, from working with legitimate family businesses, and from being paid for the internship. With time, it became evident that such direct intervention increases the risk of having the student placed in the "wrong" field, and decreases the quality of learning that takes place. This, in turn, negatively affected the attainment of the course learning outcomes, and deprived the students from participating in much-valued international experiences. In real-life situations, engineers have the freedom to choose their technical field of work, to interview and secure jobs only with their employers of preference, and to engage in international travel as part of the work experience.

In an effort to ensure that the course replicates, as much as possible, future work conditions, major changes in the placement process were introduced. Full freedom was given to the student to choose a placement of their choice, with advice and guidance from the course instructor. A self-regulating quality assurance system was implemented by simply ensuring that the students recognize that it is their responsibility at the end of the course to demonstrate completion of the tasks and achievement of the learning outcomes. The overwhelming majority of students who have access to family businesses or have placement opportunities with "friends and relatives" actually end up choosing to work in a different setting where they will learn and engage more. The current placement system enables students to explore their area of interest, allows them to explore opportunities abroad, permits them to work in a family business as long as certain rules are met to eliminate conflict of interest, and gives those who are in financial need an opportunity to work for pay during their internship.

<u>Standardization of the daily log and final report templates:</u> the daily log is a critical documentation tool for the internship activities, as it ensures focus on the activities outlined in the agreement. It also forces the student to think critically about linking the practical aspects of the course with the theory learned in class. Standardization of a daily log template had a positive impact on the quality of the final report, as it served as a starting point for documentation of activities.

The students were also originally given the freedom to write the report in any format, with no limit on the number of words or figures. This practice had positive aspects in terms of encouraging creativity and innovation and allowing the students to convey their message in whichever way they are comfortable. However, the vast majority of the students were missing one of the most important aspects of the course, which is to introduce them to common business practices. In addition, many students failed to document their achievement of the course learning outcomes. A template for the final report was developed in which the student discusses each activity as stated in the agreement, followed by an explanation of how this activity maps onto one or more of the course learning outcomes. A requirement was introduced whereby each course learning outcome is discussed at least once in the report. Grading rubrics were developed in which attainment of the course learning outcomes is linked to the field activities. Instructors who taught the course before and after this change reported measurable improvement in both the quality of the final report as well as in the extent of attainment of the course learning outcomes. It is important to mention that although the main body of the final report was standardized, the student still has the freedom to show evidence of work and competencies acquired in multiple ways in the appendices.

<u>Addition of a discipline-specific assignment:</u> as mentioned earlier, the course starts with five different class sessions

intended to prepare the students for an effective real-life work environment. Data received from civil engineering field supervisors indicated that the majority of the students lacked the ability to read and interpret engineering plans and drawings, especially when working on site. Field supervisors from other disciplines indicated other shortcomings for electrical and mechanical engineering students. An additional discipline-specific preparation session was added to address this deficiency. For civil engineering students, the session consists of presentations and in-class exercises using engineering drawings for real projects. Drawings and plans from various disciplines such as transportation, geotechnical, structural, hydraulic, and construction engineering are discussed with the students prior to the in-class exercises. The main objective is to familiarize the students with industry standard annotations and symbols, and to enhance their ability to extract relevant data from drawings.

A homework assignment is then given, in which the students draw a complete and detailed engineering plan using a drafting software. The objective of this exercise is to ensure that the student goes through all design details including scale, standard symbols and annotations, and industry drafting standards in multiple civil engineering areas in preparation for the internship. As this change has been lately introduced, more data from field supervisors are needed before evaluating the effect of this change on the course. Meanwhile, instructors teaching the course indicated that a significant improvement has been noticed in the learning outcome concerning the ability to communicate effectively through drawing.

V. Conclusion

The Field Experience in engineering represents a shift in the way students are prepared, supervised, and evaluated for off-campus experiential learning activities. Methodical preparation of the students through lectures and in-class activities enables students with limited work experience to easily transition into a real-life work environment. Accountability in the form of documentation of the activities in relation to specific learning outcomes resulted in a measurable advantage in terms of learning. The most critical element in the Field Experience is the issuance of a letter grade based on direct assessment of the student's work by the course instructor. As additional data is collected and analyzed over a five-year period during which the course was offered, hypotheses regarding the relationship between the student's performance in the course and subsequent improvement in the student's academic performance will be tested. Further information is being collected from alumni who graduated two to ten years ago, to evaluate the impact of the Field Experience on their subsequent job placement.

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