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Mixed methods assessment of project-based learning in a senior-level highway design course

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by

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NOMENCLATURE

AASHTO	American Association of State Highway and Transportation Officials
ASCE	American Society of Civil Engineers
BOK	ASCE Body of Knowledge
C3D	AutoCAD Civil 3D®
CAD	Computer-aided Design
CE	Civil Engineering
DOT	Department of Transportation
EIT	Engineer-in-training
FE	Fundamentals of Engineering
GPA	Grade Point Average
Green Book	AASHTO Policy on Geometric Design of Highways and Streets
HCM	Highway Capacity Manual
ISU	Iowa State University of Science and Technology
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
LOS	Level of Service
MUTCD	Manual on Uniform Traffic Control Devices
PBL	Project-based Learning
PE	Professional Engineer
RDG	Roadside Design Guide
STEM	Science, Technology, Engineering and Mathematics
TBL	Team-based Learning

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ABSTRACT

The lack of practical real-world applications in a classroom setting has been identified as one factor inhibiting student interest in STEM fields. Project-based learning (PBL) directly addresses this concern by providing an opportunity for students to complete an extensive, semester-long project that mirrors professional practice. In addition, PBL allows students an opportunity to refine related soft skills, such as technical writing and oral communication. This study involved the redevelopment of a senior-level highway design course using a PBL framework that largely reflects professional practice. A questionnaire survey was distributed to public and private road agencies in order to assess the importance of various classroom topics as they relate to the field of highway design. The course content was redeveloped based on the industry survey. Students were surveyed via questionnaires and focus group interviews before and after PBL implementation. These data were analyzed using mixed methods to assess advantages and disadvantages of the revised course structure. Based on these data, best practices are proposed for instruction using PBL in transportation engineering courses, particularly highway design.

CHAPTER 1: INTRODUCTION

1.1 Background

Preparing students for their future careers is the end goal of the university system. To this end, the American Society of Civil Engineers (ASCE) Body of Knowledge (BOK) outlines a series of learning outcomes that prepare today's civil engineering students to meet tomorrow's engineering challenges (ASCE 2008). Among the 24 outcomes identified as most important for engineers entering the profession, several are difficult to address by traditional classroom instruction. For example, outcomes 16-24 are focused on skills that may be more easily acquired in a professional setting including communication, teamwork, and lifelong learning which are difficult to teach when students passively accept and return information. This suggests a better learning framework could be implemented to prepare students for professional practice.

The main feature of traditional learning is that an expert (i.e. the instructor) imparts their knowledge to the novice (i.e. the student) via a lecture. Learning is intended to occur primarily between the instructor and the students. The advantages of this method is that it is familiar to instructors and ensures uniform instruction across all students. Likewise, assessment of student's knowledge can be easily derived from the content of the instructor's material.

The disadvantages of this method are, first, that it keeps the student in the position of novice. Knowledge is passively accepted and students are not responsible for critically examining the knowledge, they need only remember it for the exam. It is difficult to achieve higher order learning objectives such as evaluation from Blooms Taxonomy. Second, this method of instruction does not explicitly engage students with their peers. Learning is conducted nearly exclusively based on interaction with the instructor based on lecture content.

While this traditional approach remains a common instruction practice, research on pedagogy, as well as industry demands, suggest better methods to train new engineers. Research in Australia found that students graduating in Civil Engineering were lacking some of the necessary skills for their profession such as communication and problem solving (Nair et al. 2009, Jollands et al. 2012). Transportation engineering companies, and engineering firms in general, highly value teamwork. They also value self-learning, the ability of students to acquire new knowledge independently and apply it to solve problems. This is largely not the focus of traditional instruction and models that promote students to think for themselves and have a more active role in their own learning provide several important advantages.

A large amount of literature has been developed in engineering education about team-based learning (TBL), with these studies showing that TBL is an effective teaching methodology, which also meets the demands of employers (Hanson 2006, Michaelsen and Sweet 2011, Peterson 2012, Lamm et al. 2014). TBL has its own challenges. For instance, Mosher (2013) discussed that individuals must still have personal responsibility; otherwise, less motivated students may leave all group work to their teammates and not engage with the material. But where students still have that responsibility, their ability was shown to improve, both as individuals and as a group (Artz et al. 2016).

As TBL has garnered much attention in the engineering education community, so has Project-based Learning (PBL). Where TBL focuses primarily on group work done within the framework of a lecture, PBL focuses on tying all the group work into a semester project. This project applies all the material learned throughout the lecture times and is also done within teams that stay static during the semester where TBL is often done with teams that are different from week to week. A large amount of overlapping benefits exists between TBL and PBL such as higher student engagement, greater focus on professional skills, and more development of higher order thinking. Within the context of this study, the focus is primarily on PBL. However, many of the salient issues are also relevant for TBL and there is a natural connection between these two educational paradigms.

A wide spectrum of project based learning methods exist. In its most extreme form, PBL classrooms would not involve traditional lecture sessions, instead focusing exclusively on project-related material through hands-on-workshop type instruction. In this setting, the instructor describes or demonstrates what the students should learn and then frees the students during class time to explore solutions to the project. Conversely, several content modules could be based on PBL, with the remainder of the semester taught in a more traditional format.

The course on which this study is based includes two 50-minutes lecture periods per week, as well as a two-hour laboratory session. During previous semesters, a design project was generally introduced approximately mid-way through the semester. Prior to this point, lab sessions focused on introducing a series of software tools that are widely used in transportation engineering practice. With the conversion to a PBL framework, the curriculum was largely redesigned such that the project began immediately at the onset of the semester. The weekly lecture sessions were more closely aligned with the project, resulting in a more cohesive course structure.

To evaluate the effectiveness of the course in improving student learning, a before-and-after evaluation was conducted using triangulation mixed methods. This approach integrated quantitative data from employer surveys as well as pre- and post-course surveys with qualitative data from focus group interviews. The surveys provided a high-level examination of PBL's effectiveness. Focus group interviews were collected in parallel with the surveys to provide more unstructured feedback about PBL. Combining these different feedback mechanisms provides a more robust understanding of the strengths and weaknesses associated with the revised course structure.

1.2 Research Objective

The objective of this study was to evaluate the implementation of PBL within the context of a senior-level highway design course for civil engineering students at a large Midwestern technical university. As noted previously, this highway design course is comprised of two one-hour lecture periods, followed by a two-hour laboratory session later in the week. Anecdotal data from prior post-course surveys suggested teaching and learning would be more effective if the lecture and laboratory sessions were better integrated. To this end, prior to the Fall 2016 semester, the course was redesigned using a PBL framework. The lecture format and content remained largely similar; however, the laboratory sessions were restructured such that the project was the primary focus over the full duration of the semester.

As part of this redevelopment effort, the course content was also modified based upon the results of an employer survey, which sought to better align the course learning outcomes with the needs of industry. To determine how to best prepare students for their professional careers, this survey asked, "What should the focus of a highway design course be?"

A second focus of this project was to actively engage students in the learning process, soliciting feedback about what was working and what was not with respect to the new PBL framework. The first aim of this research sought to be very pragmatic, identifying approaches that would best benefit both students and prospective employers. The second aim was to conduct research that would prove informative and could be generalized to other transportation engineering or highway design courses. Ultimately, this study aimed to address two primary research questions:

1. What technical and soft skills are most important to employers in the area of highway design?
2. How does project-based learning (PBL) affect overall student performance and the effectiveness of teaching and learning?

1.3 Thesis Structure

This thesis contains six chapters which describe the existing literature in this field, detail the methods for data collection and analysis, present the results of the analysis, describe the classroom practices adopted to promote the learning objectives desired, and provide recommendations for future research. Specific content included in each of the subsequent chapters is detailed below:

- Chapter 2 explores literature within the field of project based learning within the engineering context, transportation engineering education research, and mixed methods research.
- Chapter 3 details the implementation and result of an industry survey that was used to redesign the course in a PBL framework.
- Chapter 4 presents an overview of the mixed methods framework, which involved pre- and post-surveys, as well as focus group interviews.
- Chapter 5 documents results of analyses of these data sources and provides a discussion of the implications of these results.

- Chapter 6 provides recommendations and concludes with a discussion of best practices and suggested area for future research.

CHAPTER 2: LITERATURE REVIEW

There continues to be increasing interest in the scholarship of teaching. In earlier work in this area, Bass (1998) states that, "The movement for a scholarship of teaching seeks first and foremost to legitimate a new set of questions as intellectual problems." Educators should be intentionally designing classrooms to include tested and superior methods of instruction.

Educators should be focused on student-centered learning. Working with the students to tailor their education to meet their need to find a job and be adequately prepared for a career. This student-centered mindset is summed up well by Laurillard (1993), who finds, "Teachers need to know more than just their subject. They need to know the ways it can come to be understood, the ways it can be misunderstood, what counts as understanding: they need to know how individuals experience the subject."

Not only must educators better understand their students, but also the industry those students will be employed in. This is important in two respects. First, this industry knowledge allows the university to better equip students with the desired skills and abilities that industry values. Secondly, this allows the university to better design real world problems that students can solve. Tseng et al. (2013) found real-world applications were effective towards encouraging broader engineering participation in general. Additionally, these real-world applications in the classroom have already been applied with great success at 29 universities as noted in a summary from the National Academy of Engineering (NAE 2012).

2.1 Industry Needs

Numerous university programs have implemented industry surveys to evaluate the readiness of recent graduates upon entering the engineering profession (Lianggrokapart et al.

2002; Crosthwaite et al. 2006; McDonald 2006; Nair et al. 2009, Hartmann and Jahren 2016). Developing degree programs and courses that match in-demand industrial skills with those acquired in a classroom setting is critical for universities to meet the labor demands of a world transitioning from a "goods society" to a "knowledge society" (Witt et al. 2013). The International Engineering Alliance (2009), which oversees bilateral recognition of engineering degrees between the 18 current Washington Accord countries, also recognizes the importance of higher order communication and problem solving abilities.

However, gaps do exist between the industry and classroom settings (Sinha et al. 2002, Howe et al. 2009; Donnell et al. 2011), which motivate the need for well-designed surveys to better align the two. Such integration would also help to meet the 24 outcomes outlined by the ASCE Body of Knowledge for the 21st Century (ASCE 2008), particularly those outcomes focused on professional issues. These outcomes, which focus on practice-oriented skills such as communication, leadership, teamwork, professional and ethnical responsibilities are generally satisfied during the pre-licensure professional experience rather than as a part of the undergraduate experience.

Continuing on this point, engineering employers generally prefer students to have a combination of both strong technical and soft skills. For example, an industry survey by Hawkins and Chang (2016) found that companies often emphasize traits such as willingness to learn over more technical skills. Research also suggests these skills are particularly beneficial if acquired in a practical setting that mirrors industry (Vaz and Quinn 2015). Prior research has suggested this is an important element that is generally lacking from many engineering education programs (Anderson et al. 2009). Greater use of such active, hands-on learning could also improve the acceptance of women (Pereira et al. 2010) and minorities (Haak et al. 2011) in engineering.

An employer needs survey addresses a broad area of interest with respect to educational outcomes and is particularly important as prior research has shown that materials and methods are generally not shared effectively between transportation faculty based on an assessment of curricula from more than 200 universities (Peters et al. 2015; Hurwitz et al. 2015). This means a wide variety of teaching methods and topics may be taught at any of a number of universities across the United State without a common set of "best practices" for teaching.

2.2 Project-based Learning

Research suggests the lack of practical, real-world applications in a classroom setting is one of several factors that have contributed to students shying away from STEM fields. To this end, project-based learning (PBL) has proven an effective means to mitigate this concern and improve learning (Dong et al. 2015, Lopez-Querol et al. 2015). Brunhaver et al. (2010) suggests this "approximation of practice" helps engineering students begin to cope with the system of supports and barriers they will find in their workplace. Martinez et al. (2011) found PBL to be one of several effective pedagogical methods under the broader umbrella of cooperative learning techniques. Over a five-year analysis period, classes taught in a PBL environment received favorable reviews from students and appeared to improve academic performance. Fini and Mellat-Parast (2012) evaluated the effectiveness of PBL as compared to a more traditional lecture-style format and concluded that PBL improved student's teamwork skills, as well as their ease of learning the material. It can also improve student's motivation to learn (Perrenet et al. 2000). Additionally, Guerra and Holgaard (2013) found that PBL can improve student's critical thinking skills, addressing concerns as students can struggle to operate in a diverse group and use abstract theories to solve concrete problems. Given this wide range of positive support, PBL appeared to be a methodology well worth exploring the benefits of.

Transportation engineering, and highway design specifically, is well suited for the use of PBL. Problems in transportation engineering are often ill-structured with multiple feasible solutions, none of which is necessarily optimal across all levels. Ahern (2010) presented the results of a case study examining the use of PBL for civil engineering students in transportation courses. She found that PBL helped students go deeper into their material and improved their ability to do self-directed learning. Kyte et al. (2010) detailed how more effective use of active instruction in transportation courses would help attract students to the field of transportation and develop important skills by solving real-world problems and developing innovative and cost-effective solutions. These solutions are badly needed in light of continuing concerns as to the United States' deteriorating transportation infrastructure. Subsequent work by Kyte et al. (2012) advocated for the use of student-centered learning paradigms, such as active or collaborative learning, outlining a design process to effectively engage students through a series of activities completed in a team setting. Gavin (2011) concluded that PBL, while time-consuming, was ultimately a rewarding experience for both instructor and students and led to a higher degree of learning.

Given the multi-disciplinary nature of transportation engineering, the field is well suited for the implementation of PBL (Nambisan 2002). Nambisan (2002) utilized a team-oriented, case-based approach to bridge the gap between theory and practice through a semester-long project completed in a manner to mirror professional practice. Working on a realistic project can challenge the realm of theory that relies on equations and assumptions from ideal conditions. There has been a longstanding gap between an engineering education system focused on theory while the industry is focused on practice (Sinha et al. 2002). While these are not mutually exclusive outcomes, a capstone highway design project is a good bridge between the two, allowing students to apply theory in a realistic, practical setting. This has been shown to be important in forming the engineering identity of students and allowing them to enter into an expert, rather than novice, frame of thinking (Lutz 2015).

2.3 Mixed Methods Analysis

For studying the effect of PBL, mixed methods analyses present a promising and rigorous evaluation framework that has already been encouraged within transportation engineering education research. Young et al.(2015) identified mixed methods research as the most persuasive among existing methods and recommended future research using rigorous inquiry methods to evaluate innovative approaches to teaching. Li and Faghri (2016) stated that qualitative comparison of project based learning vs. the traditional approach should be conducted in transportation engineering.

Cambell et al. (1959) were among the first to discuss how finding convergence (also called triangulation) among multiple methods within the same framework can increase a study's validity. These studies can be weakened by failing to give a rationale for using mixed methods (Kajfez et al. 2014.) Furthermore, Borrego (2007) noted rigorous mixed methods research requires an explicitly stated theoretical framework. This stems inherently from qualitative research which is subjective in nature. The worldview of the researcher must be stated to aid in objectifying the research. Researcher bias is frequently discussed within this research field. Greene et al. (1989) stated that mixed methods data must have different biases to avoid spurious correlations between qualitative and quantitative data. Borrego et al. (2009) noted that while it is difficult to generalize from a single case, knowledge can be transferable from one situation to another when the reader understands the relationship between the separate contexts. Context is the key to interpreting and applying qualitative and mixed-methods research. Koro-Ljungberg and Douglas (2008) define the theoretical frameworks behind qualitative research. The interpretivist (also called constructivist) worldview is discussed as situational in nature, not constrained by pre-formed hypotheses, the researcher is subjective and open about their biases.

Rossman and Wilson (1985) found qualitative data brings a more detailed elaboration to help solve research problems. Goncher and Johari (2015) used qualitative data to effectively evaluate a freshman engineering design class as a case-study. They also evaluated student perspectives on learning through interviews with the groups and analysis of the coded results.

2.4 Action Research

Ultimately, the desire is to foster the spirit of what Greenwood and Levin (2005) describe as cogenerative inquiry. This is a collaboration between researchers and stakeholders developing “action research” to solve problems. In this case the direct stakeholders are transportation engineering employers. These employers have vast local knowledge and know what kind of candidates they are looking for. In order to validate this research it is important to have a “warrant for action” and engage in a social change based on the research proposed. This also comes with challenges that Greenwood and Levin (2005) found come from “context-centered knowledge” which is heavily based in the context established, namely transportation engineering organizations in the Midwest United States.

While some of the results of this study are generalizable, it was not conducted for the express purpose of being generalized. This research was intended to be action research. This puts the focus not on a methodology or the method of inquiry, but rather toward the immediate research goal (Somekh and Zeichner 2009) which is improving the ability of students at Iowa State University to meet the demands of the workforce that they are entering.

CHAPTER 3: EMPLOYER SURVEY

As a part of the course redevelopment, a main objective was to identify the knowledge, skills, and abilities sought by employers when hiring entry-level engineers for highway design positions. Partnering with industry to determine their needs is a necessary step for the future for two primary reasons. First, aligning the learning outcomes in consideration of the needs of industry better prepares graduates for a more seamless entry to their professional careers. Second, the industry is changing quickly and periodically revisiting the topics and skillsets that are most in-demand allows academia to be more dynamic and provide employees with skills that are better suited to this changing environment.

In the fast-moving field of technology, even instructors with past industry experience may find their knowledge of the industry needs have become outdated. While core design principles change slowly, the tools and techniques such as computer aided design (CAD) software and technology will change, often rapidly. CAD providers update their software constantly, creating a potential challenge that may be difficult to address given the static nature of many university courses in this area. Intelligent Transportation Systems have the potential to challenge the fundamental assumptions behind how roadways are designed. Instead of roadways designed for humans, future roadways will start to be designed for computers, as well. The transportation engineering educator must follow advances closely with industry to ensure their students are adequately prepared to enter the workforce.

3.1 Methodology

A questionnaire survey was developed and distributed to public and private road agencies in order to assess the importance of the following items when hiring candidates for such positions:

- Various reference manuals, guidebooks, and software programs commonly used in highway design;
- Topics generally included in highway design curricula;
- Specific soft skills pertinent to engineering practice; and
- Experience in co-op or intern positions, completion of FE/PE exam, and completion of a master's degree. See Appendix A for the full survey format.

For each of the previously listed topics, questions were structured on a five-point Likert scale to indicate the relative importance of each item from the perspective of the hiring entity. Respondents were also asked to self-identify their company as either a state DOT, county/municipality, local/regional private firms, or national/international private firm. The questionnaire was distributed using an online survey tool. The survey was ultimately distributed to two groups of employers in the highway design industry. The first group included engineering companies with a transportation sector or division that had hired students from the university during the past five years. Initially, a total of 893 contacts were identified from private sector companies and public agencies. This list was reduced by investigating whether the company had a transportation sector. The resulting list included 236 contacts. Many of these contacts were professionals involved in the human resources division of their respective company, so instructions were given to forward the emails to engineers in transportation design within their company. The second group that was contacted was comprised of the head design engineers for each state Department of Transportation (DOT) for the 50 states and District of Columbia.

3.2 Data Analysis

A total of 74 agencies/companies replied to the employer survey including 17 of the 51 state DOTs participated in the survey (33% response rate) a list of which can be seen in Appendix B. Geographically, the survey respondents were primarily distributed throughout the Midwestern United States in the area surrounding the university at which the study was conducted as seen in Figure 1. Although 19 responses did come from outside the Midwest, these were largely received from State DOTs.

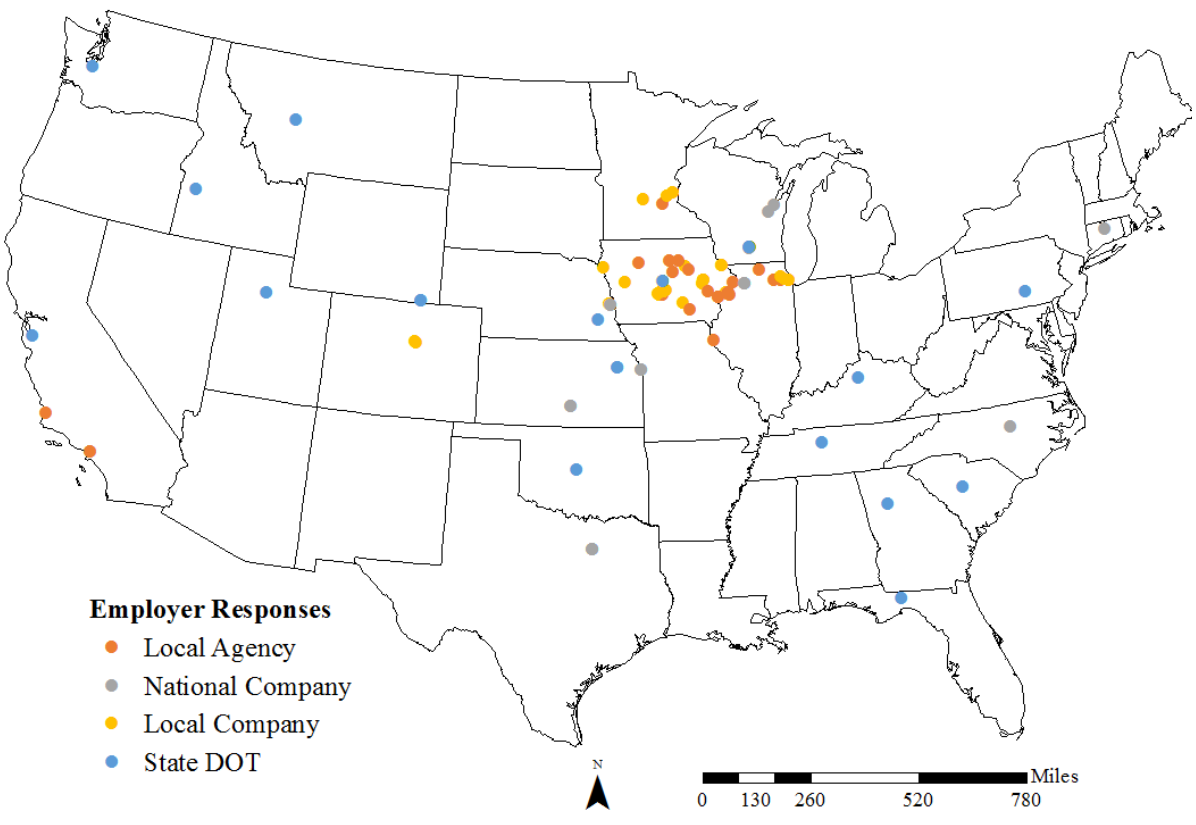

Figure 1 - Map of Employer Survey Participants

In reviewing response data, there were six entries out of 99 responses to the survey that were largely incomplete. These entries were removed from analysis entirely. While most respondents identified themselves as engineers, there were two who appeared to be human resources personnel. As a significant portion of the survey content focused on technical skills, these responses were removed from the sample, as well, leaving a total of 91 completed surveys. The distribution of respondents by transportation agency type is summarized in Table 1.

Table 1 - Summary of State-of-the-Practice Survey Respondents

Agency/Position	Junior Engineer	Senior Engineer	Executive	Unknown	Total
State DOT	1	3	13	3	20
County/Municipality	5	17	1	0	23
Private (National)	5	7	4	0	16
Private (Regional)	3	23	5	1	32
Total	14	50	23	4	91

The position of the respondent was not an initial question on the exam. After the data was collected, the researcher identified respondent's positions via LinkedIn® and internet search engines. Those with more than 10 years of experience were classified as senior engineers, less than 10 as junior engineers, those with a position as a manager or president/vice president as executives which includes those who come from the list of top identified DOT design engineers.

Missing data within the remaining surveys was present, but limited. Those individual items within completed surveys were counted as non-entries, though the remaining fields filled out for that response would be included. Some respondents may have been filling out the survey too quickly, or they may not have had knowledge about the specific entry due to their specialization in another field of transportation engineering. For example, Vissim was omitted 11 times while ArcGIS was omitted 7 times by respondents.

3.3 Results

Tables 2 through 4 present the survey results for each of the questions described previously. Each table presents the average importance of each topic on a five-point scale (with 1 corresponding to unimportant and 5 very important). Responses are disaggregated by agency type, along with a total average across the entire sample.

Table 2 - Importance of Design Reference Texts and Software Programs

Reference Text	State DOT	Local Agency	National Company	Local Company	Avg.
A Geometric Design Policy of Streets and Highways (Green Book)	4.15	4.09	4.50	4.22	4.22
Roadside Design Guide	4.05	3.96	3.94	3.84	3.93
Manual on Uniform Traffic Control Devices (MUTCD)	3.40	4.17	3.71	4.03	3.87
State/Local Specifications	3.05	4.43	3.18	3.91	3.72
Highway Safety Manual (HSM)	3.35	3.57	3.35	3.72	3.53
Highway Capacity Manual (HCM)	3.05	3.00	2.81	3.23	3.05
Software Program	**State DOT**	**Local Agency**	**National Company**	**Local Company**	**Avg.**
AutoCAD Civil 3D	2.63	4.00	3.88	3.56	3.57
Microstation	3.79	1.95	4.29	3.63	3.41
ArcGIS	2.67	3.70	3.13	2.71	3.06
Synchro/SimTraffic	2.35	1.48	2.82	2.59	2.31
Vissim	2.16	1.40	2.53	2.15	2.04

Table 4 details the importance of several reference materials and software programs frequently used as a part of the highway design process. Unsurprisingly, the reference considered to most important for new hires was the American Association of State Highway and Transportation Officials (AASHTO) A Geometric Design Policy of Highways and Streets, also referred to as the “Green Book”. The Green Book is generally adopted as the standard reference for highway design by state DOTs, outlining minimum criteria that are consistently used across the United States.

While the Green Book was viewed as the most important reference overall across the sample, local agencies (i.e., counties and municipalities) placed a greater emphasis on knowledge of state- or local-level design specifications, which typically provide additional guidance that is pertinent to local conditions. The Manual on Uniform Traffic Control Devices (MUTCD) and ArcGIS software were also emphasized more strongly by local agencies. This may be reflective of the broader skillset required of employees of such agencies, which are generally smaller and require employees to have more extensive breadth of knowledge as compared to state/national agencies that are generally larger and more specialized in terms of the scope of tasks provided to entry-level employees.

Beyond the Green Book, the other resource that was consistently viewed as important or very important by agencies was the AASHTO Roadside Design Guide (RDG). The Green Book and the RDG were the most frequently referenced resources in a review of highway design syllabi conducted as a part of this study. Other resources, including the MUTCD, the Highway Safety Manual (HSM), and the Highway Capacity Manual (HCM) were viewed as being less important. However, it is important to acknowledge these resources are generally covered more extensively in courses from complementary areas such as operations and traffic engineering. Interestingly, most of these additional references were viewed as being more important by local agencies, whether public or private. These data suggest further support that local agencies hire employees with an emphasis on breadth of knowledge. Both state DOTs and larger national companies, on the other hand, considered such familiarity to be less important. Presumably, the larger structure of these entities means they expect new employees to have a narrower skillset coming in, with much of the additional expertise being acquired while on the job. To this end, larger agencies frequently have in place training programs that allow new hires to rotate across various divisions, each of which has a narrower focus with more depth in specific areas such as design.

Continuing on this point, it is observed from Table 2 that the knowledge of reference guidelines and standards is generally of more importance to prospective employers than proficiency with technical software. This is an area that has generated considerable discussion within the civil engineering program at the university where this study was conducted. In senior-year exit interviews, students have consistently emphasized a need for more extensive software integration in the curriculum. However, with the exception of computer aided design (CAD) software, other programs were viewed as being less important. It should be noted that several of these software are of more of a supplementary nature to the design process. For example, Synchro/SimTraffic and Vissim are focused on level-of-service and capacity analysis. While important, these types of analyses are conducted to justify or evaluate design alternatives early on in the design process.

One discrepancy of note when comparing the importance of software across agencies is the striking difference in importance between the two major CAD packages, C3D and Microstation. State DOTs (3.79) and national companies (4.29), in particular, were more likely to prefer experience with Microstation. This is largely because projects conducted by, or for, state DOTs typically require use of this program, which includes several specialized highway design applications. In contrast, C3D has a broader focus that is applicable across a wider range of disciplines beyond highway design. In fact, several professionals explicitly noted this difference in their survey responses.

Turning to the fundamental highway design course content, Table 3 illustrates the importance of 20 topics generally taught in design courses or utilized in the practice of highway design. The list of topics was assembled based upon a review of content from syllabi of university-level highway design courses, as well as from sections of state DOT design manuals.

Table 3 - Importance of Various Highway Design Topic Areas

Topic Area	State DOT	Local Agency	National Company	Local Company	Avg.
Design drawings	4.11	4.27	4.18	4.39	4.26
Drainage and runoff	3.84	4.23	3.94	4.35	4.13
Vertical curves	3.95	3.77	4.18	4.45	4.12
Horizontal curves	4.00	3.77	4.24	4.35	4.11
Intersections	3.79	4.00	3.71	4.07	3.92
Earthwork	3.74	3.82	3.76	4.03	3.87
Stopping sight distance	3.95	4.00	3.53	3.83	3.84
Design controls	3.89	3.68	3.63	3.77	3.75
Roadside	3.63	4.09	3.65	3.47	3.69
Pedestrians	3.22	3.32	3.59	4.10	3.62
Traffic control	3.00	4.05	3.24	3.50	3.48
Pavement systems	2.95	3.95	3.18	3.42	3.40
Temporary traffic control	3.00	3.77	3.18	3.50	3.40
Design flexibility	3.58	3.09	3.31	3.13	3.25
Capacity and level-of-service	3.37	3.05	3.00	3.27	3.18
Traffic safety	3.53	3.14	3.06	2.77	3.08
Economics	3.16	3.32	2.76	2.84	3.01
Environmental impacts	3.11	3.18	2.65	2.97	2.99
Access management	2.59	2.68	2.65	3.10	2.80
Intelligent transportation systems	2.89	2.57	2.56	2.50	2.62

Interestingly, the topic receiving the highest rating was design drawings, followed by drainage/runoff, horizontal curves, and vertical curves, each of which had average ratings ranging between important (4 on Likert scale) and very important (5 on Likert scale). The importance of design drawings to employers addresses a shortcoming of the curriculum at the university where this study was conducted. In fact, the curriculum of a freshman-level graphics course was modified the subsequent semester based on these survey results to include more extensive coverage of design drawings and CAD packages. The importance of design drawings to employers is also likely reflective of the context of this survey, which was focused on entry-level hiring practices. Plan sheet creation is a common task included in the practical experience students gain as interns or co-ops.

The other topics that were highly rated by employers are generally part of the standard curriculum in highway design courses, such as the design of horizontal and vertical curves, intersections, and the roadside environment. The importance of these topics tended to be quite consistent across the four types of transportation employers. Design flexibility and traffic safety were both found to be significantly more important to state DOTs. These topics have increasingly been emphasized more nationally in recent years, particularly with the publication of national-level design guides and manuals on these specific topics. Local agencies and private companies generally tend to track changes at the DOT-level, so it is expected these topics will become increasingly important among these employers moving forward, as well.

In contrast, local road agencies tended to rate several additional topics as being more important, such as permanent and temporary traffic control, pavement design, and consideration of pedestrians in the design process. These findings are reflective of the nature of design of lower class roadways that would fall under the jurisdiction of counties and municipalities. It is interesting to note that the economic aspects of highway design tended to be of greater importance to public versus private organizations. Recently, there has been an increased focus on the manner in which public funds are utilized for transportation improvements.

It was somewhat surprising to see such strong emphasis on drainage and runoff design across all agencies. In a review of syllabi from 20 civil engineering programs, Turochy (2009) found only one class included drainage in its syllabus content. At the university where this study was conducted, this topic has historically been covered in a hydrology course, but not actively integrated into highway design. Several survey respondents also suggested that several software programs should be considered when teaching students about drainage within the context of highway design, such as the Federal Highway Administration's HY-8, the Army Corp of Engineers' HEC-RAS, and AutoCAD Storm Sewers.

It was also noteworthy that capacity and level-of-service ranked in the bottom third of topics among employers, especially considering Beyerlein (2010) found traffic flow characteristics and capacity studies to be rated very high among topics that should be taught in transportation courses as part of a 2009 survey. Also, Thomas (2006) found that among the public sector, highway capacity was the most desired skill from new hires. This difference may reflect that capacity/level of service knowledge are viewed as complementary, rather than necessary skills. Intelligent transportation systems (ITS) also received low scores across all agency types, though it is important to note ITS and related technologies are expected to become an increasingly important aspect of the design process with the continuing emergence of connected and autonomous vehicles. This finding may simply reflect this is not a widely desired skill among entry-level employees.

Additionally, ITS received low scores across all agency types, though it is important to note ITS and related technologies are expected to become an increasingly important aspect of the design process with the continuing emergence of connected and autonomous vehicles.

What can be determined from this is that employers, although valuing these technologies, do not expect entry level employees to have knowledge in this area. Combine this with the information presented in Table 4 and the high importance placed on the ability to learn. Intuitively this makes sense as the new transportation engineering world has a wide variety of skills to cover which are impractical to learn in a semester with typically only 40 hours of instruction time available. Since many schools only have one required transportation engineering course, this means that many students only have one work week of exposure to transportation engineering topics by the time they graduate.

The last section of the survey focused on the importance of various soft skills and other qualifications of entry-level engineers to prospective employers. Table 4 provides a summary of feedback as to the importance of these areas.

Table 4 – Importance of "Soft" Skills and Other Qualifications

Skill/Qualification	State DOT	Local Agency	National Company	Local Company	Avg.
Teamwork	4.48	4.09	4.41	4.60	4.41
Lifelong and self-learning	4.01	4.20	4.49	4.56	4.34
Critical thinking	4.21	4.38	4.19	4.40	4.31
Ethical judgment	3.95	4.15	3.98	3.99	4.01
Engineer-in-Training (EIT)	3.79	3.76	4.41	4.06	4.00
Innovation/creativity	3.69	3.81	3.68	3.71	3.73
Co-op/intern experience	3.47	3.29	3.94	3.87	3.64
Technical writing	3.55	3.46	3.83	3.46	3.55
Technical presentations	3.29	3.01	3.39	2.94	3.11
Management skills	3.16	3.19	2.94	2.83	3.00
Master's degree	1.63	1.38	2.18	1.58	1.69

Supporting research by Hawkins and Chang (2016), employers identified the abilities to work as part of a team and to learn independently to be among the most important traits for new hires. Development of these skills is also a potential asset in the conversion from a traditional to PBL course design. Table 4 shows that several soft skills, such as technical writing and presentation skills, are not valued as much. This is interesting as there have been extensive efforts to address limitations of engineering students in these areas in higher education. Soft skills have been emphasized by engineering employers for decades (Lipinsky and Wilson 1991). By now this is an established fact that communication skills are critical to engineers. It is remarkable then to observe in Table 4 that presenting and writing fall far behind teamwork for new hires. It is possible that although writing skills are important, employers assume this will be learned after employment begins. This is supported by Donnell et al. (2011) who observed a deficiency between writing skills students have versus what is expected.

Local agencies, such as counties and municipalities, tended to diverge from the other employer types and found innovation, ethics, and creativity to be more important and teamwork to be less so. This is yet another finding that suggests smaller local agencies value the ability of engineers to work independently. These same employers also tended to put less emphasis into teamwork.

For desired qualifications, employers were particularly interested in students who had completed the Fundamentals of Engineering (FE) examination (and were thus Engineers-in-Training, or EITs). EIT certification was particularly important among private consultants, where professional licensure is often a requirement for various types of design work. All employer types also tended to value candidates who had completed co-op or intern positions, considering this moderately important for new hires. In relation to each other, private companies desired a higher level of skill than public agencies. Collectively, these findings highlight the importance of practical experience to hiring agencies, though it is interesting to note master’s degrees were the least important among the skills and qualifications evaluated.

CHAPTER 4 STUDY METHODS

Ultimately, the objective of this study was to evaluate the effectiveness of the project-based learning (PBL) framework in the context of the senior level highway design course. This before and after study was conducted over the span of the spring and fall semesters of 2016. The spring semester was administered in a traditional lecture format while the semester was taught in a PBL framework.

Table 5 provides a detailed course schedule for the Fall 2016 offering, which utilized the PBL framework. Examination of the schedule shows that the weekly laboratory topics largely build upon the content introduced in the preceding lectures. In comparison to prior offerings, the following list highlights the most substantive differences with the transition from a more traditional to a PBL framework:

- Laboratories focused exclusively on the semester-long project under the PBL design. Previously, the earlier laboratories introduced students to a suite of software tools that were used in a project over the second half of the course.
- Homework assignments were submitted every one to two weeks. For each assignment, one problem was randomly selected for grading. During prior semesters, weekly quizzes were conducted instead. Due to time constraints, this change was implemented concurrently with the introduction of PBL.
- Teams were divided into groups equally by the instructor on the basis of interest, gender and nationality. Each week's topic was discussed in a weekly memo which was incorporated first into an intermediate report and then a final report.

- During the fall 2016 semester, the content coverage was also adjusted. This included reducing the amount of overlap on fundamental topic areas (e.g., capacity and level-of-service, horizontal curve design, vertical curve design) that were already covered extensively in a prerequisite introduction to transportation engineering class.

Table 5 - Course Schedule for PBL Offering

Week	Monday Lecture	Wednesday Lecture	Thursday Laboratory	Deliverables
1	Introduction; Design Overview	Freeway/Multilane Level-of-Service (LOS)	Introduction to Course Route Location	Survey (HW 00)
2	Two-Lane Hwy LOS	Stopping and Decision Sight Distance	Level-of-service (LOS)	HW 01 Memo 01
3	No Lecture Labor Day	Horizontal Alignment	Horizontal Alignment	HW 02 Memo 02
4	Horizontal Alignment	Vertical Alignment	Vertical Alignment	
5	Coordinating Alignments	Earthwork and Mass Balance	Earthwork and Mass Balance	HW 03 Memo 03
6	Cross-Sections and Roadside Design	Highway Safety	Cross-Sections and Roadside Design	HW 04 Memo 04
7	Highway Safety	Interchange Warrants and Types	Highway Safety	HW 05 Prelim Design
8	Exam Review	Exam Review	Mid-Term Exam	
9	Interchange Design	Weaving LOS	Interchange Design	
10	Intersection Sight Distance	Intersection Sight Distance	Interchange Design	HW 06 Memo 05
11	Intersection Design	Alternate Intersections	Alternative Intersections	HW 07, HW 08
12	Roundabout Design	Access Management	Access Management and Non-Motorized Users	Memo 06
13	Flexible Pavement Design	Rigid Pavement Design	Pavement Design	
14	Temporary Traffic Control	Designing for Non-Motorized Users	Project Reports Due	HW 09 Final Design
15	Project Presentations	Project Presentations	Project Presentations	Presentation

In order to provide context for this research, it should be noted the course was taught by a different instructor in the semester immediately preceding the conversion to a PBL framework. The teaching assistant, who was responsible for teaching the laboratory sessions, was the same during both semesters. The instructors also provided extensive consultation with one another to provide for consistency across semesters to the extent possible. Nonetheless, it is important to note these differences.

In the course of the semester, many students were included in the class improvement process. Their opinions were asked frequently and they gave candid feedback about what was working and what was not. As PBL at its core is a student-driven learning experience, this was critical for the project that students were engaged in their own learning and had a voice as to establishing how they were taught.

4.1. Mixed Methods Approach

With respect to an overarching worldview, the research was conducted out of a constructivist perspective. Inside constructivist thinking, meaning is derived or “constructed” from an interaction between the research and the participants. They work together to build meaning as opposed to the more traditional post-positivistic view which sets the researcher apart as an impartial observer who will, “test hypotheses and to determine cause-and effect relationships between variables” (Creswell 2007).

Furthermore, constructivist theory places greater emphasis on the participant’s voice than the researcher’s. This perspective allows the participants to “speak for themselves.” As a result, this research may not be generalizable to all classroom environments, though some aspects may be more broadly generalizable outside of transportation engineering and highway design courses. Koro-Ljungberg and Douglas (2008) suggest that additional studies in separate contexts would be necessary to validate more universal generalizability.

This study used a mixed methods design, which provides an "approach to inquiry involving collecting both quantitative and qualitative data, integrating the two forms of data, and using distinct design that may involve philosophical assumptions and theoretical frameworks" (Creswell 2014). The research approaches mixed-methodology from a pragmatic worldview, emphasizing neither the qualitative nor quantitative research aspects. This worldview provides a background that examines, "actions, situations, and consequences rather than antecedent conditions" (Creswell 2014). Philosophically, this places the focus back on the research question itself and seeks methods to solve the problem at hand rather than focus on the background of preexisting social phenomenon.

One of the advantages of a mixed-methods design is to simultaneously exploit the strengths of both qualitative and quantitative methods while minimizing their weaknesses. Quantitative research has an advantage of being more familiar to engineers; questions are developed prior to research and tested. In this study; however, the close-ended nature of quantitative research is necessary. The most unrestricted opinions of students are given through qualitative questions. This also helps remove the bias of only answering questions related to the specific hypothesis. The weakness of qualitative data is that the dissimilarity between different responses creates difficulties drawing definite conclusions from the data.

Beyond the advantages of qualitative and quantitative analyzed separately is the "convergence" or "triangulation" comparative analysis. Convergence finds the similarities between different methods that increases validity and improves the academic rigor of merely quantitative or qualitative analysis separately. Jenkins (2001) is an excellent example of a convergence study, showing how survey data can be enhanced by adding focus group interviews from the same population to offer insights that would have been missed otherwise.

Because of this the triangulation method was used. Greene et al. (1989) stated that the triangulation method places equal weight on both quantitative and qualitative data in analyzing the results.

Figure 2 provides an overview of the mixed-methods design from this study. Ultimately, for the purpose of this study, data were evaluated from two primary sources:

1. pre- and post-course surveys; and
2. focus group interviews.

Data resulting from these tools were analyzed to identify trends and similarities between their results. The findings were also compared to the results of the employer survey detailed previously.

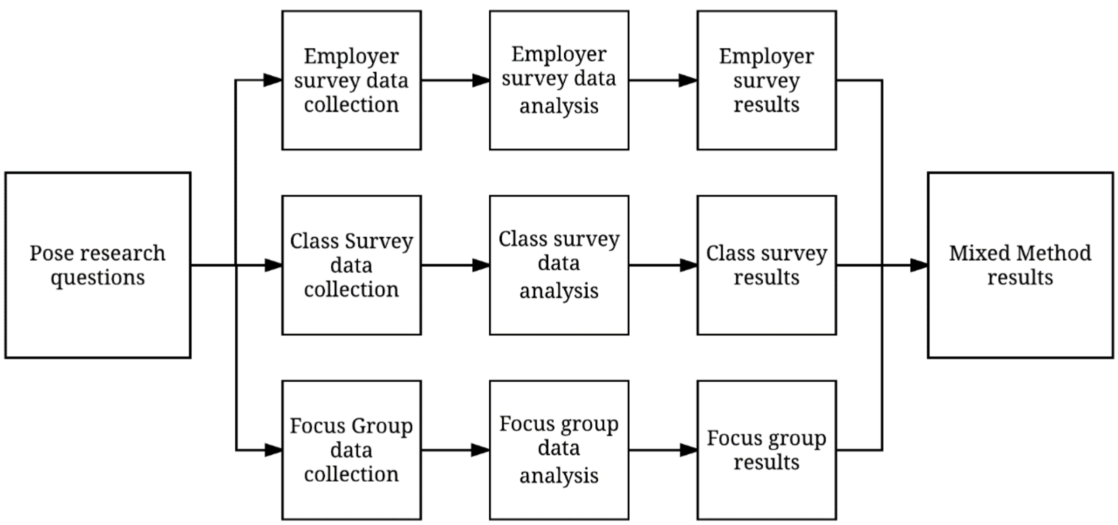

Figure 2 - Project-based Assessment Procedure

As suggested by Creswell et al. (2007), data from these sources were initially analyzed independently from each other. This resulted in independent conclusions necessary to reduce the correlation between data origins which would cause agreement or disagreement between sources to become more pronounced. Ultimately, this contributed to the validity of the research, making it more generalizable and rigorous.

This research could only be achieved with similar sample populations. This helped limit any selection bias which would cause an artificial similarity or dissimilarity between data. As a result, there could be an accurate corroboration between the two types of data. The group samples were different between interviews and post-course surveys because they were administered separately as optional extra credit. However, both sample groups had similar attributes in multiple categories. Firstly, the pre-class interest levels were similar among both focus group/non-focus groups as well as student with or without post course survey completion. This indicates that there was not a bias toward students who were uncommonly interested in the class. Secondly, the demographics of the class between female students as well as international students within the class remained consistent from semester to semester and within pre and post course interviews/survey, besides international students of which none participated in the second semester focus group interviews. Finally, the post-course skills assessments had similar results between focus group and non-focus group students. This indicates that students who participated in the interviews evaluated their learning equally to the remainder of the class. From these observations, it was concluded that the students who took the surveys and focus groups were largely similar to each other.

4.2. Pre- and Post-Course Surveys

At the onset of each semester, a pre-course survey was administered during the first week of class. See Appendix C which provides the full set of 22 questions that were asked. During the PBL offering, a post-course survey was also conducted, which included 15 questions and was administered the last week of class. See Appendix D for a full list of these questions. The pre-course surveys were completed by all participants in the course as a requirement for team placement.

The post-course survey participation was completed by slightly more than half of the students during the fall 2016 semester. Survey participation was voluntary in both semesters. It was incentivized by adding class extra credit for students who completed the survey. As the preceding (spring 2016) semester was taught by a different instructor, a post-course survey was not administered in this semester. Consequently, data from a post-course survey taken in the fall 2015 semester are provided for comparison purposes. An advantage here is that the same instructor taught the fall semester offering both years. However, it is important to note that the focus group interviews were conducted during the spring 2016 and fall 2016 semesters. Consequently, it is difficult to make consistent comparisons between the various evaluation instruments in light of these differences.

4.3. Focus Group Interviews

In order to receive more detailed feedback, focus group interviews were conducted during the last week of class time and finals weeks. Six fixed questions were asked to every focus group.

- What was the most valuable thing you learned from highway design?
- What was the least valuable thing you learned from highway design?
- How prepared do you feel to go into the professional workforce with the software skills that you developed?
- What would you think about highway design being built around a semester long project?

- What would you think about highway design being turned into a "flipped" classroom?
- How prepared do you feel this class made you to work on a team in a professional environment?

An Internal Review Board (IRB) human test subject exempt study review was submitted and reviewed by May 13th, 2016 to the Office for Responsible Research, IRB ID 16-212. See Appendix E for a copy of the cover sheet from that approval. Before the start of interviews, students were informed that the proceedings would be recorded but remain confidential and any form of personal identification would be removed from publication. Students were also informed that there would be no repercussions on their grade for comments made in the discussion. A nominal amount of extra credit was offered to incentivize students to participate in the interviews.

Based on the results of these questions the interviewer tailored follow-up questions. Follow-up questions often asked for more detail about what helped or hindered student learning and what suggestions they had for improving the course. This method proved a rich source of ideas for course improvements, drawing feedback freely from students in a comfortable setting. At the same time, it was more challenging to draw uniform conclusions about course effectiveness since topics discussed varied substantially from interview to interview. The results in the classroom scaffolding category arose out of follow-up questions since it was not a topic explicitly asked during the interview process. This helped remove a response bias from the questions. The fact that a topic was discussed means that it was at least on the minds of the students, or at most maybe one of the critical strengths or weaknesses of the class.

In the focus group data collection phase all of the interviews were transcribed by the researcher from the recordings to a text document. This text was then coded by hand. Coding is the process of categorizing text into distinct “packets” and then assigning a tag or description about that text so it can be more easily analyzed. The coding method used in this research is the simplest one and is commonly known as descriptive coding and is more thoroughly explained in *The Coding Manual for Qualitative Researchers* (Saldana 2016). Descriptive coding is where the topic of a section of text is summarized by a word or phrase that describes it. These codes are then placed in a codebook and lumped together into broader categories. Quotations from these sections are accumulated into groups and the most illustrative examples included in the results section.

CHAPTER 5. RESULTS AND DISCUSSION

5.1 Class Survey Results

Details as to the overall class size and other general statistics are shown in Table 6. The Fall 2014 and Fall 2015 semesters are provided merely to provide context as to the composition of the class. On average, the class had 16% attendance by woman and 22% by international students over the 4 semesters observed. Pre-class course interest, both in transportation as a career choice and in the highway design course itself, remained relatively similar across the study period. Student interest level tended to be quite similar, as well. Classroom demographics did not substantially change from semester to semester as a whole, indicating that the classes studied represent a typical example.

Table 6 - Course Descriptive Statistics

Term	n	International	Female	Students Interested in Transportation Career	Pre-course Interest in Highway Design (5-pt scale)
Fall 14	66	18 (27%)	10 (15%)	17 (26%)	3.85
Fall 15	72	15 (21%)	10 (14%)	33 (46%)	4.13
Spring 16	67	12 (18%)	11 (16%)	27 (40%)	4.03
Fall 16	71	16 (23%)	14 (20%)	33 (46%)	3.97
Total	276	61	45	110	4.00

From the students who responded to the pre-course survey, between 26% and 46% of the sample declared an interest in a transportation career. For the fall 2016 semester when the course was converted to a PBL framework, only 10 out of 71 (14%) students declared a sole interest in transportation, which resembles data from a national survey by Agrawal and Dill (2003) that showed 18% of civil engineering seniors declaring an interest in transportation.

5.1.1. Self-assessed student learning

Students were surveyed to self-assess their competency in the topics presented in the course (e.g. Horizontal curves, LOS etc.). These scores were averaged across all the categories before and after the classroom was switched to the PBL format.

As there was not a post-course survey administered during the spring 2016 semester, due in part to different instructors teaching the course, a comparison is instead provided between the fall 2015 and fall 2016 semester when both pre- and post-course surveys were completed. Figure 3 provides a comparison of self-assessed student knowledge across all course topics during each of these semesters.

These results are based on a series of questions that were scored on a five-point Likert scale where a "1" was defined as "I have never heard of it [class topic]", "2" was "I have heard of it, but do not know what it is", "3" was "I have some idea of but not very clear", "4" was "I understand the concept, but could not perform the calculations" and finally "5" was "I could perform calculations and understand and explain the concept to others."

From a big-picture perspective, these data indicate little change in student knowledge. While overall the average score from the 2015 students increased slightly from 4.00 to 4.10 in 2016, students in the 2016 semester also had higher initial self-assessed skills. The sample from the pre-course assessment was only from students who also completed the post-course surveys. The percent of topics which were in the "5" category rose from 33% to 43% between the 2015 and 2016 semesters. This is significant since this category represents topic mastery. It indicates not only comprehension but also application of the material. As found in the employers survey, these higher-order critical thinking skills are important for entry level hires.

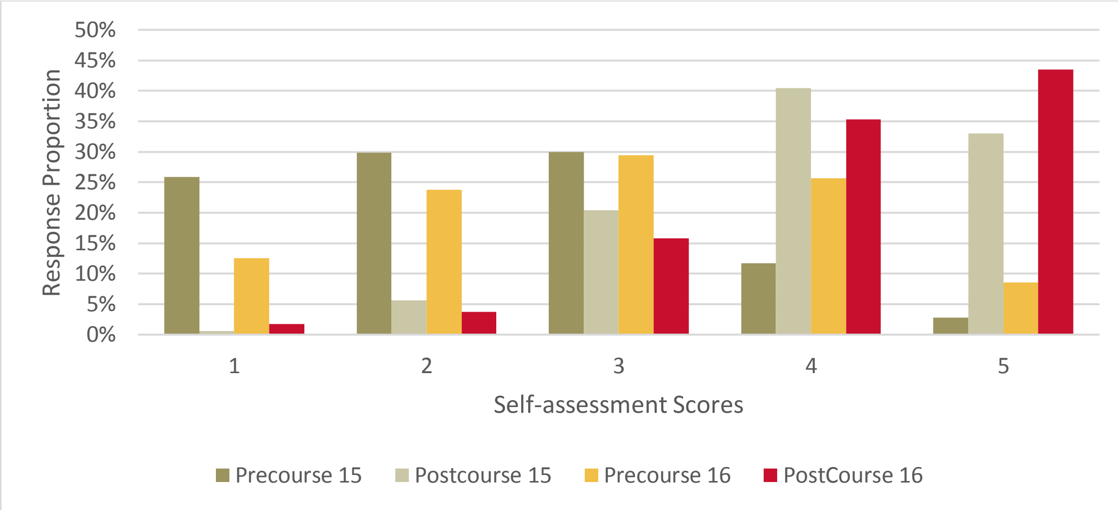

Figure 3 – Pre-course vs. Post-course Self-Assessed Understanding of Classroom Topics

Table 7 provides a detailed breakdown of self-assessed content knowledge by topic areas for students during the fall 2016 semester when the PBL framework was implemented. The results are compared side-by-side with results from the employer survey, as well as with a survey of transportation engineering educators by Beyerlein (2010), both of which expressed the general importance of these topics.

Table 7 was sorted from the employers' survey from highest ranking to lowest ranking. Wherever the table has dashes this indicates that the field was not surveyed in that particular survey. There was not an exact overlap between these surveys. When several categories overlapped, such as the different type of LOS categories, they were both given the same attributes of the LOS category from the employer survey.

Table 7 – Classroom and Employer Survey Comparisons

Classroom Topic	Pre-class Survey	Post-class Survey	Empl. Survey	Educators
Cross-section, Plan & Profile Drawings	-	-	4.26	-
Drainage/Runoff Design	-	-	4.13	-
Vertical Curve Design	3.66	4.63	4.12	4.67
Horizontal Curve Design	3.70	4.68	4.11	4.67
Superelevation	3.41	4.38	4.11	4.67
Intersection Sight Distance	2.82	4.10	3.92	4.1
Intersection Design	2.56	4.10	3.92	4.1
Earthwork/Mass Balance	2.89	4.43	3.87	-
Stopping Sight Distance	3.68	4.75	3.84	-
Functional Classification	2.73	4.40	3.75	4.4
Cross-Section & Roadside Design	3.13	4.18	3.69	-
Bicyclists, Pedestrians & ADA Design	-	-	3.62	3.43
Traffic Control Devices	2.92	3.88	3.48	4.26
Rigid Pavement Design	2.39	4.35	3.40	-
Flexible Pavement Design	2.34	4.33	3.40	-
Temporary Traffic Control	2.79	3.70	3.40	-
Design Flexibility/Context Sensitive Design	-	-	3.25	-
Freeway Capacity/LOS	3.45	4.70	3.18	4.33
Multilane Highway Capacity/LOS	3.54	4.70	3.18	4.33
Two-Lane Highway Capacity/LOS	3.51	4.65	3.18	4.33
Traffic Safety	3.35	4.28	3.08	4.28
Economics/Life-Cycle Cost Analysis	-	-	3.01	3.4
Environmental Impact Assessment	-	-	2.99	-
Access Management	2.39	3.80	2.80	-
Intelligent Transportation Systems (ITS)	-	-	2.62	3.77
Highway Design Controls/Criteria	2.96	4.40	-	-
Highway Location/Scoping	2.55	4.38	-	-
Interchange Design	2.69	4.15	-	-
Roundabout Design	2.42	3.63	-	-
Traffic Calming	1.99	3.28	-	-

Intersection design and intersection sight distance had a difference in relative importance between employers and educations. Employers ranked it highly for new employees to know, just below horizontal and vertical curves and just above the stopping sight distance concept. On the other hand, the transportation educators, although giving it an overall score higher than the industry placed it only in the middle of importance for skills important for beginning a job at their company. Additionally, it only ranked in the middle of student's self-assessed knowledge level. This indicates that intersection design should be emphasized more than it is currently in the classroom.

Traffic control devices was a topic that students did not seem comfortable with. It was in the middle of the survey for both educators and employers. This indicates that it would be a topic worthy of more attention in the course syllabus and warrant a more prominent position in the design project.

Beyerlein et al. (2010) in a survey of transportation engineering educators found traffic flow characteristics and capacity studies to be near the top of topics that should be taught to some degree in transportation engineering. This somewhat agreed with the emphasized position of capacity in transportation engineering curricula compared to employer needs. While geometric design of highways (e.g. vertical and horizontal curvature) rises to the top of lists from students, employers and faculty, LOS seems to be overemphasized beyond the value placed on it by transportation engineering employers in the Midwest.

5.1.2. Computer aided design (CAD) skills

Table 8 shows a comparison between students who indicated their AutoCAD Civil 3D skills improved or not during the Fall PBL semester. The survey shows that students in the category "Did not Improve" actually showed a larger improvement than the students who indicated they had "Improved". Possible reasons for this include that students with low initial skill would have more potential for improvement. The majority of students who indicated they had improved actually gave themselves the same evaluation of Civil 3D scores as previously. This could be an indication of the, "more you learn, the less you know" phenomenon. Students realized how complex the software is and gave themselves a more moderate self-evaluation. What is more curious is that students indicating no improvement actually had an increase of 1 full point, bringing their average knowledge from "awareness of Civil 3D" to "novice." This may come from students merely being exposed further to the software, but not learning as much as they expected. The third category of "intermediate" represents a shift toward mastery of the software instead of simply exposure to it.

Table 8 – Comparison between Civil 3D Skills in Focus Groups and Surveys

Instrument	Improved	Did not Improve	Did not answer
Focus Group Interviews	6 (29%)	11 (52%)	4 (19%)
Pre-class Survey Civil 3D	2.67	1.18	2.00
Post-class Survey Civil 3D	3.20	2.20	1.50

A greater emphasis was placed on CAD during the Spring 2016 semester. This was continued during the Fall 2017 semester since, as noted previously, the employer survey showed that plan sheet creation was considered among the most important skills for students to know as a new employee in the highway design field. Continuing on this point, many job applications include CAD expertise as either preferred or required qualifications for entry-level positions. Table 9 below shows a search conducted on March 17th, 2017 through the Iowa State Cyhire website for full-time jobs listed as civil engineering, excluding jobs that look for all majors. Then a keyword search was done, first for all civil engineering positions, then on a subset that identified it as "transportation." The results show that jobs in transportation prefer the experience of either of the two major drafting software, AutoCAD, and Microstation. This does not include companies that desire the software and simply do not mention it.

Table 9 – Cyhire Keyword Search

Keyword	FT Positions	Percent
Civil Engineer	**136**	**100%**
Microstation	12	9%
AutoCAD	28	21%
Transportation	**23**	**100%**
Microstation	8	35%
AutoCAD	12	52%

Consequently, more time was devoted to CAD during lab sessions and additional resources were developed that students could utilize outside of class. Initial training was provided via classroom demonstrations and video tutorials. In addition, during the second week of the semester, an introductory workshop was presented to assist students in learning how to use the software.

Unfortunately, this in-class demonstration introduced challenges given the significant variability in skills among students. Consequently, a more effective way to present the material was through a series of "quick tutorials", which were comprised of short step-by-step PDFs that were posted to the course website. These proved popular among students because they could clearly see the progression of steps. These paper tutorials are provided in the knowledge transfer packet.

One important note related to the PBL framework as it relates to the highway design course is the manner in which CAD was utilized by project teams. In general, the CAD work was not distributed very evenly within and across the project teams. Teams were generally comprised of four to five students and this size proved too large to allow every member to participate in the design process. The challenge arose that only one student may have a design drawing open at a time. This meant that the remaining members of the team either work solely on other parts of the project, or passively watch their teammate do all the work. One possible direction for the future would be to allow rotating roles within project teams instead of letting them become fixed into specific roles. This idea was received with mixed feedback during student interviews. Some students said they would prefer the freedom to choose what role they have. Others expressed regret not having the opportunity to learn more software skills. Ultimately, there would need to be a good system of equipping and rotating all the students within a group into the different roles as well as a more balanced software load throughout the semester.

5.1.3. Effectiveness of learning aids and course reference materials

Table 10 presents the result of a question in the post-course survey asking about what materials contributed most to student learning. Although the focus of the class was on the project, it ranked as only the third most useful resource. As the traditional means of teaching resulted in the highest level of learning effectiveness it appears that student's familiarity with a teaching method correlated to its perceived usefulness. As this was only one question on the exam it would be interesting to expand this line of inquiry into further potential survey questions and even expand into the realm of qualitative inquiry to delve deeper.

Table 10 - Most Effective Learning Aids

Learning Aid	Rating (1 not useful to 5 very useful)
Sample Problems	4.50
Lecture	4.30
Project	4.15
Homework	4.08
Exam	3.75
Laboratory	3.73
References	3.45

It is notable that references were the least useful teaching aid in Table 10. Table 11 shows the references that were most frequently used by students. This reflects the manuals that students used over the semester. A response of "5" represents that the manual was used 10 or more times during the semester while "1" indicates it was never opened. The AASHTO Green Book was the top read book with and average on the high side between 3-5 and 6-10 times. This reflects the nature of the times these manuals were referred to, with the Iowa DOT design manual consulted frequently along with the Green Book The least widely used was the roadside design guide and pavement design guides used on average between 1-2 and 3-5 times during the semester. It is not abundantly clear from this survey why references are the least used resource. Their importance was stressed during lab.

Table 11 – Most Used References

Learning Aid	**Rating (1 least frequently used to 5 most frequently used)**
Geometric Design Manual	3.85
State Design Manual	3.65
Highway Capacity Manual	3.48
State or Local Specifications	2.73
Pavement Design Guide	2.68
Roadside Design Guide	2.68

5.2. Focus Group Interview Results

This section focuses on results of the series of focus group interviews that were conducted during the spring 2016 (pre-PBL) and fall 2016 (post-PBL) semesters. Focus group sampling is first evaluated to examine the extent to which participants are a representative example of the class. Table 12 shows that females tend to be overrepresented in both semesters' focus groups. International students are somewhat overrepresented in the spring semester, but entirely absent from the fall. The pre-course class interest shows a significant difference in the spring semester with the non-focus group students far more interested on average and narrowing to a smaller difference in the fall. The difference in self-assessed classroom topic ability is higher for the non-focus group students in the fall.

Table 12 - Focus Group Participants Descriptive Stats

Division/Field	n	International	Female	Pre-course Interest in Highway Design (5-pt scale)	Pre-course Self-assessment of Course Subjects
Spring Non-Focus Group	42	6 (14%)	3 (7%)	4.33	2.64
Spring Focus Group	25	6 (24%)	8 (32%)	3.25	2.84
Fall Non-Focus Group	50	16 (32%)	9 (18%)	4.00	2.87
Fall Focus Group	21	0 (0%)	5 (24%)	3.80	3.04

These data somewhat contradict preconceived notions as to who would volunteer for these interviews. It was assumed prior that only students interested in the course and transportation engineering would attend. However, since extra credit was offered and all the assignments had already been completed in the class at this point, it is possible only students who needed the credit volunteered. It would be useful to compare grades or other additional metrics in the future to see if they show any other even or uneven sampling patterns.

Six groups each semester were interviewed in total ranging from two to six participants per interview as seen in Table 13 below. The students were given the choice between six interview times to choose from, resulting in uneven group sizes. The interviews were recorded and hand-coded at a later time. Interviews views were conducted in a conference room, office, empty classroom or the highway design computer lab at the civil engineering building as they were available. It took around seven hours to transcribe and analyze each hour of interviews.

Table 13 - Focus Group Session Breakdown

Interview Session	Group Size	Interview Length (min)	Transcribed Words
Tues, 1pm April 26th	5	63	9,198
Tues, 3pm, April 26th	6	43	6,736
Tues, 4pm, April 26th	3	35	4,725
Tues, 10am, May 3rd	2	31	3,483
Wed, 10am, May 4th	5	60	8,135
Thurs, 10am, May 5th	4	57	9,386
Tues, 2pm, Dec 6th	5	32	3,914
Tues, 3pm, Dec 6th	3	40	6,791
Wed, 2pm, Dec 7th	4	28	4,576
Wed, 3pm, Dec 7th	3	22	3,118
Wed, 2pm, Dec 12th	4	29	4,824
Tues, 2pm, Dec 13th	2	35	5,873
Total	46	7 hr 55 min	70,759

The location that the interviews were administered seemed to have a slight difference on the character of each interview. Students seemed the most comfortable in the department computer lab, which is where many of them studied and worked on projects during the semester. This lab was only available to students in the class via key card access, so it retained a private feel. The conference room had a more formal atmosphere as it was an unfamiliar place to many of the students. The classroom was the worst environment, as it was too formal. In the final two interviews an available office was used, as the groups were small . This worked well, making both those interviews feel personal and the responses seem less filtered. In the future, it would be preferable to conduct all the interviews with identical group sizes and the same location. Students tended to be most relaxed and give more candid feedback in smaller, familiar rooms that fit their group size.

There were four main themes that arose out of the interviews that are relevant to the research questions in this paper:

1. assessment of project based structure;

2. classroom scaffolding;
3. software and teamwork skills; and
4. use of course reference manuals.

These are discussed one by one in the following sections.

5.2.1. Assessment of project-based learning

One important limitation that was noted prior to conversion to a PBL framework was that a limited amount of time was available to complete the project since the first few weeks of the course focused on topics other than the project. This was found to limit the creativity of students, with many of the designs following a very similar format. As one student noted, “It was just too clear cut at that point.”

Overall, there was not strong consensus in terms of student opinions regarding the use of a PBL framework. This was true of the semester both before and after course conversion to PBL. Interestingly, students who received it favorably included those from various disciplines. There was not a significant difference between those who declared a career interest in transportation engineering and those who did not. Several students thought PBL would present a more useful framework and specifically mentioned a senior capstone design class at the university that is taught in a PBL format. Another student mentioned it would help them learn the design process by contextualizing lab assignments into a larger project.

A first semester (pre-PBL) student felt PBL was particularly suitable for a transportation design class, “I feel like transportation is one of the more realistic subjects, like there’s not much theory involved compared to other structural classes for instance, which helps already, but having that [project based classroom] would be another step forward like what you would be doing in your job is create this whole roadway and just learning that step would give me a good foundation of your process where to even begin, 'build this project and which part do I start at' and I think that would really lay it out. I think it would be really beneficial."

This was common feedback among students from both semesters. A preference was identified for a step-by-step process where students learned the contextual background of transportation engineering along with the material itself. A student from the post-PBL conversion agreed, stating "I liked how what we did in lab [project material] was covering what we learned in lecture that week. So we applied what we learned in lecture in the project." This was a common theme, where students mentioned they enjoyed the overlap between lecture and the project lab. Learning only one topic at a time and integrating with the project was useful for student learning. Another student from the PBL group noted, "I really liked the project, it was long and it was hard, but it was really nice to be able to apply something through the project and apply everything we are learning through this one project that everything we are learning applies to. So, I liked that."

Overall, students had more positive feedback for the PBL semester over the traditional semester. They felt it was more practical and tied into the course material well.

5.2.2 Classroom scaffolding

A theme that emerged during the coding process was the challenge that the course gave. While difficulty does not equate directly to direction provided by the instructor, it can give a picture of how students are learning. Of the students in the spring semester (pre-PBL) focus group interviews, 9 out of 10 who mentioned class difficulty indicated the class and project were too easy. In contrast, during the fall (post-PBL) semester, four out of five students mentioning difficulty said the course was challenging.

Prior to the PBL conversion, one student interested in transportation found that, “I don’t know, it’s tough because we just don’t have that many transportation courses that challenge us… So I think it would be nice to have one transportation class that did challenge me, specifically for transportation.” Another pre-PBL student stated, “I had never once felt challenged this semester.” This particular student was fairly outspoken in support of the project based learning environment because of previous PBL experience through another class at the university.

In contrast, a post-PBL student interested in transportation made this observation, “I guess the lecture I didn’t feel was too extremely challenging, I thought [the professor] taught it really well and the homework tested over the course material really well. And then the lab I thought was challenging, it was challenging to work on the project with a group like that, when most people haven’t even done anything remotely like that.”

The relative unfamiliarity with PBL at the institution seemed to present a challenge to complete the project in a group. Non-project related coursework was not considered difficult. Another fall student not interested in transportation said this: “I think it’s like two different things, like the coursework itself, the homework and the tests I didn’t think it was that challenging, it was just a review of [introduction to transportation class] for the most part, but definitely the CAD stuff and the memos took a lot of work.”

Anecdotally, the overall impression students had on the class before and after changed, especially among student interested in transportation. The PBL classroom structured around the semester-long project was considered more practical and rigorous. A number of students expressed disappointment in the depth of content prior to PBL conversion. One student commented that their teammates' attitude was focused more on simply completing the project than on demonstrating mastery of the content.

As seen in the focus group interview comments, expectations must be set by the instructor to set a bar for project quality. Without this, students will fall into the pitfall of simply chasing grades instead of pursuing a greater knowledge of the design process. Students have to be talked through the process of why they are doing the project related tasks as opposed to simply working on one more class project. They need to recognize the difference between solving well defined problems and approaching problems that are not well structured. They need to understand the tools available are given to them and they have to reason their way through the uncertainty, stating assumptions in the process. This is harder than projects, and depends highly on the motivation of the students. In order for this classroom to be successful the instructor must foster the ambition within students to learn and take initiate of their own learning. When students have high expectations for their own projects, they can thrive in a PBL environment. Without it, the lack of structure could cause students to learn even less than in a traditionally based course.

5.2.3 Software and teamwork skills

Two fixed questions that remained the same in both semesters' focus ground interviews were about software and teamwork skills. The responses from the interviews were transcribed to a manuscript and then categorized into different groups of responses. In this way, qualitative data is quantified as previously demonstrated by Sandelowski et al. (2009). The final coded results are seen below in Table 14.

Table 14 - Focus Group Comparison Before and After PBL Implementation

Teamwork Improvement	Improved	Did not Improve	Did not answer
Spring (Before PBL)	3 (12%)	13 (52%)	9 (36%)
Fall (After PBL)	8 (38%)	5 (24%)	8 (38%)
Improvement Civil 3D	Improved	Did not Improve	Did not answer
Spring (Before PBL)	4 (16%)	17 (68%)	4 (16%)
Fall (After PBL)	6 (29%)	11 (52%)	4 (19%)

While more students mentioned they had improved their teamwork skills after conversion to a PBL framework, the proportion of students who felt there was improvement in this area was still relatively low. Prior to converting to PBL, one student said, “I think by having the projects so late in the semester, it didn't really force people to work together as it could have.” Another student stated they learned much more through a concurrent class that was taught in a PBL framework than from the (pre-PBL) highway design course. A common theme during the semester prior to conversion was that the course was either too easy or the necessary skills had already been learned previously and students doubted much benefit was gained from merely the end-of-semester project.

As revealed in the focus group interviews, 26% more students felt their skills improved from the first to second semester after PBL implementation. However, there were still only 8 out of the 21 students who mentioned that their teamwork skills were improved. The feedback remained mixed, students often expressed the drawbacks with the course along with the benefits. Many students found their teammates did not carry the appropriate workload, others found that as their classmates skipped class or project meetings regularly it became difficult to include all students in the projects. One student from the second semester mentioned that this class was useful as it prepared him to work in bad groups in the future. While promising, these are not the shining outcomes that would have been hoped for from PBL.

A marginal increase in CAD skills was seen from previous semesters; however, over 50% of students still indicated during the interview that their CAD skill had not improved. Several overarching attitudes emerged concerning software learning (1) I already knew a lot and didn't learn anything new, (2) I can learn it when I need to, (3) it was easy to just let my teammate do all the CAD work. A first semester student reflected on their software knowledge, "I hope I can figure it out [on the job]." What this student indicated was similar to a number of others who did not actively participate in their team CAD work. There was a consistent desire to know the software, most students acknowledged it would be useful to know for their careers, but they seemed to generally lack motivation to learn it if another teammate took that responsibility.

Relatedly, students in both semesters indicated a low confidence level in using CAD software. A good attitude was key for every team. A second semester student not pursuing transportation said about the software, "there is like a million different buttons… and I still don't know if I would be able to do the very specific lab." Software ability seems to relate closely to the confidence of students in job application as well. A first semester student pursuing transportation said, "filling out job applications, that [software ability] was definitely my weak point." A second semester student not pursuing transportation said, "Companies want you to have the [software] experience, but they don't want to hire you until you have that experience. But they are the ones who are going to give it to you, not school."

This indicates students believe employers prefer to hire employees that know how to use software prior to application. In contrast, another first semester student said, "I know enough to open up a file and figure it out and… not be a lost puppy." Although not necessarily reflected in actual ability, this student had a greater confidence in their CAD ability through project application that resulted in more positive attitude toward a transportation engineering career in general. A perceived lack of software qualifications was found to be a barrier preventing student from pursuing careers in transportation engineering.

The level of detail in interviews was sometimes shrouded by the fact that not every student answered every question, at least not verbally. Table 14 showed that around 16-38% of the respondents did not answer the question stated directly. There may have been times that a student does not feel the need to state their opinion because it was already agreed with previously and they don't feel the need to join. Conversely, a previously stated opinion may conflict with their own and they may not want to spark a confrontation with the previous student. For focus groups larger than four lack of individual input was an issue.

5.2.4 Use of course reference manuals

The references were not discussed frequently by students. It was only discussed one time in the first semester. This limited response is meaningful in itself. Even while the importance of manuals was stressed in both semesters, the short project at the end of the first semester did not force students to apply the manuals in much detail as it was not as in-depth. The second semester's students seemed to be more engaged with manuals. One student said understanding the manuals was the most challenging part of the class. Others mentioned it was extremely useful to be familiar with the manuals as they were used extensively in the capstone design class. A second semester student going into the transportation profession said, “I did like the fact that it went through basically all the AASHTO Green book and covered all the topics that as going forward into transportation engineering or design, that would be beneficial to know outside of class.” Another second semester student, unsure about what career path they would take said, “I’ve looked through the HCM and I’ve looked through the DOT manual. I mean, you’ll have some innate knowledge there…” This mentality is one that the instructor has passed down to the students. They are not expected to become masters of all transportation engineering manuals in a 15-week course, however this “innate knowledge” does stay with the students. Since all discussion about reference manual flowed freely from interviews with students, it gave greater strength to the argument that students are engaging more with the reference manuals.

5.3 Student Course Performance

While the pre- and post-course surveys revealed that students perceived greater learning than previously, student course grades were also examined to provide additional evidence as to the efficacy of the PBL format on improving student learning. To this end, data were examined regarding the grades received by both groups and individual team members. During the fall 2016 (PBL) semester, students were evaluated on the basis of two group project submittals (40%), nine sets of homework (20%), a midterm exam (30%) and peer evaluations (10%). Together, these represent the in-class assessment of student learning, as well as final course grade.

Teams were built by the instructor such that the weighted grade point average (GPA) would be approximately equal across teams on average. Figure 4 illustrates the relationship between individual student GPA and the corresponding project grade for the fall 2016 semester. Collectively, these data show that the performance of individual teams on the group project tracked reasonably well with respect to the pre-course GPA of the best (i.e., highest GPA) student in each group.

When considering student performance among those with the low and average GPAs on teach team, a positive trend exists, but the results are much more variable as compared to the top students. These findings suggest that GPA is a particularly important factor to consider when developing teams for a course that is instructed in a PBL format. It is important to note that a variety of additional factors were also considered in team formation, so there are certainly other aspects to consider in this regard, as well.

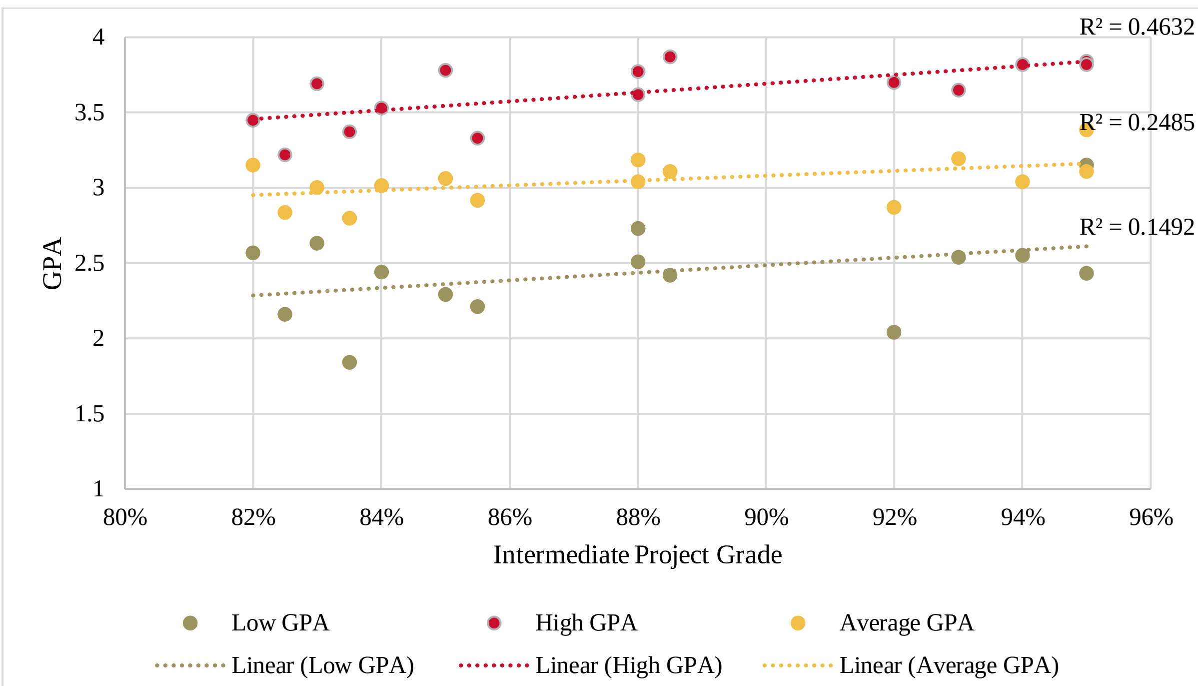

Figure 4 – Team GPA vs. Intermediate Project Grade

Continuing on this investigation, Figure 5 shows a comparison between individual course grades from the highest achieving student on each team and the lowest achieving student on each team. The individual grades consist of the homework and exam scores of the students. Unsurprisingly, the highest achieving student's individual grades within each team were highly correlated with that group's project grades. This may be a reflection of intrinsic or extrinsic differences between higher achieving students and their peers. Perhaps more interestingly, the individual grades of lower achieving students rose along with their team grades as well.

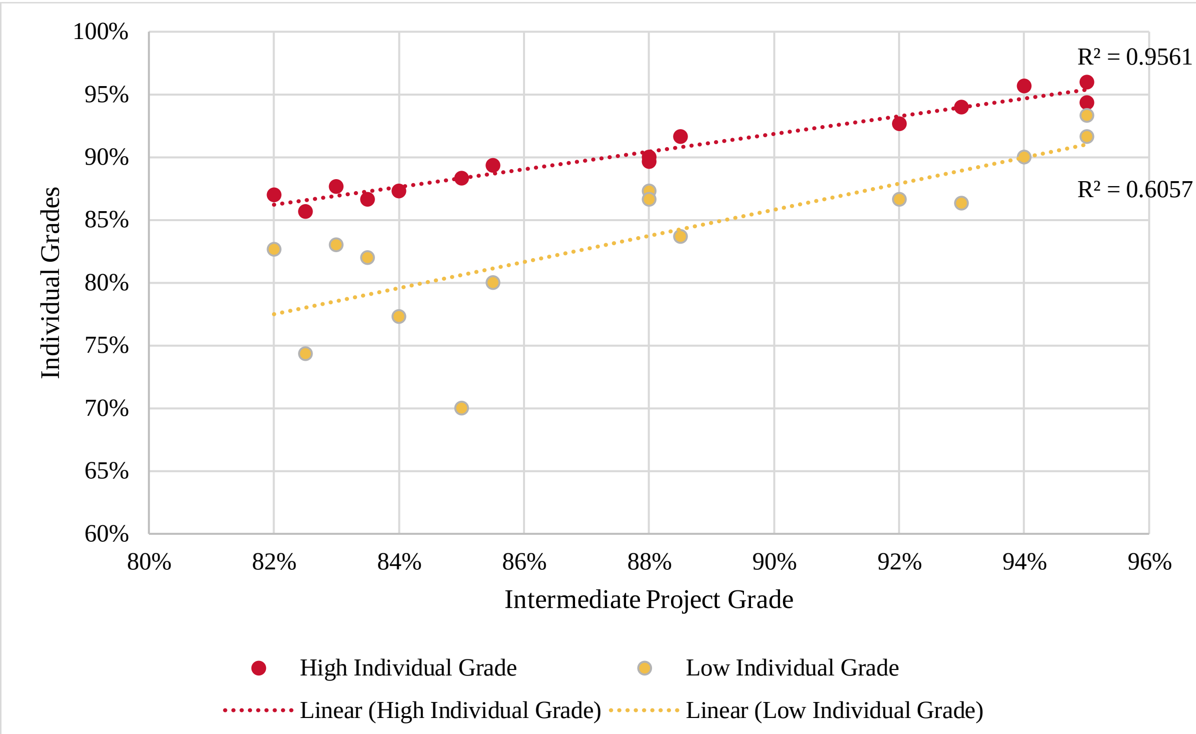

Figure 5 – Project Grade vs. High and Low Individual Grades per Team

The results from Figure 5 provide some evidence that additional learning may have occurred within the groups as a result of PBL. Considering the equality in group pre-course GPA, the greater performance among lower performing students in the higher performing groups may be attributable, at least in part, to team learning. Anecdotally, this is supported by several students in the focus group interviews, who indicated they used their teammates as a reference for homework and studied for the exam together in the project groups.

It was thought students' interest level in transportation may also be a factor affecting academic performance. A pre-course survey question asked for discipline specific focus (e.g., structural, transportation). This question allowed students to select multiple disciplines or no specific discipline of interest, as well. As seen in Table 15, only 10 students indicated transportation was their only interest, while 33 included it together with other disciplines. These students were generally ranked slightly higher than their classmates on the peer evaluations, but tended to achieve lower scores on the exam. Overall, this analysis revealed that few differences existed between course outcomes based on transportation interest.

Table 15 - Focus Group Comparison Before and After PBL Implementation

	Transportation Interest Only	Not Transportation Interest Only	Transportation Among Others	No Transportation Interest
Count	10	61	33	38
GPA	2.92	3.07	3.01	3.08
Homework	86.6%	88.0%	87.9%	87.7%
Exam	74.0%	82.4%	80.9%	81.4%
Peer Eval 1	1.03	0.97	0.98	0.97
Peer Eval 2	0.99	0.97	0.97	0.97

Students were also assessed by their peers for grading and team evaluation purposes. These peer evaluations were conducted twice over the course of the semester, once after the intermediate project submission, and again after the final project submittal. Peer evaluation scores were normalized such that the within-group average was equal to 1.0. Students in groups with low performing members could receive as high as 1.05 on their peer evaluation. Figure 6 below shows the comparison between grade relative to the group average and the average peer evaluations they received. Twelve students received high peer evaluations and yet performed worse than their peers (represented in the bottom right portion of Figure 6). Conversely, 13 other students performed better on individual assignments than their peers, yet received lower peer evaluations (top left portion of Figure 6.) These results are highly uncorrelated, being almost evenly distributed across the y-axis. It does, however, attest to the presence of other factors contributing toward high and low peer evaluations. Many of the students receiving low peer evaluations were non-native English speakers. On average, this group scored higher than their teammates on individual assignments and yet received far lower peer evaluations. These students were typically international and faced challenges communicating and coordinating work with their domestic peers. Understanding cultural diversity among teams is an excellent area of future study in light of this result.

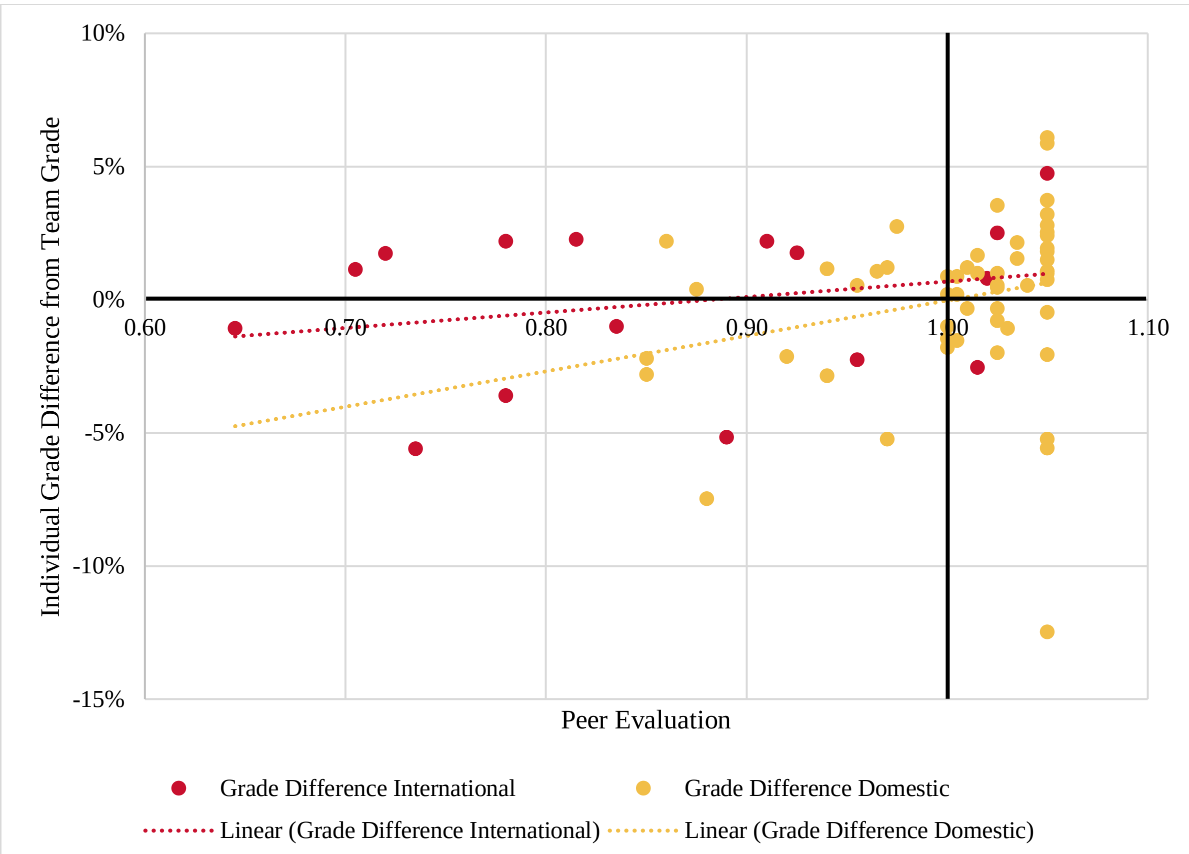

Figure 6 – Peer Reviews vs. Individual Grade Difference from Team Average

CHAPTER 6: CONCLUSION

Ultimately, the results of this study provide several important contributions to the research literature. First, the results of an agency survey were used to better align course learning outcomes with industry expectations as to the skillsets of entry-level employees. This provided critical insights as to how classroom practices may be tailored to meet the needs of prospective employers. The study also details differences as to the relative importance of various skills from the perspectives of various types of transportation sector employers. Many of the findings affirm the foci of existing highway design courses, in addition to supporting previous research as to the importance of soft skills and other strengths that are most critical to entry-level professionals.

This study also examines the efficacy of converting the highway design course from a more traditional lecture format to a project-based learning (PBL) framework. This assessment shows some important benefits, including general improvements in self-assessed student learning across the topic areas most relevant to the course project. This has several pedagogical implications of PBL within the transportation engineering classroom. PBL was found to:

- Elicit greater student enthusiasm for the highway design course.
- Enhance student course performance and self-confidence.
- Enable learning to occur within groups, as high performing students assisted their teammates to learn course content.

The results of focus group interviews also showed the revised course structure addressed existing concerns as to the degree of overlap in course content between the highway design course and a pre-requisite introduction to transportation engineering. Table 16 shows that in the spring (pre-PBL) semester, nearly half of the students mentioned the degree of overlap as a particular concern. This rate was significantly reduced during the fall (post-PBL) offering of the course.

Table 16 – Overlap with Prior Course Content from Focus Group Interviews

Semester	Students Interviewed	Good Overlap	Too much Repetition
Spring (pre-PBL)	25	1	11
Fall (post-PBL)	21	2	3

The study also led to the identification of several areas that could be improved in subsequent offerings. Several students indicated that it was challenging for them to learn the computer aided design (CAD) software, particularly as many students were in their final semester or two in the program. Various students suggested they would have received more benefit from learning CAD earlier and this finding, in part, led to the integration of CAD software into a freshman level course during the spring 2017 semester. Further integration of CAD into sophomore- and junior-level classes is recommended and, in addition to improving CAD skills, would increase marketability for entry-level design positions.

One important drawback of the PBL approach was the degree to which all team members participated in the project during the semester. This issue was raised during the focus group interviews conducted prior to course conversion. Consequently, a peer assessment tool was added during the fall 2016 (post-PBL) offering. Students were asked about each team member's contributions, interactions with teammates, general quality of performance, and level of relevant knowledge, skills and abilities. Unfortunately, interviews with students after the fall 2016 semester indicated that peer evaluations at the mid-way and end of the semester were generally too late to improve team dynamics. Consequently, an additional peer evaluation is recommended within the first four weeks for subsequent semester. This will help students solve any potential issues within their groups sooner.

6.1 Limitations

There are several potential limitations of this study that should be acknowledged. The first of these is the positioning of the focus group interviewer. All interviews were conducted by the teaching assistant, who had also established a professional relationship with the majority of students over the semester. Potentially, students may be less likely to give negative feedback about the class to their teaching. The relationship between researcher and students does temper how the feedback is understood, but it also brings a strength in that the interviewer had an intimate knowledge of the class and was someone that students were comfortable talking to.

Students were incentivized to take the post-course survey and participate in the focus group interviews through the provision of a nominal amount of extra credit. This could introduce a bias by encouraging participation by lower performing students. However, the outcomes from post-course surveys were similar and this did not appear to be a significant factor.

Another important limitation is the difference in instructors between the spring 2016 and fall 2016 semesters. This creates potential confounds in the data and it is unclear how significant this impact is on comparisons across semesters. To mitigate this concern, the general course content did not change substantially between instructors, except for strategic changes made based on the spring 2016 focus group interviews. Furthermore, the teaching assistant who led the laboratory sessions remained the same between both semesters, which is expected to have also improved consistency across the groups.

With respect to the industry survey, it should be acknowledged that recipients were asked to answer the questions on the basis of preparing students for a career in highway design. This could explain, in part, why the survey found relatively low importance regarding topics such as highway capacity, LOS, and ITS. These differences may also be reflective of the Midwest region where the survey was conducted. The responses are expected to be somewhat different if the survey was implemented in other areas of the United States or, particularly, in other countries.

6.2 Future Work

For subsequent research, it will be useful to gain insights and perspectives from junior engineers who have recently graduated. Their perspective will be valuable since they are the least removed from the university setting and could offer important feedback as to valuable workplace skills or what were the biggest gaps between their education and professional practice. If these surveys are conducted on students who previously participated in the focus group interviews it could become a longitudinal study to see how project based learning affects students' attitudes over time and what gaps they had in their learning if any.

Another future topic of interest could be to analyze regional differences in highway design practice. These differences would be crucial to understanding how transportation engineering education can be tailored to the needs of industry. For example, there are likely differences in the degree to which engineering companies value specific topic areas across geographic regions. Similar variation may be expected based upon the context of the university where a highway design course is taught. How these findings translate in consideration of differences in students, departments, and university climates is one area that could be explored through future research.

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APPENDIX A: EMPLOYER SURVEY QUESTIONS

Iowa State University (ISU) is seeking input into the curriculum for Civil Engineering (CE) 453: Highway Design. This survey is intended to obtain input as to the most important knowledge, skills, and abilities among students pursuing a career in highway design. Your participation in this survey and input on these questions is greatly appreciated.

Question 1.)
Contact information:
Name, Position title, E-mail, Phone number

Question 2.)
Which category best describes your company/organization?
- ❍ State DOT
- ❍ County, Municipality, or Other Public Organization
- ❍ Private Company (National or International)
- ❍ Private Company (State or Regional)
- ❍ Other ____________________

Question 3.)
Does your company/organization conduct any highway/transportation design work?
- ❍ Yes
- ❍ No

Question 4.)
How important is it that civil engineering graduates are familiar with the following software/manuals before beginning an entry-level position at your company/organization?

	Not imp.	Slightly imp.	Moder. Imp.	Imp.	Very imp.	Unsure
AutoCAD Civil 3D	☐	☐	☐	☐	☐	☐
Bentley Microstation	☐	☐	☐	☐	☐	☐
ESRI ArcGIS	☐	☐	☐	☐	☐	☐
Highway Capacity Manual (HCM) and Highway Capacity Software (HCS)	☐	☐	☐	☐	☐	☐
Trafficware Synchro/SimTraffic	☐	☐	☐	☐	☐	☐
PTV Vissim/Vissum	☐	☐	☐	☐	☐	☐
AASHTO Green Book	☐	☐	☐	☐	☐	☐
AASHTO Roadside Design Guide	☐	☐	☐	☐	☐	☐
AASHTO Highway Safety Manual (HSM)	☐	☐	☐	☐	☐	☐
MUTCD	☐	☐	☐	☐	☐	☐
State/Local Design Manuals and Specifications	☐	☐	☐	☐	☐	☐

Question 4a.)
Please list any additional software/manuals for which you believe prior experience is important among recent civil engineering graduates.

Question 5.)
How important is it that civil engineering graduates are familiar with the following highway design topics before beginning an entry-level position at your company/organization?

	Not imp.	Slightly imp.	Moder. imp.	Imp.	Very imp.	Unsure
Access Management	❍	❍	❍	❍	❍	❍
Bicyclists, Pedestrians, and ADA Design	❍	❍	❍	❍	❍	❍
Capacity and Level of Service	❍	❍	❍	❍	❍	❍
Cross-Section, Plan, and Profile Drawings	❍	❍	❍	❍	❍	❍
Decision, Passing, and Stopping Sight Distance	❍	❍	❍	❍	❍	❍
Design Controls, Criteria, and Functional Classification	❍	❍	❍	❍	❍	❍
Drainage/Runoff Design	❍	❍	❍	❍	❍	❍
Earthwork and Grading	❍	❍	❍	❍	❍	❍
Economics/Life-Cycle Cost Analysis	❍	❍	❍	❍	❍	❍
Environmental Impact Assessment	❍	❍	❍	❍	❍	❍
Design Flexibility/Context Sensitive Design	❍	❍	❍	❍	❍	❍
Highway Safety and Crash Countermeasures	❍	❍	❍	❍	❍	❍
Intelligent Transportation Systems (ITS)	❍	❍	❍	❍	❍	❍
Horizontal Curve Design (e.g., simple, compound, reverse, spiral, transitions)	❍	❍	❍	❍	❍	❍
Intersection Design and Intersection Sight Distance	❍	❍	❍	❍	❍	❍
Pavement Design	❍	❍	❍	❍	❍	❍
Roadside Design	❍	❍	❍	❍	❍	❍
Temporary Traffic Control/Work Zones	❍	❍	❍	❍	❍	❍
Traffic Control Devices (e.g., signs, markings)	❍	❍	❍	❍	❍	❍
Vertical Curve Design (e.g., crest, sag)	❍	❍	❍	❍	❍	❍

Question 7.)
Please list any additional topics you believe are important for recent graduates to be knowledgeable about when beginning an entry-level highway design position.

Question 8.)
How important are the following skills among civil engineering graduates beginning an entry-level position at your company/organization?

	Much less important	Less important	More important	Much more Important
Making technical presentations	❍	❍	❍	❍
Report writing	❍	❍	❍	❍
Working with others in a team	❍	❍	❍	❍
Management skills	❍	❍	❍	❍
Critical/analytical thinking	❍	❍	❍	❍
Innovation and creativity	❍	❍	❍	❍
Ethical judgment and decision-making	❍	❍	❍	❍
Ability to independently learn new technical skills	❍	❍	❍	❍

Question 9.)
Please list any additional skills you believe are important for recent civil engineering graduates beginning an entry-level highway design position.

Question 10.)
How important are the following when hiring a recent graduate for an entry-level highway design position?

	Not important	Slightly important	Moderately important	Important	Very important
Co-op or internship experience	❍	❍	❍	❍	❍
Engineer-in-Training (EIT) or Professional Engineer (PE) license	❍	❍	❍	❍	❍
Master's degree	❍	❍	❍	❍	❍

APPENDIX B: EMPLOYERS SURVEY RESPONSES

Company/Agency Name	Employer Type	Responses
Adams County, Illinois	Local Agency	1
Anderson Bogert	Local Company	1
Bollinger, Lach and Associates	Local Company	1
Burns and McDonnell	National Company	1
Butler County, Iowa	Local Agency	1
CDA Engineering	Local Company	1
CGA Consultants	Local Company	1
City of Ames, Iowa	Local Agency	1
City of Davenport, Iowa	Local Agency	1
City of Elk River, Minnesota	Local Agency	1
City of Geneva, Illinois	Local Agency	1
City of Wheaton, Illinois	Local Agency	1
Clinton County, Iowa	Local Agency	1
Crawford County, Iowa	Local Agency	1
Des Moines Area Regional Transit Authority (DART)	Local Agency	1
Fehr Graham	Local Company	1
FHU Engineering	Local Company	1
Florida Dept. of Transportation	State DOT	1
Foth Infrastructure and Environment	National Company	2
Franklin County, Iowa	Local Agency	1
Garden Associates	Local Company	1
Georgia Dept. of Transportation	State DOT	1
Grundy County, Iowa	Local Agency	1
Hall Engineering	Local Company	1
Hardin County, Iowa	Local Agency	1
HDR Inc.	National Company	2
HGM Associates	Local Company	1
HR Green	Local Company	1
Icon Engineering	Local Company	1
Idaho Dept. of Transportation	State DOT	1
Iowa Dept. of Transportation	State DOT	1
Jackson County, Iowa	Local Agency	1
JEO Consultants	Local Company	1
Johnson County, Iowa	Local Agency	1
Kansas Dept. of Transportation	State DOT	2
Kentucky Dept. of Transportation	State DOT	1
Kimley-Horn	National Company	3
Kirkham Michael	Local Company	1
KL Engineering	Local Company	2

Company/Agency Name	**Employer Type**	**Responses**
Linn County, Iowa	National Company	1
Los Angeles County Dept. of Public Work, California	Local Agency	1
McClure Engineering Company	Local Company	4
Minnesota Dept. of Transportation	Local Company	1
Montana Dept. of Transportation	Local Agency	1
MSA Professional Services	Local Agency	2
Muscatine County, Iowa	Local Agency	1
Nebraska Dept. of Public Roads	Local Agency	1
Oregon Dept. of Transportation	Local Agency	1
Pocahontas County, Iowa	Local Agency	1
Primera Engineering	Local Agency	1
Santa Barbara County, California	Local Agency	1
Shoff Engineering	Local Company	1
Scott County Iowa	Local Company	1
SE3	State DOT	1
SEH inc.	National Company	1
Shive-Hattery	Local Agency	1
Shoemaker Haaland	Local Company	1
Snyder & Associates	State DOT	1
South Carolina Dept. of Transportation	Local Agency	1
SRF Consulting	Local Company	1
Stanley Group	Local Agency	5
Strand Associates	National Company	1
Sundquist Engineering	Local Company	1
Tennessee Dept. of Transportation	Local Company	1
TKDA	Local Company	1
Transsystems	State DOT	1
Unknown	State DOT	4
Utah Dept. of Transportation	Local Agency	1
Village of Lombard, Illinois	Local Company	1
Washington Dept. of Transportation	Local Agency	1
Winnebago County, Illinois	State DOT	1
Wisconsin Dept. of Transportation	State DOT	1
WSP |Parsons Brinkerhoff	National Company	1
Wyoming Dept. of Transportation	Local Agency	1
Total		91

APPENDIX C: PRECOURSE CLASS SURVEY

Q1 Name

Q2 Nickname

Q3 Hometown, State/Province, Country

Q4 Academic standing
- ❍ Junior
- ❍ Senior
- ❍ Graduate Student
- ❍ Other (please specify) ____________________

Q5 Interest areas in Civil Engineering (check all that apply)
- ❑ General Civil
- ❑ Construction
- ❑ Environmental
- ❑ Geotechnical
- ❑ Materials
- ❑ Structural
- ❑ Transportation

Q6 How interested are you in this course? (be honest!)
- ❍ Very interested
- ❍ Somewhat interested
- ❍ Indifferent
- ❍ Somewhat disinterested
- ❍ Very disinterested

Q7 Do you prefer having lecture notes available on blackboard before class?
- ❍ Yes
- ❍ No

Q8 How do you prefer to work on homework/projects?
- ❍ Alone
- ❍ In a group
- ❍ No preference

Q9 Which style of teaching do you prefer?
- ❍ Inductive (start with examples, then overall concept)
- ❍ Deductive (start with overall concept, then example)
- ❍ No preference

Q10 I prefer courses that focus on:
- ❍ Theory
- ❍ Application
- ❍ No preference

Q11 I am likely to be considered:
- ❍ Outgoing
- ❍ Reserved

Q12 Which of these courses have you taken? (check all that apply)

	Already Taken	Currently Taking	Not Taken
CE 306	❍	❍	❍
CE 355	❍	❍	❍
CE 372	❍	❍	❍
CE 382	❍	❍	❍

Q13 Are you potentially interested in graduate school?
- ❍ Yes
- ❍ Maybe
- ❍ No

Q14 Rate your skill level with the following software programs: See the NIH competencies proficiency scale as a guide, this will help explain your software skill level to employers.

	No Awareness (0)	Fundamental Awareness (1)	Novice (2)	Intermed. (3)	Advanced (4)	Expert (5)
Excel	❍	❍	❍	❍	❍	❍
Civil 3D	❍	❍	❍	❍	❍	❍
Microstation	❍	❍	❍	❍	❍	❍
GEOPAK	❍	❍	❍	❍	❍	❍
HCS	❍	❍	❍	❍	❍	❍

Q15 How Familiar are you with the topics presented in CE 453?

	I have never heard of it (1)	I have heard of it, but do not know what it is (2)	I have some idea of but not very clear (3)	I understand the concept, but could not perform the calculations (4)	I could perform calculations and understand and explain the concept to others (5)
Functional Classification	❍	❍	❍	❍	❍
Highway Location/Scoping	❍	❍	❍	❍	❍
Freeway Capacity/LOS	❍	❍	❍	❍	❍
Multilane Highway Capacity/LOS	❍	❍	❍	❍	❍
Two-Lane Highway Capacity/LOS	❍	❍	❍	❍	❍
Highway Design Controls/Criteria	❍	❍	❍	❍	❍
Stopping Sight Distance	❍	❍	❍	❍	❍
Vertical Curve Design	❍	❍	❍	❍	❍
Horizontal Curve Design	❍	❍	❍	❍	❍
Superelevation	❍	❍	❍	❍	❍
Cross-Section & Roadside Design	❍	❍	❍	❍	❍
Traffic Safety	❍	❍	❍	❍	❍
Interchange Design	❍	❍	❍	❍	❍
Intersection Sight Distance	❍	❍	❍	❍	❍
Access Management	❍	❍	❍	❍	❍
Intersection Design	❍	❍	❍	❍	❍
Roundabout Design	❍	❍	❍	❍	❍
Traffic Calming	❍	❍	❍	❍	❍
Flexible Pavement Design	❍	❍	❍	❍	❍
Rigid Pavement Design	❍	❍	❍	❍	❍
Earthwork/Mass Balance	❍	❍	❍	❍	❍
Traffic Control	❍	❍	❍	❍	❍
Temporary Traffic Control	❍	❍	❍	❍	❍

Q16 List up to 2 students you are NOT comfortable working with on a team (If none, leave blank)

Student 1
Student 2

Q17 Who is your favorite band or musician?

Q18 What is your favorite professional sports team?

Q19 What is your favorite television show?

Q20 What is your favorite thing about Iowa State/Ames?

Q21 What was your summer break highlight?

APPENDIX D: POSTCOURSE CLASS SURVEY

Q1 Name

Q2 After taking this course, would you say your interest in transportation engineering has:
- ❍ Decreased significantly (2)
- ❍ Decreased slightly (4)
- ❍ Remained about the same (5)
- ❍ Increased slightly (6)
- ❍ Increased significantly (7)

Q3 How frequently did you refer to the following resources over the course of the semester?

	Never (1)	1-2 times (2)	3-5 times (3)	6-10 times (4)	More than 10 times (5)
AASHTO Green Book (A Policy on Geometric Design of Highways and Streets)	❍	❍	❍	❍	❍
AASHTO Pavement Design Guide	❍	❍	❍	❍	❍
AASHTO Roadside Design Guide	❍	❍	❍	❍	❍
Highway Capacity Manual	❍	❍	❍	❍	❍
Iowa DOT Design Manual	❍	❍	❍	❍	❍
Statewide Urban Design and Specifications (SUDAS)	❍	❍	❍	❍	❍

Q4 Indicate your perceived value of the following course components (in terms of how well each component helped you to learn the material).

	Not valuable (1)	Somewhat valuable (2)	Unsure (3)	Valuable (4)	Very valuable (5)
PowerPoint Lecture Slides (1)	❍	❍	❍	❍	❍
Reference Texts (8)	❍	❍	❍	❍	❍
In-Class Example Problems (2)	❍	❍	❍	❍	❍
Worked Out Sample Problems (Blackboard) (7)	❍	❍	❍	❍	❍
Homework Assignments (3)	❍	❍	❍	❍	❍
Laboratory Sessions (4)	❍	❍	❍	❍	❍
Course Project Work (5)	❍	❍	❍	❍	❍
Mid-Term Exam (6)	❍	❍	❍	❍	❍

Q5 How familiar are you with the following topics that were covered in CE 453?

	I have never heard of it (1)	I have heard of it, but do not know what it is (2)	I have some idea of but not very clear (3)	I understand the concept, but could not perform the calculations (4)	I could perform calculations and understand and explain the concept to others (5)
Functional Classification (1)	❍	❍	❍	❍	❍
Highway Location/Scoping (2)	❍	❍	❍	❍	❍
Freeway Capacity/LOS (3)	❍	❍	❍	❍	❍
Multilane Highway Capacity/LOS (4)	❍	❍	❍	❍	❍
Two-Lane Highway Capacity/LOS (5)	❍	❍	❍	❍	❍
Highway Design Controls/Criteria (6)	❍	❍	❍	❍	❍
Stopping Sight Distance (7)	❍	❍	❍	❍	❍
Vertical Curve Design (8)	❍	❍	❍	❍	❍
Horizontal Curve Design (9)	❍	❍	❍	❍	❍
Superelevation (10)	❍	❍	❍	❍	❍
Cross-Section & Roadside Design (11)	❍	❍	❍	❍	❍
Traffic Safety (12)	❍	❍	❍	❍	❍
Interchange Design (13)	❍	❍	❍	❍	❍
Intersection Sight Distance (14)	❍	❍	❍	❍	❍
Access Management (15)	❍	❍	❍	❍	❍
Intersection Design (16)	❍	❍	❍	❍	❍
Roundabout Design (17)	❍	❍	❍	❍	❍
Traffic Calming (18)	❍	❍	❍	❍	❍
Flexible Pavement Design (19)	❍	❍	❍	❍	❍
Rigid Pavement Design (20)	❍	❍	❍	❍	❍
Earthwork/Mass Balance (21)	❍	❍	❍	❍	❍
Traffic Control (22)	❍	❍	❍	❍	❍
Temporary Traffic Control (23)	❍	❍	❍	❍	❍

Q6 Rate your skill level with the following software programs: See the NIH competencies proficiency scale as a guide, this will help explain your software skill level to employers.

	No Awareness (0)	Fundamental Awareness (1)	Novice (2)	Intermediate (3)	Advanced (4)	Expert (5)
AutoCAD Civil 3D (2)	❍	❍	❍	❍	❍	❍
Highway Capacity Software (5)	❍	❍	❍	❍	❍	❍

Q7 How did the course workload compare to other 400-level CCEE courses you have taken?
- ❍ Significantly less work (1)
- ❍ Slightly less work (2)
- ❍ Similar work to other CCEE courses (3)
- ❍ Slightly more work (4)
- ❍ Significantly more work (5)

Q8 How would you compare the pace of this course to other 400-level CCEE courses you have taken?
- ❍ Significantly slower pace (1)
- ❍ Slightly slower pace (2)
- ❍ Similar pace to other CCEE courses (3)
- ❍ Slightly faster pace (4)
- ❍ Significantly faster pace (5)

Q9 How much do you feel you learned in this course as compared to other 400-level CCEE courses you have taken?
- ❍ Significantly less (1)
- ❍ Slightly less (2)
- ❍ Similar amount of learning compared to other CCEE courses (3)
- ❍ Slightly more (4)
- ❍ Significantly more (5)

Q10 How useful do you feel supplemental instructional videos would be for the following general areas?

	Not valuable (1)	Somewhat valuable (2)	Unsure (3)	Valuable (4)	Very valuable (5)
AutoCAD Civil 3D (1)	❍	❍	❍	❍	❍
Review of CE 355 Material (2)	❍	❍	❍	❍	❍
Introduction/Overview of CE 453 Topics (3)	❍	❍	❍	❍	❍
Sample Problems for CE 453 Topics (4)	❍	❍	❍	❍	❍

Q11 Would you prefer weekly quizzes or weekly homework assignments for a grade?

❍ Strongly prefer quizzes (1)
❍ Slightly prefer quizzes (2)
❍ No preference (3)
❍ Slightly prefer homework (4)
❍ Strongly prefer homework (5)

Q12 What grade do you believe you deserve in this course?

Q13 Please provide any suggestions you may have that could increase the level of attendance for the lecture sessions.

Q14 Please provide any additional suggestions you feel would improve the quality of this course and your ability to learn the material.

APPENDIX E: IRB APPROVAL SHEET

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
1138 Pearson Hall
Ames, Iowa 50011-2207
515 294-4566
FAX 515 294-4267

Date: 5/13/2016

To: Steven Younkin
394 Town Engineering

CC: Dr. Peter T Savolainen
482A Town Engr

From: Office for Responsible Research

Title: Identifying Problems in the Current Highway Design Class

IRB ID: 16-212

Study Review Date: 5/13/2016

The project referenced above has been declared exempt from the requirements of the human subject protections regulations as described in 45 CFR 46.101(b) because it meets the following federal requirements for exemption:

- (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey or interview procedures with adults or observation of public behavior where
  - Information obtained is recorded in such a manner that human subjects cannot be identified directly or through identifiers linked to the subjects; or
  - Any disclosure of the human subjects' responses outside the research could not reasonably place the subject at risk of criminal or civil liability or be damaging to their financial standing, employability, or reputation.

The determination of exemption means that:

- **You do not need to submit an application for annual continuing review.**
- **You must carry out the research as described in the IRB application.** Review by IRB staff is required prior to implementing modifications that may change the exempt status of the research. In general, review is required for any modifications to the research procedures (e.g., method of data collection, nature or scope of information to be collected, changes in confidentiality measures, etc.), modifications that result in the inclusion of participants from vulnerable populations, and/or any change that may increase the risk or discomfort to participants. Changes to key personnel must also be approved. The purpose of review is to determine if the project still meets the federal criteria for exemption.

  Non-exempt research is subject to many regulatory requirements that must be addressed prior to implementation of the study. Conducting non-exempt research without IRB review and approval may constitute non-compliance with federal regulations and/or academic misconduct according to ISU policy.

  Detailed information about requirements for submission of modifications can be found on the Exempt Study Modification Form. A Personnel Change Form may be submitted when the only modification involves changes in study staff. If it is determined that exemption is no longer warranted, then an Application for Approval of Research Involving Humans Form will need to be submitted and approved before proceeding with data collection.

Please note that you must submit all research involving human participants for review. **Only the IRB or designees may make the determination of exemption**, even if you conduct a study in the future that is exactly like this study.

Please be aware that **approval from other entities may also be needed.** For example, access to data from private records (e.g. student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. **An IRB determination of exemption in no way implies or guarantees that permission from these other entities will be granted.**

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.