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Concepts in roundabout resources: A comparison between academic and practical text using content analysis

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Abstract

Through the analysis of textual resources in reference to roundabout design, researchers explored possible differences in context presented in academic and practice-based resources through comparison of use and representation of engineering concepts. Researchers completed a content analysis of academic resources (i.e. textbooks) and field-collected, workplace resources (i.e. state and federal design guidelines and standards). Using engineering concepts (i.e. "sight distance," "superelevation," etc.) as units of analysis, researchers compared these two forms of material resources according to the prevalence of engineering concepts utilized, types of inscriptions utilized in concert with the concepts, structural differences in the layout of the resources, and differences in meaning associated with word usage in the two different forms of texts. Initial findings indicate suggestive (but inconclusive evidence) of a difference in use of visual representations in the texts. In regards to use and representation of engineering concepts, concepts descriptive of geometric elements of roundabouts were equally prevalent in both types of resources. Overall, there existed suggestive, but inconclusive evidence, in a difference in density of use of words relating to transportation engineering concepts between the two types of textual resources. The most interesting outcome of the analysis of data is the apparent different functions of auxiliary verbs between the sources in communicating information regarding design of roundabouts. This research explores textual resources from a situated learning lens allowing identification of concepts that are relevant to engineers as they design a specific transportation facility. It also initiates the identification of contexts relevant to the day-to-day work of practicing engineers. Students are viewed as "newcomers" as they transition from academia to industry and are poised to learn and be mentored by "old timers" through firsthand and secondhand experiences. As such, newcomers tend to learn via the perspective of their mentors, and- as cited by studies of newcomers to industry - they may not utilize their academic resources in the same way or even at all as they make their transitions to the workplace. By comparing the types of resources relevant to newcomers' experiences, and in particular, differences in the ways concepts are presented and the discourse emergent within the text, the gap between academia and practice may be better bridged.

Introduction

The ability to recognize, identify, choose, and utilize relevant resources in the workplace is a necessary skill for engineers as they complete tasks. However, the type of resource (as well as its presentation of content, concept, and context) varies in determined necessity. In research of learning, existing perspectives tend to define concepts as authoritatively and cognitively inclined—a concept is a single thing that is non-negotiable and has a specified approach. In the workplace, concepts may function differently as posed beyond these ideals. Concepts may be situated, distributed, and pragmatic, and may be negotiated according to the project at hand. This study initiates a series of studies proposing the malleability of concepts in the workplace that is not actively addressed in academia and engineering instruction. Studies regarding the validity of the utilization of resources in academia with concerns to preparedness for the workplace is very sparse. This study attempts to provide insight into this gap in engineering education literature.

During their undergraduate education, engineering students are often required to utilize a myriad of textbooks and other academic resources. Indeed, it is commonplace for most engineering courses to require these types of textual materials suggesting that such resources will allow for the most apt preparation with regards to the workplace and future endeavors. This assumption must be critically assessed to ensure that students – "newcomers" within the engineering community of practice – are introduced to the contexts they may face as they engage deeper into the civil engineering community. Additionally, researchers and practitioners have been concerned about the lack of creativity and practical knowledge amongst recently graduated engineering students. Results from a study of six firms indicated that engineers commonly prided creativity and flexibility over concrete technical understanding[1].

Despite this identification of value, there still exists substantial investment required to ensure engineering graduates have such skills. The engineering industry commonly invests time in training students who have recently entered the workforce, especially with concerns on how to approach problem-solving, which has led to efforts being made to reform engineering education[2]. Engineers who enter the workplace face difficulty in defining problems when the problems do not fit a specific mold the engineers faced as students in school, thus leading to confusion as to what pieces of knowledge they can use or what resources would be applicable in solving ill-defined problems[3]. One study noted engineering students who entered the workplace did not realize the importance of relative size of machinery, how to use relevant tools in their practice, and could not determine outcomes and impacts of engineering production[4]: One participant described one of the difficulties she faces in a mineral processes environment noting, "a particle attaches to a bubble in flotation, but you learn absolutely nothing about these huge machines in which it takes place. And then you go onto the plant and you don't care about the bubble…, you've got to go work with this massive piece of equipment" (p. 171). This potential gap between academic contexts and practical use may be reflected in the different types of resources prevalent within these "worlds." The research described in this paper aims to deepen insight of engineering concept representation, description, and usage in academia and practice (i.e. the workplace).

Two specific issues guided the use of roundabout design as the medium for analyzing concept use, representation, and description:

1) roundabouts are specific transportation design facilities emerging in use and design within the United States, and
2) the design of roundabouts served as the larger context for an ongoing case study exploring concept use, representation, and interpretation in engineering activity and interactions.

The application of roundabouts as a transportation facility is relatively new in the United States[5]. As such, textual resources referencing this type of facility are relatively new compared to other traffic controlled applications, such as signalization and stop-control. In other words, examining this subject allowed opportunity to look at novel applications in design. Secondly, this study initiates a larger case study on use, interpretation, and representation of concepts within design activities. The larger case study examined activities, interactions, and practices as a group of practicing engineers pursued the delivery of project artifacts constructed during design of two roundabouts. The concepts identified in this study served as sensitizing concepts at the outset of the larger case study. This was in response to Patton's message of caution regarding fieldwork[6]: "Once in the field, however, the observer must somehow organize the complex stimuli experienced so that observing becomes and remains manageable" (p. 278) As such, this study provided insight into various textual resources, while adding value and information to a large case study of the engineering workplace.

Research Questions

Engineers interact often with artifacts. The focus of this paper regards textbooks and instructional manuals, which are relevant to engineering practice and academic experiences. The engineers' interaction with these artifacts reflects activity relevant to their community of practice. The documents themselves are also a reflection of the environment in which they are utilized. Textbooks are common in the academic community, while instructional manuals are common in the industrial community. This research addresses two lines of inquiry regarding concepts and their respective representation in practical and academic textual resources:

- What engineering concepts are relevant to roundabout design?
- How are concepts represented in practical and academic texts?

Such inquiry allows opportunity to determine specific ways practical and academic resources differ from one another, particularly in their structure, the inscriptions presented within them, and the concepts noted within the text. Using content analysis of 4 practical transportation engineering resources and 11 transportation engineering textbooks, a comparison of approaches to roundabout design between practical and academic texts is provided.

Literature Review

There is a vast array of terminology and meanings associated with situated cognition, representing multiple fields, including psychology, sociology, mathematics and ecology. Fundamentally, most of these perspectives share the approach of understanding the interaction between an individual and their environment: knowledge and the use of knowledge are connected in a complex and immensely layered way. Situated cognition is the idea that knowledge and learning are situated in the "physical and social context of its acquisition and use"[7]. Moreover, knowledge is not coded information; it is not "knowing what," but "knowing how" to act in a particular social setting[8,9].

Theories and theoretical frameworks under the umbrella of situated cognition vary substantially among authors and research approaches. Cognition itself depends not simply on the brain, but also on the body, the structure of the natural and social environments, and the other existent objects in the environment[10]. Situated cognition fundamentally includes the relationship between mind and body, mind and context, and mind and social environment. Because it focuses on the environment of the situation, there is an emphasis on an individual's relationship with its context, its content, and its surroundings and then how those impact the individual's reactions, which would incorporate the idea of mind and body. The mind understands and the body reacts accordingly[10].

In situated learning, individuals gain and demonstrate knowledge through participation in social practice. They are in a community with a range of expertise and perspectives, and how the newcomers to an environment will apply their knowledge is influenced by their interaction with the more experienced individuals within the community and by observing how the most experienced members if the community approach situations[8]. Learning is a situated activity and its central defining characteristic is legitimate peripheral participation within a community of practice[8]. "Legitimate peripheral participation" is a term that can be used to describe the relationship between newcomers and elders (or "old-timers"), and also about the activities, identities, artifacts, and the community itself. What is meaningful for newcomers' learning is determined by the interactions they have and what they observe as they become a part of the community. How artifacts are utilized, what artifacts are utilized, and how they are interpreted for use are also observed and learned through experience within the community. Therefore, legitimate peripheral participation is essentially a lens on learning that espouses the importance of observation of those who have more experience for developing skills and knowledge in a community than actively participating from the start[8,11].

Greeno, Collins, and Resnick used the term "situative" while comparing various lenses on learning[12]. Again, the theme of active engagement and participation in the community is used to describe situative learning, rather than motivation based on either intrinsic or extrinsic forces[12]. Additionally, cognition is described as being distributed in the world, whereas the behaviorist and cognitive perspectives espouse knowledge as being purely associational or individually cognitive-based[12,13]. Distributed cognition forms another area of research examining cognition beyond the human mind. In this perspective, shared tasks, goals, and responsibilities ultimately construct knowledge that is distributed across individuals and the material context in which those individuals are embedded[14,15].

One of the central characteristics that tie all of these variant definitions is the central role of the material context in the practices of individuals. In a review of the situated learning lens within engineering education, Johri and Olds identified "material context" as inclusive of all objects, tools, symbols, representations, or materials that mediate activities leading to understanding of the world[13]. In this study, textual resources - namely textbooks and practical references - serve as the tool of interest mediating learning in engineering. Indeed, past studies note the role of these resources in learning. For example, Lee and colleagues examined the role of textbooks in students' problem-solving processes noting that students included in the phenomenological study tended to utilize the textbooks for gaining information on problem constraints and as models for solutions on examples provided in the textbooks[16]. Other studies of the role of symbols, visual representations, and inscriptions note the central role of these tools in mediating communication and knowledge sharing in not only engineering, but also in mathematics and the sciences[17,18,19,20]. For this study, a comparison of tools (i.e. textbooks and practical references) relevant in two communities within engineering is completed. These tools provide a means to examine a portion of what is agreed by members of two communities (i.e. academia and practice) while also allowing insight into how practices may be shaped differently as reflected in the language utilized within the two sources. It is assumed that these tools reflect two potentially variant communities within engineering.

Beyond comparison of the two types of textual resources and tools, the utilization and representation of engineering concepts is examined and compared between the two types of textual resources. It is commonly accepted within engineering education research that concepts provide a foundation for engineering knowledge and expertise[21]. Traditional views of cognition view concepts as a means for humans to categorize and organize the world[22] and serve as "big ideas" upon which knowledge may be founded[23]. Research within engineering education have explored issues of conceptual knowledge[24,21,25], development of assessments such as concept inventories[26,27,28,29,30,31], differences in understanding of concepts between novices and relative experts[32], and identifying relevant concepts for various engineering domains[33,34]. Despite this wide range of inquiry regarding concepts in engineering academia, there exists a gap within literature addressing the role of concepts in transportation engineering practice and in the material contexts in which engineers are embedded.

Informed by the situated perspective on learning and its emphasis on the relationship between material context and engagement into practice, this study compares tools of the trade typically utilized in two different stages of participation in engineering. Using engineering concepts as the units of analysis, this study attempts to determine differences in the ways information is delivered between the two types of textual resources. Understanding possible differences between the deliveries of information – particularly of noted foundational ideas within the field - between the two types of sources may provide insight into the gap of knowledge exhibited amongst novice engineers as they transition from academia to practice.

Methodology

Content analysis informed the research methodology provided within the study[35,36,37,38]. Berg and Lune[35] describe content analysis as "not inherently quantitative or qualitative and may be both at the same time" (p. 354). Per Hsieh and Shannon's three approaches to content analysis[37], the approach for this study was summative content analysis, which entailed counts of relevant words and sentences within the text to determine patterns of potential interest followed by the exploration of latent themes and meanings emergent within the data.

The study followed a three-phase process typical of inductive content analysis: preparation, organization, and resulting phases[36]. The preparation phase included the selection of textual resources to be analyzed for the study. Following the selection of the text, a systematic procedure to unitize, sample, and code the text was completed[38]. The reporting phase provided insight into the data via description of descriptive statistics, statistical analysis comparing the texts, determination of most prevalent transportation engineering concepts, and interpretation of latent meanings associated with verb usage in the textual resources.

This study seeks to span beyond analysis of manifest content to deeper structural meanings that may reveal differences in practical and academic contexts that novice engineers must traverse as they enter the engineering community of practice. The purpose of this study – particularly concerning the use of the statistical results – is not to generalize to the entire engineering population. Rather, the focus is to initiate deeper understanding of tools mediating knowledge within engineering education and practice. In other words, the intent of this study is deeper insight into one facet of material context relevant to the engineering community of practice, rather than broad generalization of all textual resources available to all domains of engineering.

Sampling of Textual Resources

Two types of textual resources were chosen to epitomize the academic and practicing world: textbooks and reference sources commonly utilized by practicing engineers. Sampling of the actual textual resources was based on convenience and availability[39]. The nonprobability sampling and subsequent non-normal distribution of the data sets (which limited the statistical analysis to permutation testing) did not allow the generalizability of the results to a population beyond those included in the study[40].

Despite this, past research examining transportation engineering practice identified the textual resources utilized in this study as being relevant to practice and academia[41,42,16,43,44]. For example, a previous study examined syllabi of introductory transportation engineering courses within the United States, and identified 7 textbooks (with two of the textbooks being represented in various editions) utilized within such courses[41]. For this study, seven of the textbooks analyzed match those mentioned in the previously conducted syllabi analysis[41]. Data from another study comparing embedded knowledge between engineering practitioners and instructors identified the common use of the referential text, "A Policy on Geometric Design of Highways and Streets" [42]. This book is commonly referred to as the "Green Book." Additionally, the American Association of State Highway and Transportation (AASHTO), which publishes the Green Book, is recognized as representing highway transportation engineering as a field throughout the United States[45]. Two editions of the AASHTO Green Book are utilized within the study. Turochy's work[43,44], which establishes priorities for content that the industry seeks in engineering graduates, heavily relies on participation from the Institute of Transportation Engineers (ITE). This group's membership currently spans 17,000 practitioners, researchers, and other professionals focused on transportation engineering as a field[46]. Two of the textual resources exemplifying the practicing world utilized in this study were published by ITE. Noting the relevance of such textual resources to academia and practice, the list of the textbooks and practical references examined in the study was deemed appropriate for gaining insight into possible differences between "practical" referential texts to "academic" textbooks.

Noting the results of the previous studies, as well access to the text, a pool of 25 resources (19 transportation engineering textbooks and 6 practical resources) were originally considered for the study. These texts ranged in publication years between 1972 and 2011. The final analysis limited this pool to 15 resources (11 textbooks and 4 practical resources). Noting the relatively recent application of roundabouts within the United States[5] and the results of the syllabi analysis[41], the research team decided to only include texts whose publishing dates ranged between 1997 and 2012 for the final analysis. Table 1 summarizes the resources analyzed in this study.

Source Type	ID	Authors/Title	Year of Publication
Practical	P01	AASHTO / "Green Book"	2001
	P02	ITE / Freeway & Interchange Geometric Design Handbook	2005
	P03	ITE / Urban Street Design	2008
	P04	AASHTO / "Green Book"	2011
Textbook	T01	Garber & Hoel / Traffic and Highway Engineering	1997
	T02	/ Transportation Engineering Planning and Design, 3rd Edition	1998
	T03	Banks / Introduction to Transportation Engineering	1998
	T04	Khisty & Lall / Transportation Engineering: An Introduction, 3rd Edition	2002
	T05	/ Traffic Engineering	2004
	T06	Wright & Dixon / Highway Engineering, 7th Edition	2004
	T07	Mannering, Washburn, & Kilareski / Principles of Highway Engineering & Traffic Analysis, 4th Edition	2009
	T08	Khisty / Transportation Engineering: An Introduction, 2nd Edition	1997
	T09	Mannering & Kilareski / Principles of Highway Engineering & Traffic Analysis, 2nd Edition	1997
	T10	Garber & Hoel / Traffic & Highway Engineering, 4th Edition	2009
	T11	Wright, Ashford, Stammer / Transportation Engineering Planning & Design, 4th Edition	1998

Table 1. Resources analyzed in study

After establishing a list of textual resources for examination, a systematic procedure to identify relevance of roundabouts within the text, concepts relevant to roundabout design, and visual representations of roundabouts and related concepts was established. The first phase of the procedure focused on collecting and analyzing quantitative data. The results from the statistical comparison (via permutation or randomization testing) informed the focus of the qualitative phase. The analysis of the qualitative data focused on the use of auxiliary verbs (i.e. "should") and action verbs relating to suggestions or requirements of engineering practice (e.g. "recommend") within the textual resources.

Systematic Procedure for Unitizing, Sampling, and Coding

Textual materials were unitized according to systematic divisions (i.e. at page, sentence, and figure/table level). Per Berg and Lune's definition of major elements of written messages[35], the elements counted in this study included words, paragraphs, items (i.e. textual resource type), and concepts. A census of all figures and sentences relating to roundabouts, as well as concept use, exemplified the sampling procedure in this phase of the study. These counts were saved in Microsoft Excel. Ratios, such as visual representations per page and sentences relevant to roundabouts per total sentences present in textual resource analyzed, were developed from raw counts reflecting these divisions.

Researchers devised sampling plans geared toward quantitative description of relevancy of roundabout design within the text, identification of concepts relevant to roundabout design, use of visual representations, and verb usage in sentences containing concepts. Rather than accounting for all pages in the textual resources, the researchers limited the pages to those relevant to roundabout design. To determine this, the researchers searched the index of each of the textual resources for the word "roundabouts." The only deviance from this process occurred when another, unindexed page, section, or figure was called out within the accounted text. For example, if a sentence referred to "Figure 5.6 in page 76" but the index did not specifically call out page 76, the figure was still accounted for in the analysis.

The researchers uploaded scanned copies of all the textual resources into Atlas.ti[47], a qualitative research software allowing storage, organization, and coding of documents included in the study. All sentences, figures, and tables in the pages were coded according to relevance to roundabouts, inclusion of engineering concepts, and verb usage in each sentence. Table 2 summarizes the counts completed for the study.

		Counts Completed for Unitizing Stage			**Counts Completed for Sampling Stage**			
Source Type	ID	Pages Analyzed	Figures/ tables counted	sentences analyzed	sentences in pages analyzed relevant to roundabouts	sentences including at least one transportation engineering concept	concepts coded in textual resource	Sentences with both concepts and auxiliary verbs (should, must), or "recommend"
Practical	P01	6	3	87	80	53	65	14
	P02	15	9	165	54	26	18	1
	P03	2	2	32	9	1	1	1
	P04	15	10	206	202	144	140	24
Textbook	T01	0	0	0	0	0	0	0
	T02	1	0	15	6	3	0	0
	T03	0	0	0	0	0	0	0
	T04	2	1	25	5	5	1	1
	T05	3	4	19	9	4	0	0
	T06	2	0	37	8	0	0	0
	T07	0	0	0	0	0	0	0
	T08	1	0	20	5	3	1	1
	T09	0	0	0	0	0	0	0
	T10	5	3	32	14	7	8	0
	T11	2	0	43	7	2	2	0

Table 2. Summary of counts reflecting unitizing and sampling procedure

Sentence relevance to roundabouts and verb usage were openly coded, with concern at open inquiry, but identification of concepts was guided by existent research within engineering education. In order to frame the study and ensure focus on relevant concepts, the researchers utilized findings from knowledge tables created to guide transportation engineering educators' curriculum development[33,48,49], along with emergent and repeated words or phrases identified by the researchers. To ensure validity in the coding of the concepts, two researchers separately coded the textual resources, compared coding schemes, discussed conflicting codes, and resolved final codes[6].

Additionally, the visual, or symbolic representations utilized within the practical resources and textbooks were counted and compared according to source types. Visual representations denoted all non-text symbols included within the analyzed pages. These included photographs, naturalistic drawings, diagrams, graphs, tables, and equations. Past literature have placed these visual representation on a spectrum of abstraction spanning from the most abstract (words) to the least abstract and most tangible (the world) [50,51,53,20]. These visual representations are often referred to as "inscriptions" in such text. Based on a process established in earlier work[41], these visual representations were unitized according to type of inscription.

Statistical Analysis

After coding the textual resources in Atlas.ti, the finalized counts were transferred into a spreadsheet. This data was input into the statistical software "R." Output from the software provided descriptive statistics for each source type group and issue of interest. Issues of interest included percentage of sentences dedicated to roundabouts (relative to pages included in the study), visual representation per page, ratio of concept use, and ratio of use of auxiliary verbs of interest.

Subsequent analysis of the data revealed non-normal distribution: note the preponderance of zeros within the data set shown in table 2. Transformation of the data was deemed inappropriate for the study, thus limiting the applicable statistical analysis methods. Additionally, the multiple matching values in the data discouraged the use of rank-sum test. Noting these existent limitations with the data, a permutation test was chosen as the statistical tool to examine the data set. This statistical procedure allows for examination of data not able to meet assumptions of normalcy, independence, and deviation usually required for simple t-distribution[40]. Note that the permutation test disallows the generalizability of the results beyond the data presented in the study. However, the findings are still important in that they initiate exploration of possible gaps in context students may face as they transition between academia and practice.

The statistical process in R allowed the identification of statistical significance between differences in means of measures of interest. The data was first pooled into two general groups matching the sample sizes of the two source types. A t-statistic was calculated via the following equation,

$$t = \frac{\bar{Y}_{TEXTBK} - \bar{Y}_{PRACTICAL}}{S_p\sqrt{\frac{1}{n_{PRACTICAL}} + \frac{1}{n_{TEXTBK}}}},$$

where t is the t-statistic, $\bar{Y}_{TEXTBK}$ is the mean value of a measure of interest for the textbooks, $\bar{Y}_{PRACTICAL}$ is the mean value of a measure of interest for the practical resources, S_p is the pooled standard deviation, $n_{PRACTICAL}$ is the sample size for the practical resources, and n_{TEXTBK} is the sample size for the textbooks. The software program repeats this calculation 10,000 times with randomly assigned groupings between the two source types to obtain a permutation distribution of the t. The software program compares the observed statistic produced via the aforementioned equation (t) to the permutation distribution of the randomly assigned groupings to produce a two-sided p-value.

Thematic Analysis of Emergent Patterns and Meanings

Noting the results of the permutation test examining the pairing between verb use and concept inclusion, the researchers interpreted an emergent theme within the data set. Qualitative analysis specifically relating to use of auxiliary verbs (i.e. “should” and “must”) and action verbs relating to suggested or requirements of engineering practice (i.e. “recommend”) was completed allowing further exploration of the ways practical and academic texts differ in communicating information. This portion of this analysis allowed interpretation beyond statistical differences in count means. Noting the lens of situated learning and literature on communities of practice, this portion of the analysis sought to interpret differences in discourse emergent within texts serving two different populations of transportation engineers.

Results

Finding 1: The most prevalent concepts pertain to geometric elements of roundabouts in both types of resources

Upon analysis of the textual resources, seven categories of transportation engineering concepts were identified. These categories included: control, element, alignment, safety, sight distance, traffic operations, user, and vehicle. Table 4 summarizes the words and phrases coded within the noted categories. These categories reflected 93.6% of the concepts identified within the practical text, and 97.6% of concepts identified within the textbooks. Other concepts, such as types of traffic circles, did not account for a substantial portion of the concepts. Thus, these concepts were not placed in the noted categories.

Concept Categories	Words/phrases included in category (codes)
Control	Control, signal, yield
Element	Approach, apron, lane, circular/circulatory roadway, crossing location, crosswalk, element, feature, entrance line, entry, leg, inscribed, refuge, yield line, island, circle, landscape (buffer), marking
Alignment	Alignment, width, distance, path, curvature, geometry, grade, horizontal deflection, layout, tangent, radii, friction
Safety	Conflict, frequency, severity, crash, safety
Sight distance	Visibility, sight distance, intersection sight distance, stopping sight distance
Traffic operations	Speed, capacity, volume, flow, gap, operation, directional distribution, congestion
User	Bicyclist, driver, pedestrian, user, person
Vehicle	Bicycle, bus, vehicle, truck

Table 3. Words and phrases included in concept categories

Itemization of the categories revealed a relatively similar distribution between the source types. The authors assessed prevalence of concept categories in reference to the total number of sentences regarding roundabouts within each source type. Noting this perspective, each sentence was coded not only by singular words or phrases, but also by concept categories. This entailed that if one sentence included multiple words of the same concept category, the sentence would only be coded once for that category. For example, if a sentence included the words “yield line,” “central island,” “speed,” and “vehicle,” researchers coded the sentence as “element,” “traffic,” and “vehicle.” The result of this analysis is illustrated in figure 2. The values on the y-axis of this figure reflects the ratio of sentences coded with the noted concept category divided by the total number of sentences within the sources pertaining to roundabouts. Note that the total number of sentences pertaining to roundabouts was 345 and 54 for the practical resources and textbooks, respectively.

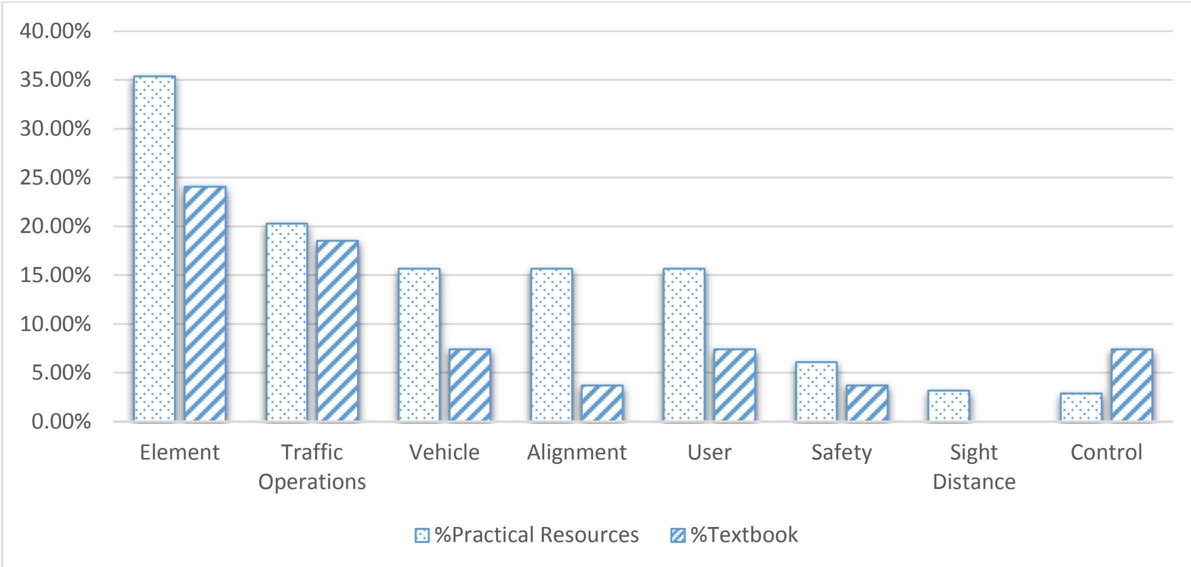

Figure 1. Percentage of sentences including noted concept categories

The results of this analysis revealed that the most prevalent concept category remained geometric elements. Approximately 35.4% and 24.1% of the sentences within the practical resources and textbooks noted the use of at least one word or phrase within the concept category, respectively. The second-most prevalent concept category for both types of resources was traffic operations with 21.0% and 18.5% of the sentences in the practical resources and textbooks utilizing words and phrases related to the category, respectively. For the practical resources, the concept categories of vehicle, alignment, and user generated equal percentages of sentences referring to words or phrases associated with the noted category: approximately 15.7% of all the sentences referring to roundabouts utilized words or phrases inclusive of the categories. Approximately, 6.1% and 3.2% of the sentences referring to roundabouts within the practical resources addressed the safety and sight distance concept categories, respectively. The textbooks showed different distributions amongst the concept categories, with vehicle, user, and control emerging amongst 7.4% of the total number of sentences relating to roundabouts. The alignment and safety concept categories accounted within approximately 3.7% of the sentences about roundabouts within the textbooks. The least prevalent concept categories for the practical resources was control, while the least prevalent concept category within the textbooks was sight distance. For the textbooks, the least prevalent concept category was sight distance with no sentences utilizing any of the terms or phrases indicated for the category.

Researchers completed a similar analysis with the inscriptions coded in this study. The results also reflected the dominance of the geometric elements concept category. Researchers first coded each inscription based on words in the figure title, along with call-outs within the figure itself. Cross-referencing the words listed in table 4 to the titles and call-outs within the figures, a list of 85 words/phrases reflecting the eight concept categories was generated. Figure 3 illustrates the distribution of these words according to the concept categories identified.

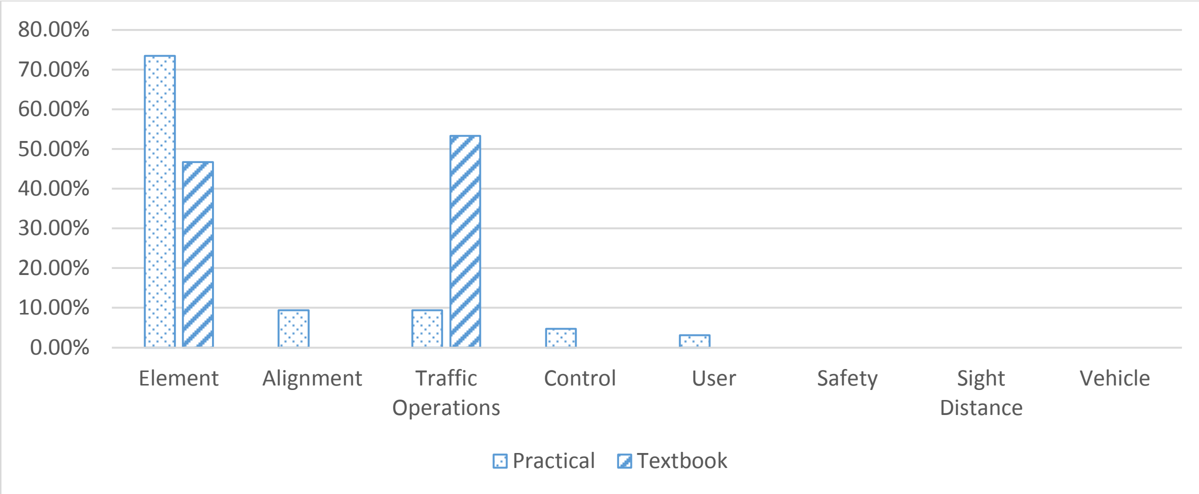

Figure 2. Prevalence of concept categories in inscriptions

Amongst the 25 inscriptions counted within the practical resource, researchers identified 47 words (either in the title or in call-outs within the figures) included in the element concept category. The textbooks generated a different result. The concept category reflecting the most coded words for the textbooks was traffic operations, with 8 words coded. However, the second-most referenced concept category for textbooks was geometric elements of the roundabout with 7 words coded. This is not a significant difference from traffic operations.

Finding 2: There is little evidence indicating a difference in density of concepts within the different source types

A comparison of density of transportation engineering concept codes was also completed. This measure of density reflected the percentage of sentences including at least one transportation engineering concept code within the various resources. The resulting permutation test revealed little to no evidence of a statistical difference between the practical resources and textbooks (observed t-statistic: 1.317, p-value: 0.212). This indicates that the difference in use of wordage relating to concepts, relative to the actual amount of text referring to roundabouts, was not statistically different between the two source types.

Finding 3: The distribution of the inscription types appear to be different according to source type

The visual representations utilized appeared to be relatively similar in both texts, accounting for amount of inscriptions found within the texts. Note that all of the inscriptions coded in the study referred to at least one concept. Researchers counted 24 inscriptions in the practical resources and 8 inscriptions in the textbooks. Figure 1 illustrates the distribution of inscription amongst the different types of representation. For both source types, the most predominant type of inscription was diagrams with 12 inscriptions and 3 inscriptions falling into this category within the practical resources and textbooks, respectively. The least prevalent inscription type for the practical resources was equations. For textbooks, pages included in the analysis did not include any naturalistic drawings.

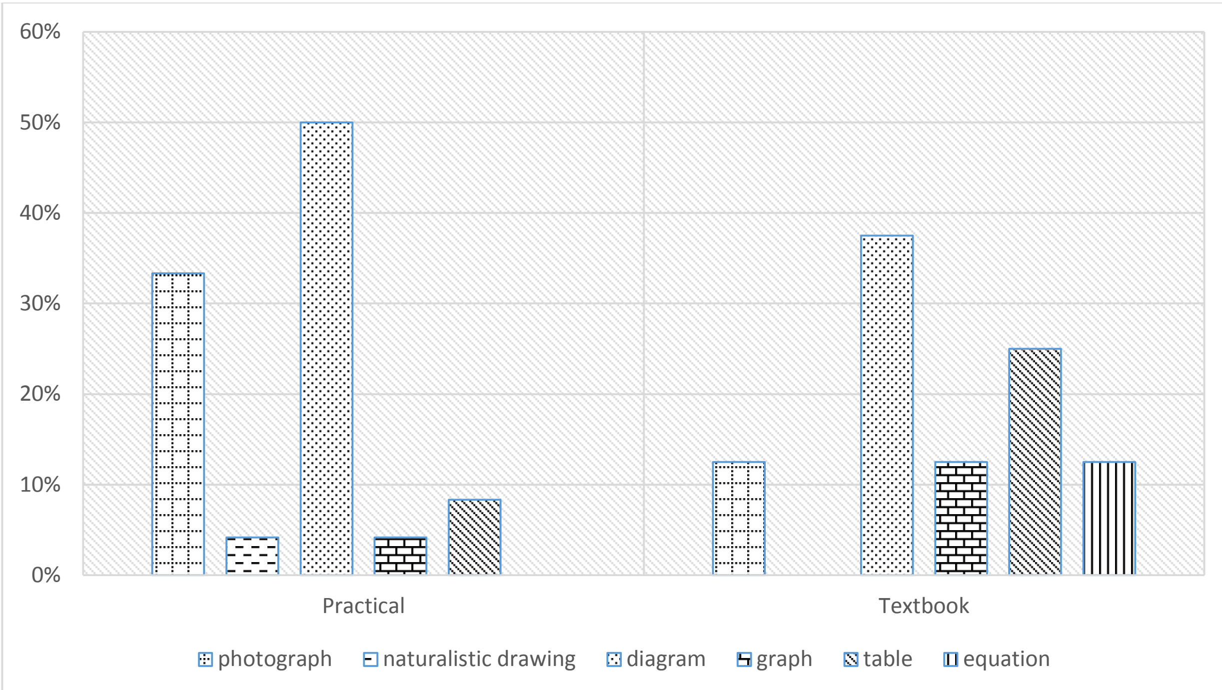

Figure 3. Distribution of inscription types by source type

Note that the practical textbooks are weighted towards inscriptions typically associated with more concrete representations of the world (i.e. photographs), while the textbooks are distributed in more abstracted forms of representations (i.e. equations)[20]. Taking into account that these representations were associated with concepts, which were largely weighted towards geometric elements (per Finding 2), the results suggest a difference in approaches in communicating information about concepts and contexts. Practical resources seem to utilize relatively more concrete examples of roundabout concepts, while textbooks tended to prefer more abstract representations such as graphs, tables, and equations in communicating concepts.

Finding 4: There is suggestive evidence - both quantitatively and qualitatively - that practical resources and textbooks use auxiliary verbs and words reflecting suggestions and recommendation for practice differently

The final count data examined regarded the use of auxiliary verbs, such as “should” and “must,” and other action verbs indication suggestions or recommendations regarding engineering practice. Upon initial pass on the data set, the researchers noticed a pattern of use of such verbs. The pairing of the verbs with a coded concept occurred 48 times in the practical resources, while it only occurred 3 times within the textbook. In order to determine if this produced a statistically conclusive difference between the source types, the researchers completed a permutation test analyzing the average number of sentences pairing the verbs to concepts relative to the total number of sentences within each resource. The results indicated suggestive, but inconclusive, evidence of a difference between the mean percentages of verb/concept pairings in sentences relative to the total number of sentences analyzed (observed t-statistic: 1.536, p-value: 0.165). Noting these results, the researchers sought to examine and provide interpretation of a possible difference in the ways these verbs reflect intention and discourse regarding practice.

Initial memos made while analyzing different textual resources was the use of the word "should". Upon review of these memos, themes emerged in regards to its use within the text. One theme was that the textbooks utilized "should" to usher in an explanation of theory or to emphasize a point that the textbook author deemed to be of particular importance for the reader. In the practical resources, however, "should" was used to express a particular solution or step regarding roundabout construction, obstacles, or implications of a roundabout. In other words, the textbooks used "should" for emphasis regarding theory, while the manuals used "should" to help alleviate confusion about a certain topic. The following excerpts (table 4) are paired with interpretations of meaning by the researchers.

Excerpt ID	**Source**	**Excerpt** *(concepts coded italicized)*	**Interpretation of function of "should"**
1	Source: P04 Code Line: 01:98	"To these ends, the *alignment* should be as straight and the *gradients* as flat as practical."	• Used to describe expectations of resulting designs • Creates a compulsion for practicality and safety
2	Source: P04 Code Line: 01:98 (2)	"The *sight distance* should be equal to or greater than the minimum values for specific intersection conditions, as derived and discussed in Section 9.5 on "Intersection Sight Distance."	• "Minimum" and "equal to or greater than" are utilized to convey certain considerations that ensure the safety and practicality of the roundabout
3	Source: P02 Code Line: 02:04	"However, it *[entry width]* should not become so large as to encourage '*high-speed' operation*."	• Used to caution the reader and to have them consider the implications of the design
4	Source: P02 Code Line: 02:05	"For design and operational guidelines of roundabouts the reader should reference the AASHTO Greenbook and the Federal Highway Administration's (FHWA) publication Roundabouts: An Informational Guide (2000)."	• Used to refer the reader to other sources
5	Source: T05 Code Line: 03:08	"It should be noted that roundabouts have no additional *control devices*, and that *circulating traffic* has the *right of way* at all times.	• Used to offer further explanation of roundabouts
6	Source: T04 Code Line: 21:03	"A well-designed roundabout should deflect *the path of vehicles* passing through an intersection by the use of a sufficiently large *central island*, properly designed *approach islands*, and staggering the *alignment* of *entries and exits*…"	• Used to offer further explanation of roundabouts • Emphasis for what seems to be a very simple explanation of roundabouts

Table 4. Excerpts from Textual Resources

Excerpts 1 through 4 are from practical resources. In the Excerpt 1 from P04, concepts regarding geometric alignment (i.e. alignment and gradient) precede "should" in the sentence. The concepts function as the subject of the sentence, while the auxiliary verb functions as a statements of expectations of practice. It serves a compulsory function communicating the expectations of design in regards to safety and practicality. Excerpt 2 from the same source follows a similar layout, wherein a concept (sight distance) precedes "should." Again, the statement communicates an expectation of practice. One difference between Excerpt 1 and 2 is that the second excerpt explicitly states "minimum values" and expected boundaries for the resulting values of the concept, while the first is vaguer in communicating boundaries of the practice. Excerpt 3 is also from a practical resource (P02). In this sentence, one concept (entry width) precedes "should," while the other concept (high speed operation) follows the use of "should." Despite these slight differences, the sentences all serve as compulsion for the reader to do something, particularly to consider concepts and its relationship to practicality and safety. Excerpt 4 from Source P02 differs from the previous excerpts in that it did not include a concept. However, it functioned in a similar way to the previous excerpt in compulsion of action was directed to the reader. That direction of compulsion was for the reader to seek resources beyond those provided in P02.

The next two excerpts were from textbooks (T05 and T04). Notably, there were very few sentences utilizing this particular auxiliary verb, thus limiting potential pool for construction of themes. In both of the excerpts, "should" preceded the concepts. The subject in the T05 excerpt was "it", while "a well-designed roundabout" served as the subject in the T04 excerpt. Noting this, an immediate difference from the practical resources can be observed: the requirement of action is not directed towards the reader. In two textbook artifacts (T05, T04), it can be noted that "should" is used to offer further explanation of roundabouts, but it seems to be in more of a general sense. The source T05 states that it "'should' be noted…" It is similar to when a professor states a piece of information that could be implied, but that they would rather have explicitly defined. In some cases, such an explicit definition of something that could be deduced can change a student's line of thinking from a more practical and common sense-oriented one, which is essential for problem-solving, to a line of thinking that is not so much thinking but aligning themselves exactly with the material. Similarly in source T04, the "should" is used as emphasis for what seems to be a very simple explanation of roundabouts, when there are actually many factors that go into the construction of them.

Discussion

Through qualitative and quantitative analysis of the collected field and academic resources for roundabouts, there is evidence of a fundamental difference between the resources. The quantitative comparisons indicate evidence of a difference in the structure and presentation of concepts between practical resources and textbooks. Although practical resources refer to concepts more often and in greater density, the categories concepts are relatively similar between the two source types. Indeed, most of the concepts identified within this study (i.e. over 90% of those coded) fell into one of the noted categories. Additionally, the inscriptions visually representing the concepts support the prevalence of concepts relating to geometric elements. This provides insight directly applicable to the larger case study looking at the role of concepts in engineering design. Another issue of interest regarding the inscriptions is the differences in distribution between the practical resources and textbooks: inscriptions in practical resources tended to be weighted towards more concrete representations of the world, while inscriptions in textbooks were shifted towards more abstracted representations of the world. Such findings initiate exploration of the differences between contexts in the practical and academic world.

One of the most interesting findings regards language use – particularly the pairing of concepts to the auxiliary verb "should." Beyond the initial suggestive evidence provided through quantitative analysis of word choice and pairing, interpretation of use of the words provide initial perspectives is differences of discourse. Note the differences in direction of compulsion between the textual resources (i.e. reader in practical resources versus generic, unnamed beings in textbooks). Also note the function of "should" in practical resources for consideration of practicality, safety, and other constraints and affordances in the world. The practical resources do not use "should" to create succinct explanations absent of context, but instead use "should" to convey caution and to enable the understanding of many different types of roundabout situations and how the environment, safety, and practicality can affect decision-making about how a roundabout could be constructed. The use of "should" can be thought of as a way to encourage a line of thinking that is geared for constructing roundabouts using both conceptual understanding as well as practical understanding. There is a marriage of the two ways of thinking to provide proficient design. In the textbooks, however, the use of "should" has the same feeling of compulsion, but it is instead a compulsion to provide simplicity and straight-forwardness.

Conclusions

The study did not cover all disciplines of engineering. Nor could it cover an extremely vast array of material from a specific discipline. However, this small study can provide insight in a difference in artifacts that can be further explored in other disciplines. The study provides a call for further inquiry and exploration of analysis of academic and practical resources. The furthering of exploration would allow for professors and professionals to expand their communities of practice in order to gain perspective and understand what could be improved upon for the education of engineering students.

Of particular interest for future research is understanding the language surrounding concepts. The general perspective from the researchers' analysis of textbooks is that the text conveys concepts as abstract ideas absent of clues of context. Note the prevalence of inscriptions shifted towards abstracted representations. Also, note the indirect compulsion for action reflected in verb usage. In the practical resources, there is evidence of another path in conveying concepts: Concepts are represented through examples and discussions that have an overall emphasis of safety and practicality. The concepts are presented in a situational manner, and are able to be used as reference points when facing different types of environments when creating roundabouts. There are suggestions that are meant to be used as guidance—there are not large explanations behind the mathematics of how wide the entry of the roundabout should be, it is put in context with concerns to what kind of traffic would likely be going through the area.

There are important qualities of both types of resources. Textbooks are relatively known to focus on theory. Indeed, it is important to have an idea of the theory so there is a greater understanding of what would occur as a roundabout is designed. Practical resources focus more on examples and real-world application. Perhaps, presenting theory (and other relevant information) with a greater focus on context may address issues of transference of knowledge between academia and practice.

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References

1. Anderson, K.J.B., McGlamery, S.S., Nathans-Kelly, T., & Nicometo, C.G. (2010). Understanding engineering work and identity: A cross-case analysis of engineers within six firms. *Engineering Studies*, 2(3), 153-174.
2. American Society of Civil Engineers. (2008). Civil Engineering Body of Knowledge for the 21st Century.
3. Sheppard, S., Colby, A., Macatangay, K., & Sullivan, W. (2006). What is engineering practice? *International Journal of Engineering Education*, 22(3), 429-438.
4. Martin, R., Maytham, B., Case, J., & Fraser, D. (2005). Engineering graduates' perceptions of how well they were prepared for work in industry. *European Journal of Engineering Education*, *30*(2), 167–180.
5. Federal Highway Administration (FHWA) and Kittelson and Associates. (2000). Roundabouts: An Informational Guide. McLean, VA: FHWA.
6. Patton, M. Q. (2002). *Qualitative evaluation and research methods*. *Qualitative Inquiry* (3rd ed., Vol. 3rd, p. 598). Thousand Oaks, CA: Sage Publications, Inc.
7. Brown, J., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, *18*(1), 32–42.
8. Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.
9. Brown, J. S., & Duguid, P. (1991). Organizational learning and communities-of-practice: Toward a unified view of working, learning, and innovation. *Organization Science*, *2*(1), 40–57.
10. Robbins, P., & Aydede, M. (Eds.). (2009). *Cambridge handbook of situated cognition*. Cambridge, UK: Cambridge University Press.
11. Li, L. C., Grimshaw, J. M., Nielsen, C., Judd, M., Coyte, P. C., & Graham, I. D. (2009). Evolution of Wenger's concept of community of practice. *Implementation Science: IS*, *4*, 11.
12. Greeno, J., Collins, A., & Resnick, L. (1996). Cognition and learning. In D. Berliner & R. Calfee (Eds.), *Handbook of Educational Psychology* (Vol. 1968, pp. 15–46). New York: Macmillan.
13. Johri, A., & Olds, B. M. (2011). Situated engineering learning: Bridging engineering education research and the learning sciences. *Journal of Engineering Education*, *100*(1), 151–185.
14. Hutchins, E. (1995). *Cognition in the wild*. Cambridge, MA: MIT Press.
15. Hutchins, E. (2005). Material anchors for conceptual blends. *Journal of Pragmatics*, *37*(10), 1555–1577.
16. Lee, C. S., McNeill, N. J., Douglas, E. P., Koro-Ljungberg, M. E., & Therriault, D. J. (2013). Indispensable resource? A phenomenological study of textbook use in engineering problem solving. *Journal of Engineering Education*, *102*(2), 269–288.
17. Arsenault, D. J., Smith, L. D., & Beauchamp, E. A. (2006). Visual inscriptions in the scientific hierarchy: Mapping the "Treasures of Science." *Science Communication*, *27*(3), 376–428.
18. Johri, A., Roth, W.-M., & Olds, B. M. (2013). The role of representations in engineering practices: Taking a turn towards inscriptions. *Journal of Engineering Education*, *102*(1), 2–19.
19. Latour, B. (1987). *Science in action: How to follow scientists and engineers through society*. Harvard University Press.

20. Roth, W.-M., & Tobin, K. (1997). Cascades of inscriptions and the re-presentation of nature: how numbers, tables, graphs, and money come to re-present a rolling ball. *International Journal of Science Education*, *19*(9), 1075–1091.
21. Streveler, R., Litzinger, T., Miller, R. L., & Steif, P. S. (2008). Learning conceptual knowledge in the engineering sciences: Overview and future research directions. *Journal of Engineering Education*, *97*(3), 279–294.
22. Perkins, D., Meyer, J. H. F., & Land, R. (2006). Constructivism and troublesome knowledge. *Overcoming Barriers to Student Understanding: Threshold Concepts and Troublesome Knowledge*, 33–47.
23. Bransford, J. D., Brown, A., & Cocking, R. (Eds.) (1999). *How people learn: Mind, brain, experience, and school* (Expanded E., p. 374). Washington D.C.: National Academy of Sciences.
24. Andrews, B., Brown, S., Montfort, D., & Dixon, M.P. (2010). Student understanding of sight distance in geometric design: A beginning line of inquiry to characterize student understanding of transportation engineering. *Transportation Research Record: Journal of he Transportaiton Research Board*, 2199(1), 1-8.
25. Taraban, R., Anderson, E. E., DeFinis, A., Brown, A. G., Weigold, A., & Sharma, M. P. (2007). First steps in understanding engineering students' growth of conceptual and procedural knowledge in an interactive learning context. *Journal of Engineering Education*, 96(1), 57-68.
26. Evans, D. L., Midkiff, C., Miller, R., Morgan, J., Krause, S., Martin, J., Notaros, B.M., Rancour, D., and Wage, K. (2002). Tools for assessing conceptual understanding in the engineering sciences. In *Frontiers in Education Conference* (p. 7803). Boston, MA:
27. Gray, G. L., Costanzo, F., Evans, D., Cornwell, P., Self, B., & Lane, J. L. (2005). The dynamics concept inventory assessment test: A progress report and some results. In *American Society of Engineering Education Conference & Exposition*. Portland, OR.
28. Jacobi, A., Martin, J., Mitchell, J., & Newell, T. (2004). Work in progress: a concept inventory for heat transfer. In *34th Annual Frontiers in Education Conference* (pp. 379–380). Savannah, GA.
29. Kitto, K. L. (2008). Developing and assessing conceptual understanding in materials engineering using written research papers and oral poster presentations. In *38th Annual Frontiers in Education Conference*. Saratoga Springs, NY.
30. Olds, B. M., Streveler, R. A., Miller, R. L., & Nelson, M. A. (2004). Preliminary Results from the Development of a Concept Inventory in Thermal and Transport Science. In *American Society of Engineering Education Conference & Exposition*.
31. Steif, P. S., Dollár, A., & Dantzler, J. A. (2005). Results from a Statics Concept Inventory and their Relationship to other Measures of Performance in Statics. In *Frontiers in Education Conference* (pp. 5–10). Indianapolis, IN.
32. Montfort, D., Brown, S.A., & Pollock, D. (2009). An investigation of students' conceptual understanding in related sophomore to gradaute-level engineering and mechanics courses. *Journal of Engineering Education, 98(2*), 111-129.
33. Bernhardt, K. S., Beyerlein, S., Bill, A., Nambisan, S., vann Schalkwyk, I., Turochy, R., & Young, R. (2010). Development of core concepts and learning outcomes for the introductory transportation course. In *American Society for Engineering Education Conference & Exposition.*
34. Streveler, R. A., Olds, B. M., Miller, R. L., & Nelson, M. A. (2003). Using a Delphi Study to Identify the Most Difficult Concepts for Students to Master in Thermal and Transport Science. In *American Society for Engineering Education Conference & Exposition.*
35. Berg, B. L., & Lune, H. (2012). *Qualitative research methods for the social sciences* (Vol. 5). Boston, MA: Pearson Boston.
36. Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing*, *62*, 107–115.
37. Hsieh, H.-F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research*, *15*, 1277–1288.
38. Krippendorff, K. (2013). *Content analysis* (3rd ed.). Thousand Oaks, CA: Sage Publications, Inc.
39. Creswell, J. W. (2013). *Research design: qualitative, quantitative, and mixed methods approaches* (4th ed.). Los Angeles, CA: Sage Publications, Inc.
40. Ramsey, F. L., & Schafer, D. W. (2002). The statistical sleuth. Pacific Grove, CA: Duxbory and Thomson Learning.
41. Bornasal, F.B. & Brown, S.A. (2014). Prevalence of inscriptions in transportation engineering text: Clues to context. In *American Society of Engineering Education Conference & Exposition*. Indianapolis, IN.

42. Davis, S., Brown, S.A., Dixon, M., Borden, R., & Montfort, D. (2013). Embeddd knowledge in transportation engineering: Comparison between engineers and instructors. *Journal of Professional Issues in Engineering Education and Practice*, 139(1), 51-58.
43. Turochy, R. E. (2006). Determining the Content of the First Course in Transportation Engineering. *Journal of Professional Issues in Engineering Education and Practice*, 132, 200–203.
44. Turochy, R. (2013). Structuring the Content of the First Course in Transportation Engineering: Perspectives of Engineers and Educators. *Journal of Professional Issues in Engineering Education and Practice*, 139, 206–210.
45. American Association of State Highway and Transportation Officials. (2015). AASHTO. Retrieved January 01, 2015, from http://www.transportation.org/
46. Institute of Traffic Engineers. (2015). Retrieved January 01, 2015, from http://www.ite.org/
47. Muhr, T. (2004). *User's Manual for ATLAS.ti 5.0*. Berlin: ATLAS.ti Scientific Software Development.
48. Bill, A., Beyerlein, S., Heaslip, K., Hurwitz, D. S., Bernhardt, K.L.S., Kyte, M., & Young, R. K. (2011). Development of Knowledge Tables and Learning Outcomes for an Introductory Course in Transportation Engineering. *Transportation Research Record: Journal of the Transportation Research Board*, *2211*(-1), 27–35.
49. Kyte, M., Bill, A., & Young, R. (2010). Everything You need to Know about Transportation Engineering in 40 Hours. *ITE Journal*, (October), 40–43.
50. Latour, B., & Woolgar, S. (1979). *Laboratory life: The social construction of scientific facts*. Princeton University Press.
51. Roth, W.-M., & Bowen, G. M. (1999). Complexities of graphical representations during ecology lectures: an analysis rooted in semiotics and hermeneutic phenomenology. *Learning and Instruction*, *9*(3), 235–255.
52. Roth, W.-M., Bowen, G. M., & Masciotra, D. (2002). From thing to sign and "natural object": Toward a genetic phenomenology of graph interpretation. *Science, Technology, & Human Values &*, *27*(3), 327–356.