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Prevalence of inscriptions in transportation engineering text: Clues to context

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Abstract

The purpose of this study is to provide insight into contemporary use of inscriptions, which include visual representations such as equations, tables, graphs, diagrams, and photographs, in representing a specific transportation engineering concept (sight distance) within three types of textual resources. These textual resources (textbooks, course notes, and referential texts used in practice) provide a means to compare the use of inscriptions across academic and workplace settings. Past research and theoretical work point toward a connection between situated learning and visual representations, noting its role in providing social and material context to learning. This study adds to this literature by investigating the current use of inscriptions regarding a specific concept (sight distance) utilized within transportation engineering education. Content analysis is utilized as a methodology in order to explore two issues regarding inscriptions: relative importance (as reflected by prevalence) of inscriptions within two different settings (practice and academia) and the degree of abstractness reflected by inscriptions based on Roth, Shaw, and Tobin's inscriptional chain. This study revealed that the distribution amongst different types of inscriptions contrasted amongst the three types of textual resources. These findings provide insight into ways in which engineering educators may bridge the gap between academic and practical settings: 1) by adopting inscriptions that reflect levels of abstractness of textual resources utilized in practice, and 2) by introducing a more varied mix of visual representations that span across various different types of inscriptions. Further, this exploratory study provides data and a protocol for further exploring the relationships between situated learning, contexts, and the materials (inclusive of visual representations) that are used in learning and work settings.

Introduction

Visual representations such as photographs, naturalistic drawings, diagrams, graphs, and mathematical equations permeate the field of engineering in both academic and workplace settings[1]. The use of such representations as a means for analyzing[2], designing [3-6], problem solving[7-8], and communicating ideas and solutions are central in identifying engineering as a unique practice. Despite its relative importance within engineering practice, research regarding the role of visual representations in learning across academic and workplace settings specific to the domain of engineering remains understudied[9]. In response to this issue, this exploratory study examines the prevalence of various types of visual representations present within textual resources utilized by students, educators, and practicing engineers. Using content analysis as a methodology, we present a comparison of presence of specific types of visual representations within introductory transportation engineering textbooks, educators' course notes, and commonly referenced practical textual resources.

Results from previous studies initiated this exploratory study. In two separate studies, the role of context appeared to influence students, educators, and practicing engineers' reasoning. This relationship has not yet been fully defined, but the results of the studies hint at some relationship between context and reasoning. In one study, changes in contextual presentation of information appeared to influence student rationale during a series of semi-structured interviews in which student understanding of engineering concepts was analyzed[10]. In the other study, results indicated differences in the ways that engineers and educators understood core engineering concepts in regards to the contexts in which the concepts were embedded within their personal experience[11]. One particular finding from this study noted that the textual resources utilized by practicing engineers and instructors differed. When asked about the process of determining sight and stopping sight distance (two transportation engineering concepts), practicing engineers referenced practical reference manuals, while instructors discussed using equations within texts or using their own course notes[11]. Considering these results, an overarching phenomenon that explains the role of context – and in particular, the ways in which visual representations mediate that context within settings disjointed from everyday practice settings – became an issue of interest.

The role of material context to the process of learning is of central concern within the situative perspective on learning. From a situative perspective, learning inherently requires participation within social practices established amongst a community of practitioners in the pursuit of developing an identity as a knowledgeable member of that community[12-14]. This pursuit of identifying oneself as a fully-fledged member of a community requires partaking in activities and interactions inherent within everyday practices of that community[15]. These everyday practices are mediated within social and material contexts specified to that domain[9]. Considering this, understanding what constitutes the material contexts within which practicing engineers partake becomes a central issue of interest within engineering education research.

This study provides a small, but meaningful addition to unfurling the complexities relating learning, practice, activity, identity, and context. Providing an appraisal of existing contexts used by both novices and experts within the engineering domain affords guidance for identifying relevant textual resources and developing tools that meaningfully deliver visual representations to students in engineering classrooms.

Research Questions

If the goal of engineering education is to integrate novices into the practices of the field, we must be able to expose students to contexts relevant to them in actual practice. Using content analysis as a methodology, this study provides an initial gauge that may fulfill this need as it relates to contemporary practices. The research question that guided this study is two-fold:

- Are there differences in the visual representations presented to students in textual resources found within academic settings and those textual resources utilized by practitioners in the field?
- What characteristics of the visual representations differ across these two contexts?

Using characteristics of visual representations defined by Roth and his colleagues[16-18], prevalence of different types of visual representations and characterization of the different ways in which the visual representations are utilized within the textual resources is addressed in this study.

Literature Review

Material context includes the physical objects, tools, artifacts, and visual representations that individuals interact with and utilize within their everyday practice[9]. Throughout the growth of an individual from novice (i.e. student) to an expert (i.e. practicing engineer), these tools, artifacts, and representations provide a means to communicate, teach, and learn with other members of the community. This study specifically focuses on visual representations of sight distance embedded within textual resources utilized by students, educators, and practicing professionals within transportation engineering.

Researchers refer to a variety of types of visual representations and operationalize them in various ways. For example, Spanjers, Gog, and Merriënboer defined videos and animations as "dynamic representations"[19]. Vosniadou, Skopeliti, and Ikospentaki referred to a globe as a "culturally accepted artifact representing the earth"[20]. Mccracken and Newstetter utilized the term "visual diagrams" in their study[21]. Dym referred to "symbolic representations" as a means to epitomize design knowledge about artifacts and design processes[3]. In order to operationalize the types of visual representations examined in this study, the term "inscription" – as described by Latour[1] – will be utilized.

While introducing a special issue regarding the role of representations in the Journal of Engineering Education (JEE), Johri, Roth, and Olds[2] called for a shift in "thinking about representations to thinking about inscriptions" (p. 8). The term "inscription" includes visual representations commonly utilized within engineering settings such as graphs, tables, diagrams, photographs, and equations[1]. The concept of *inscription* operationalizes visual representations as symbolic depictions of objects, events, and phenomenon occurring within the natural world that is physically embodied within some existent medium (e.g. paper)[1]. Johri, Roth, and Olds [2] note eight characteristics that exemplify inscriptions:

1. Inscriptions are mobile in that they can be sent to other locations as material entities electronically and physically.
2. Aspects of the inscriptions do not change across settings.
3. Inscriptions can exist in various contexts and have specified meanings within each context.
4. Inscriptions can change in scale and size without changing internal associations.
5. Inscriptions can be overlaid and combined with other inscriptions.
6. Inscriptions can be easily reproduced across different mediums.
7. Inscriptions can combine with forms of information such as indicator arrows and overlaid text.
8. Inscriptions can be rendered into other types of inscriptions.

Past work specifically looking at inscriptions have provided a means to categorize visual representations according to common themes. For example, Arsenault, Smith, and Beauchamp created three categories of inscriptions according to whether the inscription was more analog or symbolic in nature: "nongraph" illustrations (diagrams, pictures, maps, and montages), graphs, and nonvisual inscriptions (computer printouts, equations, numerical tables)[22]. Roth and his colleagues[16,18,23] provide further insight into the relationship of inscriptions to one another in accordance to its abstractness, the provision of detail present within the inscription, and its relationship to the natural world and symbolic word. Roth's work typically illustrates these relationships via an inscriptional chain demonstrating the spectrum between the material world and symbolic word[2]. Considering these descriptions and findings, Figure 1 provides a summary of the relationship between various components: the types of inscriptions accounted for in this study, the characteristics of the inscriptions according to degree of surficial detail provided in that inscription type, and several examples of inscriptions associated with sight distance.

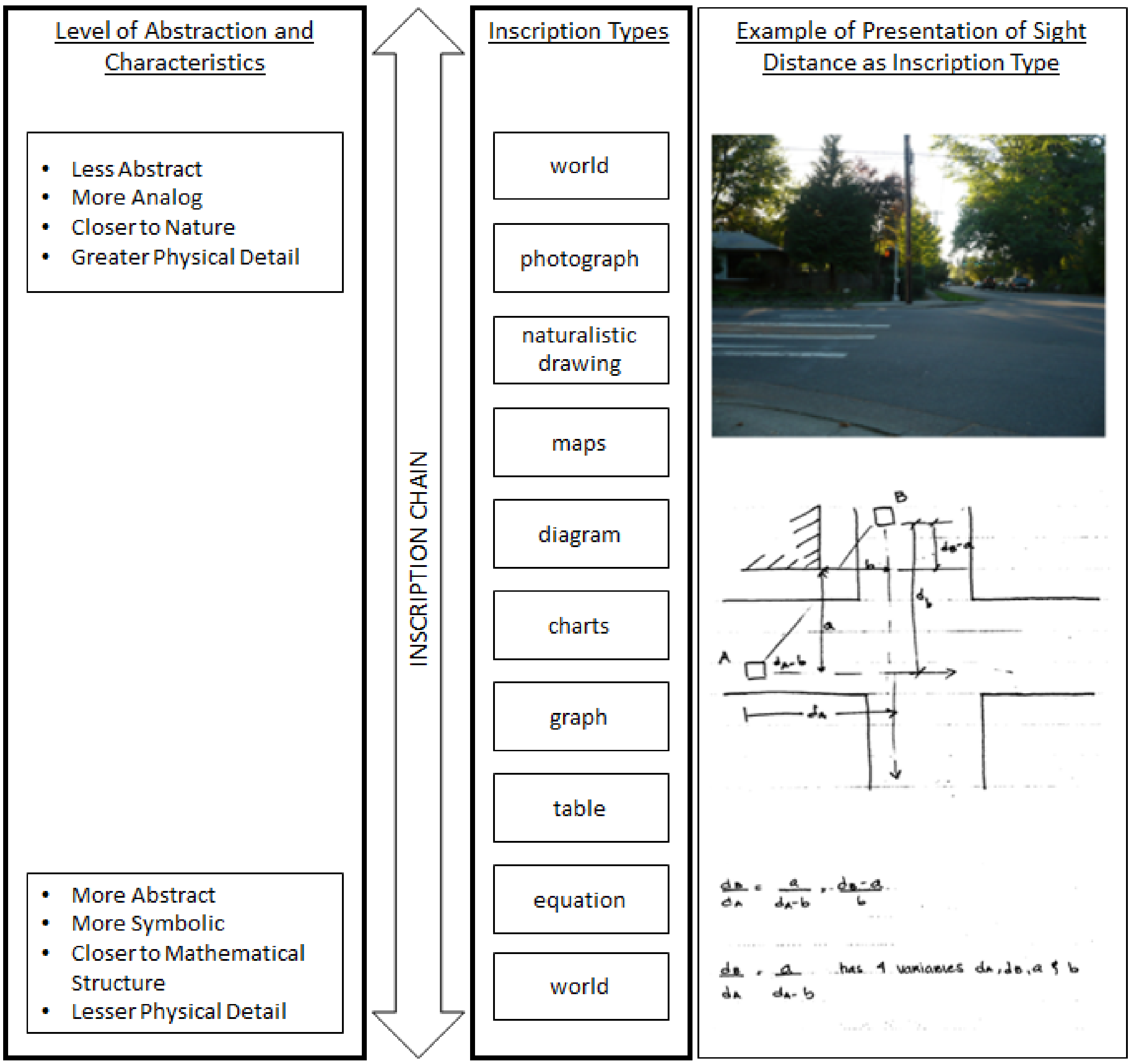

Figure 1. Inscriptional Chain and Example of Application for Sight Distance

A common area of research on inscriptions specifically examines the use of graphs within journals and related text. For example, Cleveland compared prevalence of graphs within journals from three fields (natural sciences, mathematics, and social sciences) and found that graphs were more pervasive within mathematics and science journals[24]. In a similar study, Smith et al. noted that the use of graphical representation provided a means for distinguishing between 'hard' and 'soft' sciences[25]. Roth, Bowen, and McGinn examined prevalence of graphical representations between biology textbooks and journals in the field of ecology and environmental management[26]. Such studies provide two general observations regarding the use of graphs within text: the 'hard' sciences have greater pervasiveness of graphical representation within academic texts, and graphs are central to identity of the fields associated with hard sciences. This supports the assertion that specific types of inscriptions are central to the identity of engineering and science as fields of practice[1].

Roth and his colleagues provide insight into the practices of the field, as reflected in comparison of degrees of abstraction of inscription types within textual resources. Roth, Bowen, and McGinn noted that frequency of more abstract inscriptions (i.e. equations, plots, tables, etc.) within ecology and environmental management textbooks was relatively low, while frequency of less abstract inscriptions (i.e. photographs, diagrams, drawings, etc.) was relatively high[26]. Another frequency analysis of high school biology textbooks replicated these results[16]. These studies hint at differences in role and function of inscriptions. However, the studies cited have largely focused on academic settings, rather than practical settings. Considering the importance of integrating novices into the field of practice within engineering, research of inscriptions needs to expand beyond the academic setting and stretch into relevant workplace settings.

Methods

Prior to initiating the content analysis of textual resources, we selected a specific domain and engineering concept as foci of the study. Rather than providing a broad survey of visual representations of a multitude of engineering concepts present within academia and practice, this research focuses on the specific transportation engineering concept of "sight distance." Sight distance is commonly defined as the length of roadway visible to a driver of some vehicle [27]. This concept within transportation engineering is fundamental in geometric design of transportation facilities (e.g. roadways, bicycle paths, etc.).

With this selection of a concept, we only considered those inscriptions referring to or relating to sight distance. As with many other engineering concepts, sight distance is not isolated, but rather, encompasses and relates to other engineering concepts. For example, four types of sight distance (i.e. intersection sight distance, stopping sight distance, passing sight distance, and decision sight distance) encompass the foundational definition of the concept of sight distance (i.e. the distance one is able see ahead), but each of the four types are applicable in specific settings and contexts. In order to address this issue, all inscriptions that fell under the umbrella of sight distance and met the sampling unit's requirements were analyzed for this study.

Two different settings were of interest in this study: academia and workplace/practice. In order to epitomize these worlds, we chose three types of textual resources for this study: textbooks, course notes, and reference sources commonly utilized by practicing engineers. Based on content analysis of a sample of 29 syllabi for introductory transportation engineering courses at various universities across the United States, we determined that textbooks and course notes best represented the texts associated with the undergraduate academic setting. Results from a previous study examining expert knowledge of sight distance noted that almost every participant interviewed for the study mentioned the textual resource, “A Policy on Geometric Design of Highways and Streets” published by the American Association of State Highway and Transportation Officials, or AASHTO[11].

In order to ensure transferability of the results, we conducted a separate content analysis of 29 syllabi for introductory transportation engineering courses. We identified and attained the syllabi by conducting a web search on “introduction to transportation engineering syllabi.” Table 1 below provides detailed information regarding the syllabi utilized to gauge textbook usage in introductory transportation engineering courses at various institutions in the United States. Note that some of the institutions are listed more than once. This indicates the existence of multiple syllabi representing different semesters/quarters or years in which the course was taught. Notably, a majority of the syllabi are from 2009. This is due to the availability and ease of access to 20 syllabi originally attained during the Transportation Engineering Education Conference, which took place in Portland, Oregon, in June 2009 [28].

School	Course No.	JR level	Course Name	Sem/ Qtr.	Yr.	Textbook Cited in Syllabus
Arizona	CE 363	x	Transportation Engineering and Pavement Design	Fall	2009	(Mannering, Kilareski, and Washburn 2009)
Auburn University	CIVL 3510	x	Transportation Engineering	Spring	2009	(Garber and Hoel 2009)
Boise State	CE 370	x	Transportation Engineering Fundamentals	Spring	2002	(Khisty and Lall 1998)
Bringham Young University	CEEn 361	x	Introduction to Transportation Engineering	Winter	2009	(Fricker and Whitford 2004)
The Citadel	CIVL 305	x	Transportation Engineering		2009	(Fricker and Whitford 2004)
Iowa State University	CE 355	x	Principles of Transportation Engineering		2009	(Mannering, Kilareski, and Washburn 2005)
Louisiana State University	CE 3600	x	Principles of Highway and Traffic Engineering	Spring	2009	(Mannering, Kilareski, and Washburn 2009)
Louisiana State University	CE 3600	x	Principles of Highway and Traffic Engineering	Spring	2009	(Garber and Hoel 2001)
Marshall University	CE 342	x	Transportation Engineering	Spring	2009	(Garber and Hoel 2001)
Massachusetts	CEE310	x	Transportation Systems	Spring	2009	(Mannering, Kilareski, and Washburn 2005)

Montana State University	CE 350	x	Transportation Engineering	Spring	2009	(Mannering, Kilareski, and Washburn 2009)
Purdue University	CE 361	x	Transportation Engineering		2009	(Mannering, Kilareski, and Washburn 2009)
San Diego State	CIV E 481	x	Transportation Engineering	Spring	2009	(Banks 2001)
Southern Illinois University Edwardsville	CE 376	x	Transportation Engineering	Spring	2010	(Fricker and Whitford 2004)
Tennessee Tech	CE3610	x	Transportation Engineering		2009	(Banks 2001)
Texas Tech	CE 3302	x	Transportation Engineering	Spring	2009	(Fricker and Whitford 2004)
University of Alabama Huntsville	CE 321	x	Introduction to Transportation Engineering	Spring	2009	(Banks 2001)
University of Cincinnati	CEE 351	x	Transportation Engineering	Spring	2009	(Hoel, Garber, and Sadek 2007)
University of Connecticut	CE 2710	x	Transportation Engineering	Spring	2011	no book
University of Florida	TTE 4004	x	Transportation Engineering			(Mannering, Kilareski, and Washburn 2009)
University of Maryland	ENCE 370	x	Introduction to Transportation Engineering and Planning	Spring	2009	(Papacostas and Prevedouros 2001)
University of Missouri-Columbia	CE 3100	x	Transportation Systems Engineering	Spring	2009	(Mannering and Kilareski 2004)
University of Missouri-Rolla	CE 211	x	Transportation Engineering (Lecture)	Spring	2009	(Garber and Hoel 2009)
University of Nebraska	CIVE 361	x	Highway Engineering	Spring	2009	(Mannering, Kilareski, and Washburn 2005)
University of Washington	CE 327	x	Transportation Engineering	Fall	2012	(Mannering and Washburn 2012)
University of Washington	CEE 320	x	Transportation Engineering I	Fall	2006	(Mannering, Kilareski, and Washburn 2005)
University of Washington	CEE 320	x	Transportation Engineering I	Fall	2008	(Mannering, Kilareski, and Washburn 2009)
University of Wyoming	CE 3500	x	Transportation Engineering	Spring	2011	no book
University of Nevada-Reno	CEE 362	x	Transportation Engineering	Spring	2009	(Garber and Hoel 2002)

Table 1. Syllabi analysis

Among the syllabi analyzed for this study, only two courses did not list at least one textbook as required reading for the course. This indicates the relative importance of textbooks as a textual resource within undergraduate, introductory transportation engineering education. Further, the syllabi analyzed for this study provided a list of textbooks prevalent within introductory courses of transportation engineering. Table 2 provides a summary of the textbooks cited in the syllabi, as well as counts of frequency of use of the specified textbooks. Notably, the table lists several editions of the same textbook. For this study, we chose to include only one version of each textbook in the analysis to address limited resources, as well as to avoid replicating the same data set. We examined five introductory transportation engineering texts for this study.

Textbooks	Count in Syllabi Analysis	Utilized In Study
(Banks 2001)	3	
(Fricker and Whitford 2004)	4	
(Garber and Hoel 2001)	2	
(Garber and Hoel 2002)	1	
(Garber and Hoel 2009)	2	x
(Hoel, Garber, and Sadek 2007)	1	
(Khisty and Lall 1998)	1	x
(Mannering and Washburn 2012)	1	
(Mannering, Kilareski, and Washburn 2005)	4	
(Mannering, Kilareski, and Washburn 2009)	6	
(Mannering and Kilareski 2004)	1	
(Mannering and Kilareski 1998)	0	x
(Papacostas and Prevedouros 2001)	1	
(Roess, Prassas, and McShane 2011)	0	x
(Wright and Ashford 1998)	0	x

Table 2. Textbook use in analyzed syllabi

We chose two practical reference resources in order to represent textual resources available within workplace settings. During a series of interviews with practicing engineers, participants' most commonly referenced textual resource was the AASHTO "A Policy on Geometric Design of Highways and Streets" [11]. In this study, all participating practicing engineers mentioned using the AASHTO manual or local, state, or city manual (which are typically heavily influenced by the AASHTO manual) when determining sight and stopping sight distances [11]. This point toward the relevance of this specific text in the actual practice of transportation engineers. Another commonly utilized practical text is the Manual on Uniform Traffic Control Devices, or the MUTCD. We decided to include this textual resource as a check for transferability of results.

The process of determining which textual resources would be included in the content analysis includes three steps: justifying inclusion of textual resources, identifying which types of textual resources should be included in the study, and gathering the textual resources available within the field. Figure 2 illustrates this process of reasoning.

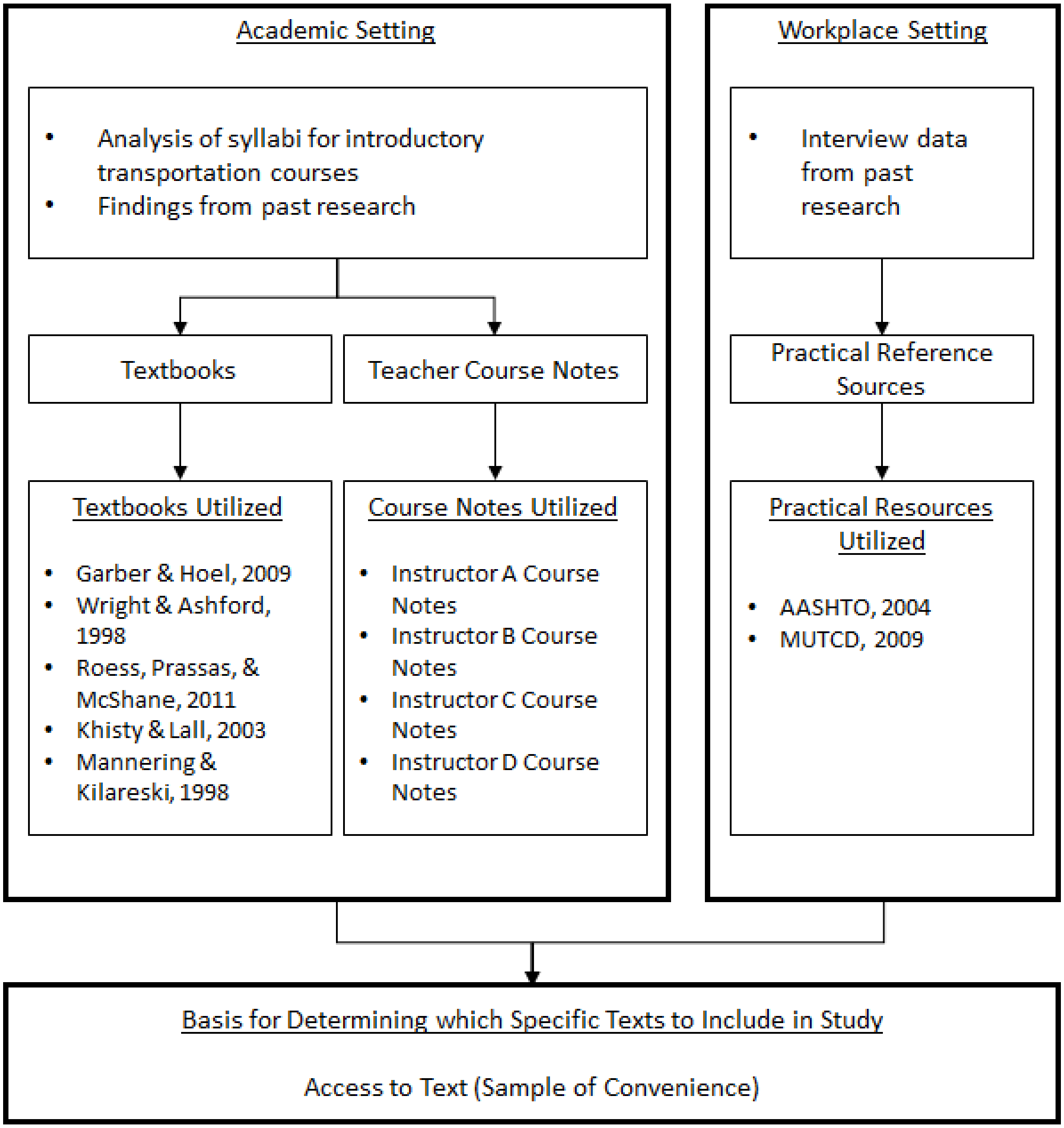

Figure 2. Process for identifying textual resources to be included in the study

Conducting the Content Analysis for Inscriptions

The methodology utilized for this study was content analysis. The methodology entails examining textual resources in order to quantitatively describe and interpret the inscribed productions of social groups[29]. Krippendorff listed several components of content analysis: unitizing materials according to systematic divisions, devising sampling plans, recording/coding based on established coding guidelines, reduction of data, interpreting the phenomena associated with text, and narrating the story told by the textual resources[30]. Figure 3 illustrates this process.

This study follows this process of methodology in examining three types of texts utilized within the academic and practical settings related to the domain of transportation engineering.

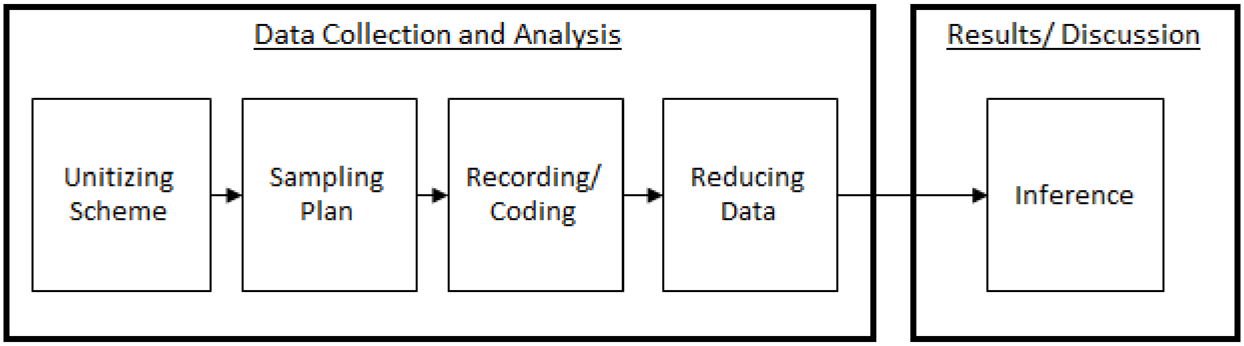

Figure 3. Process for Content Analysis of Textual Resources

Unitizing Scheme

Past research utilized units of measurement based on the fractional graph area (which is based on the amount of text misplaced by an inscription within text) [24, 25] and inscriptions per page [16, 23]. For this study, the unit of measurement was inscription per page. Generating this value included raw counts of inscriptions by type and determination of what pages counted as part of the study. Table 3 provides a summary of inscriptions per page for each of the textual resources examined.

Sampling Plan

Unlike pure quantitative designs heavily founded on statistical sampling theories whose concern is to provide a representative sample of the "textual universe," the concern of content analysis is to identify texts relevant to answering specified research questions and associate the examined texts to meaning [30]. Thus, the goal of this research is not to provide some generalized result that can infer and predict actions across various settings. Rather, the goal of this research is to explore potential differences that exists between academic and practical settings as mediated by visual representations present within textual resources in those settings.

Considering this, the sampling methodology utilized for this research is two-staged. The first stage of sampling in this study was to identify the textual resources to examine for this study. We discussed this process in detail in the previous section. This process of selecting specific textbooks and attaining course notes from faculty is classified as convenience sampling. The second stage of sampling for this study was dedicated to understanding the role of inscriptions within specific textual resources. This stage of the sampling process was a census of all inscriptions that related to sight distance within the chosen textual resources. Designing the sampling methodology in this way prevents results from being generalizable. It cannot be utilized to predict future actions [31]. However, the sampling methodology conducted for this study provides a means to address transferability of the results, while granting a detailed description of existing practices regarding inscriptions as represented in specific types of textual references.

In order to determine which pages counted (and inherently which inscriptions should be counted) for this study, we developed a basis for sampling units. For the textbooks, we looked up "sight distance" in the index, and accounted for all page numbers listed under the term. We accounted for all inscriptions inclusive of the noted indexed page numbers. If a page had multiple inscriptions illustrated, the inscriptions were accounted for individually. If the page listed in the index did not directly reveal an inscription, but rather referred to an inscription within the text (e.g. "Figure 5.5 on page 55 illustrates this phenomenon"), we took into account the page on which the inscription was physically placed. We replicated this process for the practical reference. For the course notes provided by the participating instructors, all inscriptions present within the documents were tallied.

We devised this process of elimination and inclusion based on the pursuit of objectivity as researchers. When we asked the instructors to provide their course notes, we did not give them specific direction regarding the types of documents they should submit or which portions of their notes they should provide for this research. All we asked is that they provide us with their course notes that dealt with sight distance. Thus, the instructors had complete control over which documents we saw and examined. By only accounting for those pages identified by the authors and editors of the textbooks and practical references, we hoped to replicate this emergent process of choice from the creators of the documents in which inscriptions are embedded rather than relying completely on our own, subjective judgment.

Coding Scheme and Reducing Data

After determining what characteristics defined the inscriptions that should be included in the study, we coded each inscription according to its source, the page in which it was illustrated, and its inscription type, amongst other variables. Illustrated below is an example of a coding scheme utilized for one of the inscriptions examined in this study:

Code Level 1:	Code Level 2:	Details
Source:	Book:	Garber & Hoel, 2009
Source:	Chapter Title:	CH03: Characteristics of the Driver, the Pedestrian, the Vehicle, and the Road
Source:	Section:	S3.6: Vehicle Characteristics
Source:	Sub-section:	S3.6.3: Dynamic Characteristics
Source:	Sub-sub section:	braking distance
Source:	Page Number:	79
ID:	Inscription No.:	002 - E3.27
ID:	Inscription title:	stopping sight distance
Analysis:	Inscription Type:	equation

We coded each inscription following this example. The final tally of inscriptions examined for this study was 485 inscriptions across the 11 different textual resources. This data was stored within a Microsoft Excel File in order to provide easy access for further examination and analysis of the data. After coding the inscriptions according the listed codes, we reduced the data to frequency counts for each inscription type. Using this value, inscriptions per page for each inscription type was calculated.

Results

Inscriptions were identified relatively more frequently in the textbooks and course notes examined compared to the two practical reference sources. Table 3 provides a summary of values for inscriptions per page calculated for each textual resource. As shown in the table, there existed a wide range of frequency of inscriptions across the different textual sources. Another finding gathered from Table 3 is that the delivery of inscriptions (as measured by prevalence) does not appear to be overwhelmingly consistent across all settings and textual resources. This may reflect differences in individual practices and personal choice in the delivery of inscriptions amongst the educators, textbook authors, and policy designers.

However, the range of inscriptions per page – particularly, those values for textbooks - appear slightly higher to findings from similar studies. For example, Leivas Pozzer and Roth noted that total number of inscriptions in Brazilian and North American high school textbooks were 1.88 inscriptions per page and 1.47 inscriptions per page, respectively[16]. In a survey of inscription frequencies across journal articles and textbook articles, Roth, Bowen, and McGinn noted that the ecology textbooks they analyzed had values for inscriptions per page ranging between 1.22 and 1.49[26]. Taking the value for inscriptions per page for textbooks in this study, the value (1.60 inscriptions per page) appears slightly higher than those found by Roth and his colleagues[16, 26]. This may be accounted for by differences in domains of study between this research and Roth and his colleagues' domain of interest. These results reaffirm the assertion that the engineering domain and its inherent identity - at least within the academic setting - are heavily characterized by the presence of inscriptions in the texts that we utilize.

Textual Resource Type	Source	Total Inscriptions per source	Total pages listed for "sight distance" per source	Inscription per page
Course Notes	Instructor A	50	31	1.61
Course Notes	Instructor B	30	11	2.73
Course Notes	Instructor C	76	22	3.45
Course Notes	Instructor D	105	104	1.01
Practice	(AASHTO 2004)[27]	71	101	0.70
Practice	(MUTCD 2009) [32]	17	54	0.31
Textbook	(Garber and Hoel 2009)[33]	41	29	1.41
Textbook	(Wright and Ashford 1998)[34]	13	15	0.87
Textbook	(Roess, Prassas, and McShane 2011)[35]	12	7	1.71
Textbook	(Mannering and Kilareski 1998)[37]	10	3	3.33
Textbook	(Khisty and Lall 2003)[36]	60	31	1.94

Table 3. Summary of values of inscriptions per page

An interesting result from Table 3 is the relatively lower value for inscriptions per page for the practical reference documents compared to the other textual resources. Comparing the inscriptions per page for each textual resource type, the dissonance between relative values for inscriptions per page becomes more apparent (see Table 4). These results suggest that there exists a difference between the delivery of inscriptions in workplace and academic settings, as mediated by the textual resources examined for this study.

Textual Resource Type	Inscription per page
Practice	0.57
Textbooks	1.60
Course Notes	1.55

Table 4. Summary of inscriptions per page (grouped by textual resources type)

Another issue of interest is the distribution of inscriptions according to their abstractness relative to the real, tangible world. Figure 4 provides a graph overlaying the inscriptional chain and the relative frequency with which inscriptions appeared within the textual resources. Some interesting results emerge from this graph. One such result is that three types of inscriptions representing aspects of sight distance were overwhelmingly more prominent across different textual resources and settings. These include diagrams, tables, and equations.

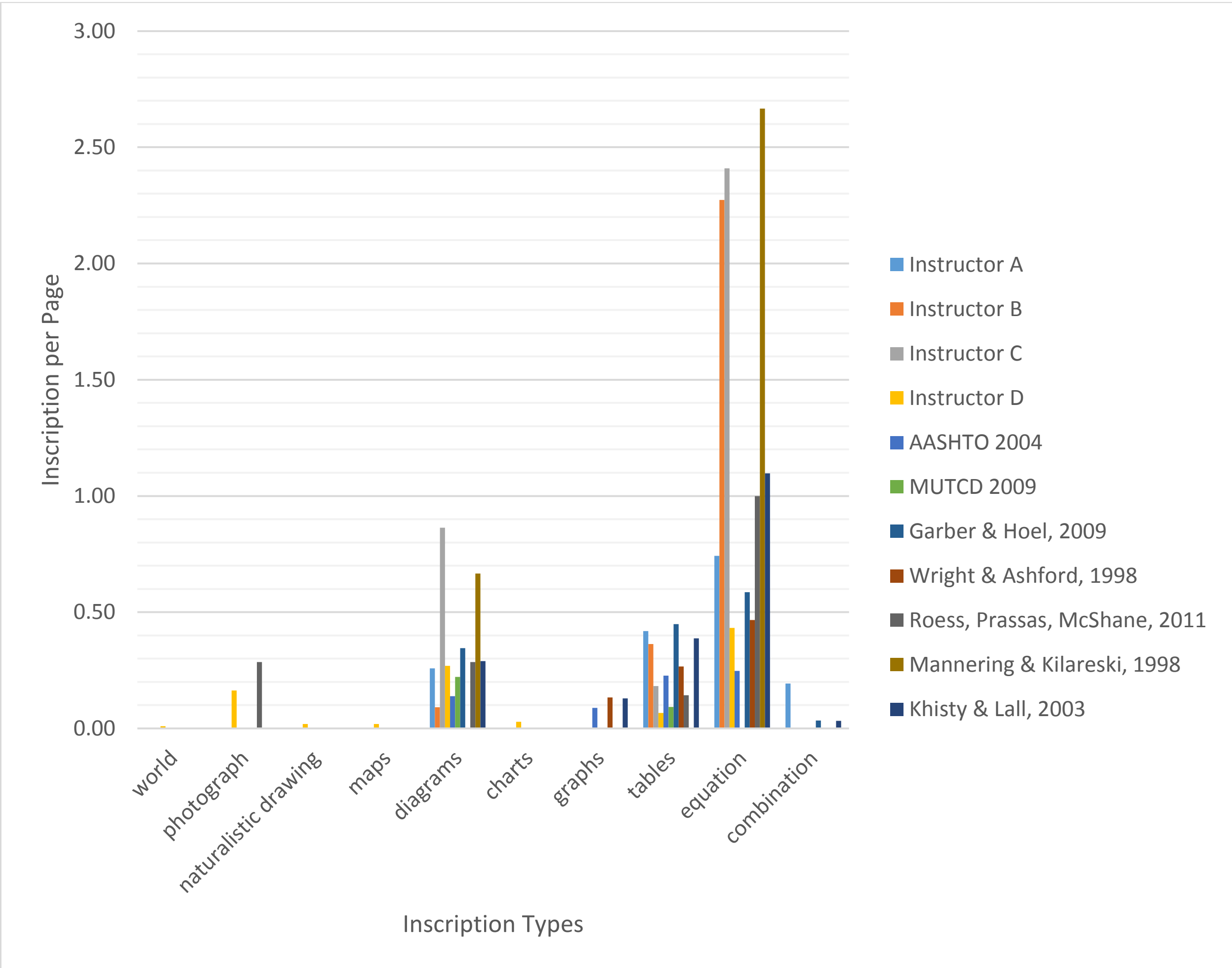

Figure 4. Distribution of inscriptions in reference to inscriptional chain

Another notable issue that emerged from this graph is that abstract forms of inscriptions were more prominent in the textual resources. Note the skewed distribution of inscriptions towards the portion of the inscriptional chain characterized by being more abstract, more symbolic, closer to mathematical structure, and providing lesser physical detail. This pattern appears to be independent of the setting in which these textual resources were embedded.

Using a similar graph, plotting the inscriptions per page for grouped textual resources (as shown in Figure 5) produces the same implications. The graph remains skewed towards the more abstract forms of inscriptions. However, a closer look at the graph reveals differences in distribution amongst inscription types between practical references sources, textbooks, and course notes. The most prominent difference exists between the frequencies of use of equations in academic texts compared to practical texts.

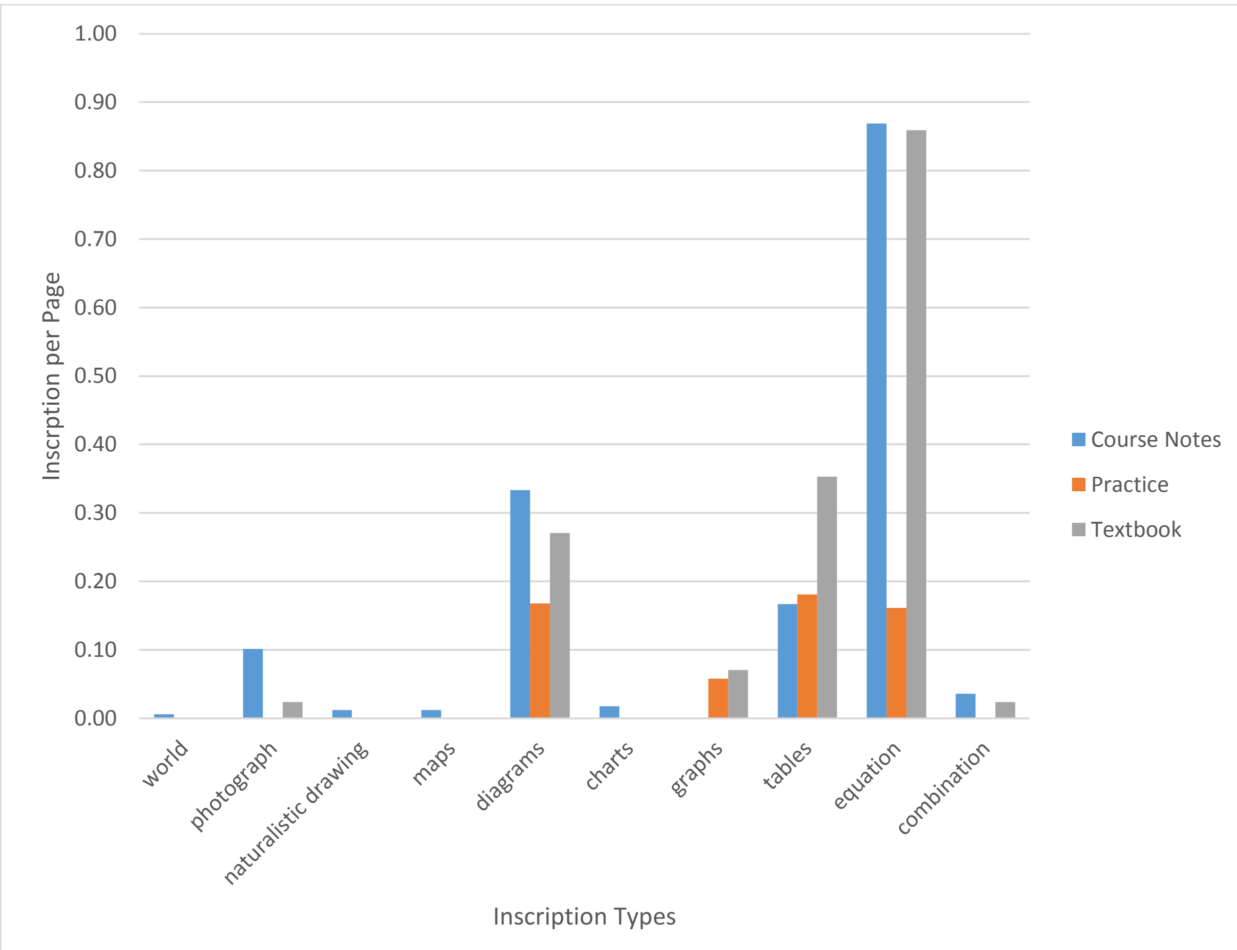

Figure 5. Distribution of inscriptions in reference to inscriptional chain (grouped textual resources according to settings of use)

An argument can be made that the data from the two sources with highest inscription per page count (i.e. Mannering and Kilareski text and the course notes from Instructor C) caused this discrepancy, particularly their effects on the equation inscription type. Rather than including the results of these textual resources, it can be argued that these values should be treated as outliers. However, removing these results would misrepresent the results of the study. As noted in the methods section, the Mannering and Kilareski text initiated one of the most prominently utilized series of textbooks within introductory courses in transportation engineering. Taking it out of the analysis without replacing it with another edition of the text would limit the transferability of our results. Further, Instructor C's course notes provide a means to consider different values held by existing educators and the practices.

Discussion

The results of this study provide initial steps towards identifying differences in the ways inscriptions are utilized within academic and workplace settings. One difference identified in this study is the frequency with which inscriptions were embedded within the textual resources. Compared to the AASHTO manual and the MUTCD, the textbooks and course notes had nearly three-times more inscriptions per page.

Another issue identified in this study is the differences in distribution of inscriptions types amongst the different mediums. The large number of equations present within academic-centered text appears to drive these differences. In a related research study, students strongly associated their conceptual understanding of sight distance to equations despite struggling with correctly utilizing equations to solve problems associated with sight distance[38]. Perhaps, the saturation of equations within the materials they reference in the academic setting influenced this assertion by students. Understanding why students have issues applying tools of learning, such as equations, graphs, or other inscriptions, despite its seemingly central nature in understanding the concept would be beneficial to both engineering education research and instruction practices. Examining this relationship between statement of beliefs and the material contexts that surround an individual as they learn may be fruitful.

Conclusions

As instructors, we provide tools and artifacts to students in hopes that they may successfully integrate into the field as knowledgeable members of the community of practice. However, understanding the role of those tools and artifacts (and the material contexts in which these are mediated) in their learning process must be addressed in order to successfully meet this goal. We must be able to answer several important questions. How do these tools, artifacts, and visual representations add to student knowledge? What quality about these tools, artifacts, and visual representations affect student conceptual understanding? In what ways are these tools, artifacts, and visual representations relevant to practice?

The implications of these findings are small, but meaningful, in pursuing further research into the integration of relevant material contexts to academic settings. For example, the results of the study indicate that the inscriptions we expose students to in academic settings – particularly in regards to sight distance as an engineering concept - largely shift towards forms of representations that are more abstract. These inscriptions tend to be nearer to symbolic representations than the tangible world. Exposing students to different types of inscriptions that span beyond that portion of the inscriptional chain is an area worth further examining. Will exposing students to more “life-like” inscriptions better help them identify as a member of the engineering community? This question directly affects the way instructors facilitate learning and deliver tools to mediate learning.

One issue not complete explored in this study is the interrelationship between the practical resources (particularly, the AASHTO document) and the academic texts. Many of the inscriptions found within the textbooks were sourced directly from the AASHTO manual. Future research can examine this relationship amongst inscriptions spanning various settings. What role do supplementary sources (those not from practical reference sources) play in student growth between novice and expert? What are these supplementary materials, and why do instructors choose to use them? Further, what inscriptions from practical reference materials did textbooks and educators choose not to utilize? Why were these decisions made?

Future research may expand upon this study by analyzing other documents associated with workplace setting such as design documents, CAD drawings, and written reports. The methodology for gathering and analyzing data proposed in this study provides guidance for forthcoming work in this field. Continued efforts toward understanding what makes up the material contexts in which we learn will provide opportunities to better implement strategies and improve the learning experiences of students.

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