AN ABSTRACT OF THE THESIS OF

Allie Peters for the degree of Master of Science in Civil Engineering presented on April 13, 2015.

Title: Understanding Instructors Curriculum Planning Process for the Refinement and Dissemination of a Digital Platform to Share Transportation Education Materials

Abstract approved: ____

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Background

The National Science Foundation (NSF) has funded multiple research projects dedicated to the development of research and evidence based instructional strategies in an effort to improve the state of science, technology, engineering and math (STEM) education in the US. These efforts have led to an abundance of research based curricular materials and instructional practices. While these efforts have been shown to positively affect student learning, there is little evidence that these materials and methods are shared between instructors.

Purpose

In order to better understand what is hindering the dissemination and adoption of research based curricular components, more insight is needed into the curriculum planning and sharing processes of engineering educators. This thesis is a collection of four chapters that describe efforts to understand and improve those planning and sharing practices.

Methods

Interviews were conducted with twenty-four transportation engineering instructors about their curriculum planning and sharing practices in order to better understand the decision making process as it relates to course planning, as well as to determine characteristics of curricular components that instructors implement in their classrooms. These results in conjunction with the results of two rounds of usability testing performed by potential users are being utilized to develop and refine a web based repository where engineering educators can easily access and share curricular materials and best practices.

Results

Instructors spoke most often about lecture components when asked about developing courses. Instructors often made changes to materials they already had, and did not directly implement materials they borrowed from others, but rather modified the materials to fit into their existing courses. Instructors had three main reasons for changing materials; incorporating active learning elements, including real world or contemporary materials, and providing greater clarity to students. The usability testing revealed inconsistencies with users' expectations of categorization of materials and concerns with security of materials, both of which have been addressed through changes to the system.

Conclusions

Those developing research based instructional strategies should focus on developing curricular components that are (1) easy for instructors to incorporate into their existing courses, (2) easily modifiable, (3) can be transferred from one subject to the next, and (4) can be incorporated into lectures. They should also focus on including active learning elements into instructional strategies. These combined efforts to design a web based repository with end users in mind can facilitate greater of sharing, adoption and dissemination of curricular materials and best practices within engineering education.

Understanding Instructors Curriculum Planning Process for the Refinement and Dissemination of a Digital Platform to Share Transportation Education Materials

by
Allie Peters

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Allie Peters, Author

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TABLE OF CONTENTS

Page

TABLE OF CONTENTS (CONTINUED)

Page

TABLE OF CONTENT (CONTINUED)

Page

LIST OF FIGURES

Chapter 1: Introduction

The need for adoption and dissemination of materials

According to the National Science Board, there is currently a need in America for a resurgence of national interest in science, technology, engineering and math (STEM) education (National Science Board, 2010). A nationwide focus on the improvement of STEM education is crucial for the long term prosperity and overall standards of living in the US (National Science Board, 2010). In an effort to improve the state of STEM education in the US, the National Science Foundation (NSF) has funded numerous efforts dedicated to the development of evidence based curricular materials and methods through multiple programs in recent years (e.g., CCLI, TUES, IUSE) (National Science Foundation, 2004, 2010, 2014). The result of this heavily funded effort has been an abundance of curricular materials and best practices. While these curricular materials and practices are generally shown to positively affect educational outcomes, they are not widely adopted or disseminated throughout STEM education. This lack of dissemination of materials and methods does not fully realize the potential of these to improve the state of STEM education, and represents a lack of return on investments in these research and development efforts.

The research described herein includes a study on faculty decision-making when developing or revising a course and an independent study on the iterative development of a web-based platform to share curricular materials. These combined efforts serve to further the adoption of curricular materials by widening our understanding of how and why faculty integrate materials into their courses and how a web based system, and associated curriculum, can be developed to facilitate sharing of curricular materials. The following is a brief introduction to the relevant literature in this area and a description of how this project fills existing research needs.

Curricular reform is a widely researched topic within both higher education and engineering education research, and it is generally agreed that even though these innovations have been shown to have many benefits to student learning, there is a lack of diffusion of research based educational innovations (Borrego, Cutler, Prince, Henderson, & Froyd, 2013; Borrego, Froyd, & Hall, 2010; Davis, 2011; Hagerty & Stark, 2014; Henderson & Dancy, 2007; Henderson, 2006; Hora & Anderson, 2012; Hora & Ferrare, 2013; Hora, 2012; Kane, Sandretto, & Heath, 2002; Lattuca & Stark, 2009).

One area of research-based instructional strategies that has received significant attention from researchers and instructors is active learning (Prince, 2004). Active learning is highlighted here because it has been a primary target for reform in STEM courses, was found to be a common topic amongst those studied in this research, and the web-based platform for sharing of materials developed and evaluated in this research contains extensive materials that can be used in active learning. Active learning can be described most simply as any teaching method designed with a purpose to get students more actively involved or engaged (Keyser, 2000; Prince, 2004). In comparison to a more traditional lecture based approach to instruction, active learning has many benefits. Students tend to not enjoy lectures, and lose focus on what the instructor is saying as the lecture goes on. Lectures also presume the learner is oriented towards auditory learning, and tend to only promote lower-level learning of factual information (Keyser, 2000). In addition, active learning places a larger emphasis on developing students' skills and exploration of their own attitudes and values, and has been found to harbor students who are more engaged in activities, and are more focused on what the instructor is saying (Ragains, 1995; Williams & Cox, 1992). Active learning is often characterized by authentic learning tasks, collaborative learning, and limited direction from instructors (Houston, 1995; Keyser, 2000; Prince, 2004). Examples of active learning include experimental learning, writing tasks, speaking activities, class discussions, group work, problem solving, simulations, role-playing, speaking activities, computer-aided instruction, independent study, fieldwork, case studies, simulations and peer teaching (Houston, 1995; Keyser, 2000; Prince & Felder, 2006; Prince, 2004). Within engineering education specifically, research based instructional methods that have been shown to positively influence student learning and make lectures more interactive include just-in-time teaching, concept tests, think-pair-share, collaborative learning, cooperative learning and use of peer instruction (Borrego et al., 2013).

Materials and the means by which they are shared

Both higher education and engineering education researchers agree that more research is needed to support the diffusion, adoption and implementation of curricular innovations. There are several ways that instructors can adopt materials. Instructors can see a material being used by another instructor, or at a professional development program, and decide that they want to adopt those materials into their classrooms. Instructors may also determine that their class needs changes or improvements and then find materials to achieve this goal.

Factors that influence adoption

In higher education and engineering education literature, studies have often looked into factors that influence instructors' curriculum planning and decision-making processes as a means to determine barriers to curriculum change. Researchers have found that these influences can comes from a multitude of sources; institutions, departments, disciplines, colleagues, students, and even the instructors themselves. (Bennett & Bennett, 2003; Borrego et al., 2013, 2010; Brew, 2013; Henderson & Dancy, 2007; Henderson, 2006; Hora & Anderson, 2012; Hora & Ferrare, 2013; Hora, 2012; Kane et al., 2002; Lattuca & Stark, 2009, 2014; Prince, Borrego, Henderson, Cutler, & Froyd, 2013; Schoenfeld, 2000). While there are many factors that influence instructors decision making and curriculum planning practices, it is important to consider these factors simultaneously, as curriculum planning is a non linear process (Stark, 2000).

Institutions can influence instructors' decision making process in numerous ways. Within higher education and engineering education research, these influences include type of institution, institutional support, institutionally determined course characteristics, instructors' discipline, instructors' workload, instructors' available time, available funding, institutionally implemented pedagogical reform projects, teaching evaluations, institutional norms, and the need to adhere to accreditation standards (Borrego et al., 2010; Hagerty & Stark, 2014; Hora & Anderson, 2012; Hora & Ferrare, 2013; Hora, 2012; Lattuca & Stark, 2009; Lowther, Stark, Genthon, & Bentley, 1990). These factors have also been determined to hinder adoption in several ways. For example, it can be difficult for an instructor to change their classroom policies if they feel they do not have support from their institution or if there is a lack of funding or available time to do so (Brew, 2013; Henderson & Dancy, 2007; Henderson, 2006; Hora & Ferrare, 2013; Hora, 2012). Previous studies have also shown that instructors feel pressured to spend time working on research and focus on tenure, as opposed to spending time improving their teaching practices (Henderson & Dancy, 2007; Hora & Ferrare, 2013; Hora, 2012). Instructors are often influenced by perceived norms that can come from numerous sources, such as their department, discipline, colleagues and students. Prior studies have found that instructors find it difficult to change their courses if they are they only instructor doing so (Henderson & Dancy, 2007). Instructors have also reported that when they attempt to include more innovative teaching methods in their courses, there is student resistance to styles of teaching they are not used to (Henderson & Dancy, 2007). At the individual level, instructors' decision making and curriculum planning practices are influenced by their own beliefs, knowledge and educational goals. These influences are especially important to consider as they are highly resistant to change, and have a strong influence on how instructors plan their courses and which teaching practices instructors find possible, plausible and desirable to include in their courses (Kane et al., 2002; Lattuca & Stark, 2009; Schoenfeld, 2000). At the individual level, a largely influential factor is the individual adopters' perception of the innovation. According to Rogers' Diffusion of Innovations Theory, the perceived difficulty of an innovation is influential in the adoption of that innovation, and the actual complexity of the innovation is not necessarily relevant (Rogers, 2003). Likewise, Henderson and Dancy stated that, based on responses from they received during interviews of university physics faculty, instructors are looking for curriculum components that they feel are easy to customize to their own needs (Henderson & Dancy, 2007). Within the same study, Henderson and Dancy also found that instructors felt that researchers and themselves had diverging expectations of how instructors were expected adopt innovations, and the difficulties that instructors would face when adopting educational innovations (Henderson & Dancy, 2007).

Web-based pathways are one avenue for the dissemination and adoption of curricular materials, and their improved design could help address some of the barriers to dissemination and adoption summarized above. Studies on the adoption of technological innovations in education has focused largely on the hardware component of the innovation, while neglecting the software components (Christensen, Griffin, & Knezek, 2001; Less, 2003). While these studies observed the use of innovative classroom practices, such as the use of computer technology, course management systems, and online teaching materials, the focus tended to be on the relationship between the use of a technology and the characteristics of the adopters, and not on the adopters' views and perspectives of the technology, which has been shown in prior studies to be necessary in the development of innovations that are to be disseminated (Aboelmaged, 2000; Bennett & Bennett, 2003; Blankenship, 2003; Christensen et al., 2001; Isleem, 2003; Less, 2003; McQuiggins, 2006; Sahin, 2006; Shea, McCall, & Ozdogru, 2006; Zayim, Yildirim, & Saka, 2006).

The research in this thesis and how it fills the gap

In order to better understand this lack of dissemination of curricular components, more insight is needed into the curriculum development, decision-making, and sharing practices of STEM educators. This thesis includes four chapters that collectively represent efforts to improve these practices.

Chapter 1 is an introduction describing the need for adoption and dissemination of curricular materials, and how the research efforts underway can improve adoption and dissemination within engineering education.

The article presented in Chapter 2 will be submitted to the American Society of Civil Engineering Journal of Professional Issues in Engineering Education in the spring of 2015 and focuses on the curricular decision making process of engineering educators. This involved interviews of 24 transportation-engineering educators on their curriculum development and sharing practices. The overarching purpose of this study was to gain insight into the decision making process of engineering educators, including what types of course components they change and create, why they change these components, how they change these components, and what materials they draw from when they are creating and changing course components.

The article presented in Chapter 3 will be published and presented in the 2015 American Society of Engineering Education Conference proceedings (Peters et al., 2015) and illustrates how the decision making research presented in Chapter 2 is applied to an effort of encouraging dissemination of curricular materials amongst engineering educators. Chapter 3 presents a two-part study for the development and dissemination of a web based repository where engineering educators can share educational materials and best practices. An important factor in the success of the repository is the potential users' perceived usefulness of the materials the repository contains. With this in mind, the decision making research described in Chapter 2, which is one of the two components of the study presented in Chapter 3, focused on identifying characteristics of course components that engineering educators implement or modify in their classrooms, reasons for implementing or modifying course components, and what resources engineering educators draw from when developing or modifying course components.

The second component of the study described in Chapter 3 is usability testing of the web-based system itself. This testing focuses on providing a usable web based repository that is designed with all potential end users in mind. A beginning step in this process was a needs assessment phase, which involved interviews with potential users of the system regarding their needs, expectations and curriculum sharing practices. Following the needs assessment was several rounds of usability testing with potential system users. Potential users of the web based repository were asked to perform tasks using PDF prototypes of the web based repository. While performing these tasks, users were asked to describe the reasoning behind their methods of performing these tasks, as well as to describe any aspects of the system that did or did not meet their expectations. For example, the first round of usability testing discovered that the categorization system in place did not meet users expectations of how transportation engineering materials should be organized. This led to a reorganization of materials to improve navigation throughout the repository and the overall user experience.

The development of the web based repository is reliant on these two studies equally, but in separate ways. According to Rogers' Diffusion of Innovations Theory, the adoption of technological innovations is dependent on potential users perceived usefulness of the technology (Rogers, 2003). If this repository is abundant with course components that educators are interested in, yet the system to access these materials is difficult to use or does not meet user expectations, the system will not be a success. Conversely, if the system is well designed and easy to use, yet does not contain course components that are of any interest to educators, the system will also not be a success.

Previous studies have examined the use of research based instructional methods by directly asking instructors to describe their use of particular methods. By asking instructors to describe their curriculum planning and sharing methods in Chapter 2, the decision making study gains insight on how instructors are already sharing and implementing materials, and the characteristics of curriculum components that instructors are implementing. Previous studies have also viewed adoption of research based instructional methods as a single incident, meaning that users either adopt the innovation at wholly at one time, or they do not adopt the innovation. The study presented in Chapter 2 looks into adoption over time by asking instructors to describe not only their curriculum planning process, but also how they change their course components over time. This is also addressed in Chapter 3 by having several iterations of website usability testing, and allowing users to test the web based system before having to adopt it.

The study described in Chapter 2 also takes a unique approach to the study of instructors' curriculum planning process by focusing on decision making at the micro-level. Instead of simply asking instructors whether or not they implemented a specific curriculum component, they were asked to describe specific instances where they implemented a component, including which part of the components they implemented, what they changed or did not change, and why they decided to do these things. This is important for the development and refinement of the web based repository considering that when instructors come to the repository, they will likely be making decisions about their classrooms at this level.

Chapters 2 and 3 address both the hardware and software components of a technological innovation. The software component is addressed by using the decision making research to ensure that the repository contains materials that are perceived as useful to potential users of the system. The hardware component is addressed by ensuring that the repository itself meets users expectations so that they can easily access desired materials. Chapter 4 is a conclusion that presents the results of the studies described in Chapter 2 and Chapter 3, and the conclusions that can be drawn from these results. Chapter 4 also presents suggestions for future researchers, curriculum developers, and engineering educators to promote the adoption and dissemination of research based curriculum materials. Higher rates of adoption and dissemination of research based instructional materials and methods can promote change within engineering education, which in turn can improve the state of engineering education overall.

Chapter 2: Understanding Transportation Engineering Instructors Curriculum Planning Process

Introduction

Nationally there is a growing interest in the reform and improvement of curriculum, one area in particular being engineering curriculum (Lattuca & Stark, 2014; National Academy of Engineering, 2008). In an effort to improve engineering education in the U.S., The National Science Foundation (NSF) has spent millions of dollars through the Transforming Undergraduate Education (TUES) in STEM, Course, Curriculum and Laboratory Improvement (CCLI), and Improving Undergraduate STEM Education (IUSE) programs developing an abundance of curriculum materials and teaching methods (National Science Foundation, 2004, 2010, 2014). While these materials and methods are evidence based, and shown to positively affect student learning and educational outcomes, they are slow to be adopted or disseminated.

In an effort to understand the underlying causes of this lack of adoption and change, more insight is needed on engineering educators' decision making processes as they relate to curriculum planning. In order to allow for adoption of curricular materials, instructors should be willing to make changes to their current classes. Focusing on how and why engineering educators create or change their curriculum will allow for more understanding of why instructors do not change or adopt certain curriculum components.

Research Goals

Keeping in mind the need to gain insight into instructors' decision making practices, this research was guided by several research goals. The first goal is to gain insight into engineering educators' decision making process as it relates to curriculum planning, including what course components are developed and changed, how instructors changed them, and why instructors changed them. The second goal is to identify characteristics of course components that faculty implement in their classrooms, including what course components faculty do or do not make modifications to when implementing them into their classes. The last goal is to identify what resources instructors use to gather materials during curriculum planning. These goals led to the development of the following research questions:

- What are characteristics of curriculum course components that faculty implement in their classrooms?
- What are the characteristics of things that faculty do/do not change in their classrooms? What are differences in the characteristics of things they change/do not change and or that they are willing/unwilling to change?
- What are factors that influence faculty to modify course components in their classrooms?
- What are differences between course components that faculty do and do not modify in their classrooms?

Understanding this faculty decision making process can help future curriculum developers create course components that will interest and be more adoptable for engineering educators.

Literature Review: Faculty Decision-Making

Research within Higher Education Research

Curricular reform is a widely researched topic in higher education literature. These studies often focus on a lack of diffusion of educational research findings into mainstream instruction (Henderson & Dancy, 2007; Henderson, 2006). In order to determine what hinders the diffusion process, many studies have looked into the factors that influence instructors' teaching related decisions and curriculum design (Hagerty & Stark, 2014; Hora & Anderson, 2012; Hora & Ferrare, 2013; Hora, 2012; Kane et al., 2002; Lattuca & Stark, 2009, 2014). These studies have uncovered a wide variety of influences on teaching practices and decisions. Influences can come from many different sources, not all of which are necessarily related, but should be all considered simultaneously, as curriculum planning is not a linear process (Stark, 2000).

In a study of undergraduate physics faculty, Henderson and Dancy found that instructors are aware of alternative teaching methods, and were also aware of the issues surrounding traditional teaching methods, yet they continued to teaching their courses in a traditional manner (Henderson & Dancy, 2007). The instructors interviewed mention several barriers to change, including student attitudes and expectations, pressure from the department and other instructors to cover certain amounts of content, and lack of instructor time, both in curriculum development and in the actual classroom itself (Henderson & Dancy, 2007).

Several studies have found structural factors to have a large influence on instructors' curriculum planning and decision making processes. In higher education, these factors include type of institution, course characteristics, discipline, instructors' workload and available time, budgets, institutionally implemented pedagogical reform projects, teaching evaluations, accreditations, and institutional policies and support (Hagerty & Stark, 2014; Hora & Anderson, 2012; Hora & Ferrare, 2013; Hora, 2012; Lattuca & Stark, 2009; Lowther et al., 1990). As noted by Hora, structural influences afford and constrain curriculum planning and decision making by placing normative pressures on teaching decisions, imposing logistical constraints on behavior, and encouraging autonomous practices (Hora & Anderson, 2012; Hora, 2012).

There are also many social-cultural factors that have influence on instructors' curriculum planning and decision making process. These factors include perceived norms from the institution, department, other faculty members, and even students. For example, several studies have discovered that instructors feel pressured to spend time performing research over improving their curriculum and teaching practices (Hagerty & Stark, 2014; Hora & Anderson, 2012; Lattuca & Stark, 2009, 2014). Instructors have also mentioned being influenced by the characteristics of students in their courses, including student goals, expectations, abilities and resistance to change (Henderson & Dancy, 2007; Hora, 2012; Lattuca & Stark, 2009). Several studies also note the difficulty for an instructor to adopt a curriculum change if he or she was the only one making the change, or if the institution did not provide time and resources to implement these changes (Brew, 2013; Henderson & Dancy, 2007; Henderson, 2006; Hora & Ferrare, 2013; Hora, 2012).

Instructors are also influenced at the individual level. Individual influences include the instructors' beliefs, knowledge, and goals. These factors may are of particular importance considering that researchers have found that teacher beliefs are highly resistant to change (Kane et al., 2002). Schoenfeld states that instructor beliefs influence which teaching practices instructors find plausible, possible and desirable, and that a combination of teach knowledge, goals and beliefs can shape the actions instructors take regarding teaching practices (Schoenfeld, 2000). Lattuca and Stark also found instructors' educational beliefs to have a strong influence on how they planned their courses (Lattuca & Stark, 2009).

Of these many influences, researchers have found several of them to be barriers to curriculum change. Henderson and Dancy (2007) interviewed physics instructors who made changes to their courses that were influenced by educational research. They found several differences in expectations between instructors and researchers, and that these differences were barriers to dissemination of educational innovations (Henderson & Dancy, 2007). Overall they found that instructors felt researchers were expecting them to adopt their innovations with little or no changes, instead of working with instructors to apply research methods to their classrooms. They also discuss the needs of researchers to address possible difficulties instructors may face, and how to overcome these obstacles, instead of telling instructors how easy a change would be (Henderson & Dancy, 2007; Henderson, 2006).

The curriculum materials themselves can be barriers to change. Henderson and Dancy also mention that, based on the responses they received, they feel instructors are looking for materials that are easy to modify and customize, and that instructors felt researchers do not provide easily modifiable materials (Henderson & Dancy, 2007).

Research within Engineering Education Research

Numerous studies have been conducted throughout engineering education with a focus on improving STEM instruction through the dissemination, adoption and implementation of research-based instructional methods and materials. These studies have also found a lack of diffusion of educational innovations, as well as uncovered many barriers to curriculum change.

Research within engineering education has found similar barriers to change as were discussed within higher education research. For example, Davis mentions instructor characteristics, perceptions of the importance of research over teaching innovations, available faculty time, and funding as barriers to the implementation of engineering education innovations (Davis, 2011). Similar studies on curriculum planning have also found funding, class characteristics, instructors' available time, discipline to influence instructors' decision making (Borrego et al., 2013, 2010; Davis, 2011; Seymour, DeWelde, & Fry, 2011). Borrego (2010), much like Henderson and Dancy (2007), found that the characteristics of the innovation itself can be influential in adoption rates amongst engineering educators, including the perceived complexity of the innovation, and whether the innovation could be easily implemented by a single instructor, or required collaboration between departments (Borrego et al., 2013, 2010).

Engineering education research has also found several barriers to change not mentioned in higher education research. Davis noted that engineering faculty members' backgrounds include skilled technical knowledge within their engineering specialty, but often are lacking in pedagogy (Davis, 2011). It has also been noted that many engineering instructors are not current with engineering education innovations, or how these innovations influence student learning (Borrego et al., 2010; Davis, 2011).

Adoption Research

A commonly used theory in the adoption of teaching innovations in engineering education is Rogers' Diffusion of Innovations theory. Rogers defines diffusion as "the process by which (1) an *innovation* (2) is *communicated* through certain *channels* (3) *over time* (4) among the members of a *social system* (Rogers, 2003)." Within engineering education, Rogers' Diffusion of Innovations Theory is often applied to study and predict adoption rates of curricular innovations based on the characteristics of the innovations and the potential adopters (Borrego et al., 2013, 2010; Davis, 2011). Rogers' considers adoption a process that happens over time, and relies on potential adopters perceptions of the following five components: relative advantage, observability, trialability, compatibility, and complexity. Relative advantage describes whether the potential users perceive the ideas of the innovation to be better than the ideas that came before it. Observability describes potential users ability to see the benefits of an innovation. Trialability describes how the potential user can try out components of the innovation before having to fully adopt it. Compatibility is how well potential users perceive the innovation to fits within their values. Complexity is how difficult potential users consider the innovation to use. Potential users will consider an innovation suitable for their use if they perceive these things to be better than the innovations that came before, the actual characteristics of the innovation are not necessarily relevant (Rogers, 2003).

Within the Diffusion of Innovations perspective, Rogers' defines an innovation as anything that can be considered new, and found that innovations are often a technological advancement or idea. A technology is defined as a design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired outcome. Technologies are composed of two components, hardware; a physical object that embodies the innovation, and software; the information base for the innovation (Rogers, 2003).

Active Learning

One area of research based instructional strategies that has been gaining attention within engineering education research is active learning (Prince, 2004). Active learning is a very general term, and covers a wide variety of research based instructional strategies. Active learning can most simply be defined as any teaching method that's purpose is to get students actively involved, and is often characterized by authentic learning tasks, collaborative learning, and limited direction from instructors (Keyser, 2000; Prince, 2004). When compared to a more traditional lecture based teaching method, active learning has many benefits, including students that are more engaged in activities and what the instructor is saying, greater emphasis on developing students' skills and allowing students greater exploration of their own attitudes and values (Keyser, 2000; Ragains, 1995; Williams & Cox, 1992). Lectures tend to be not enjoyed by students, and only focus on lower-level learning (Keyser, 2000; Ragains, 1995; Williams & Cox, 1992) Examples of active learning include group work, problem solving, discussions, fieldwork, case studies, simulations, and peer teaching, among many others (Keyser, 2000; Prince & Felder, 2006; Prince, 2004). A study of chemical engineering instructors by Prince (2004) found active and collaborative learning to have the highest percentage of implementation of those instructors that were aware of those research based instructional strategies as compared to other research based instructional strategies (Prince, 2004).

Use of Real World Materials

The use of real world materials and problems is not an uncommon occurrence within engineering education. For example a survey of engineering capstone courses found that a high percentage of universities in North America involve industry in their capstone projects (Todd, Magleby, Sorensen, Swan, & Anthony, 1995). Similarly, a study of the engineering capstone courses in the world's top ranking engineering programs found that most of the programs simulate authentic engineering projects and working environments through problem based learning, active industry involvement, group work, and assessment of design methodology, communication and teamwork (Ward, 2013).

Gaps in Previous Literature

Studies throughout both higher and engineering education agree that further research is needed on the diffusion, adoption and implementation of curricular innovations, and barriers to curricular change. By focusing on individual micro-level decisions that instructors are already making, not specifically asking them about adopting specific materials, this study gains insight into how instructors adopt materials, what characteristics they are looking for when changing and creating course components, and characteristics of components they are willing to adopt at a decision making level that has not been previously researched. This micro level method of interview also avoids a potential for over reporting of the use of research based instructional strategies.

Methods

This study consisted of interviews of 24 engineering educators. The participants in this study are college level instructors who teach transportation engineering or transportation related courses. Overall there are 24 participants from 18 universities across the country. 52 potential participants were contacted, giving a 46% response rate.

Of these 24 participants, 20 are tenure track instructors and 22 came from research institutions. There was a wide range of levels of teaching experience represented, with the number of years of teaching ranging from 2 to 28, and the number of times teaching the course in question ranging from 2 to 30 times.

Interview Protocol

The interview protocol was developed over several iterations. An original protocol was developed with the research questions in mind, and focused mainly on a new course or newer course that the respondents had developed on their own. This interview protocol was used with 5 participants, and the results were analyzed to determine if themes emerged and if certain areas of curriculum planning would warrant more interview questions.

It was decided after the first round of interviews that sending the participants the interview protocol beforehand, and asking the participants to have a copy of their most recent course syllabus as a reference during the interview could lead to responses more oriented toward the thought process behind the respondents decision making process. It was determined that many of these decisions are automatic when developing courses, and are not often thought about consciously, therefore allowing respondents more time to reflect on the process would allow for responses more in line with the research goals. It was also noted that many instructors do not develop courses completely from scratch, so the protocol was changed to include any transportation related course that the instructor teaches, versus a course they recently developed.

Each interview was recorded and saved as an audio file, then transcribed into a text document. After each interview was transcribed, it was analyzed for any responses that related to the research questions. If there were a response that related to the research questions, the response would be coded in the transcription. Follow up questions were developed based on this coding to gain further detail on responses related to the research goals. Follow up questions and the interview transcriptions were sent to the participants and a follow-up interview was conducted.

The transcribed interviews were coded using the analysis software Dedoose (Dedoose Version 5.0.11). The initial rounds of coding were for respondent and class characteristics, such as course level, required course, etc. This allowed for course and instructor characteristics to be easily extracted from the data. The transcriptions were then coded to organize responses based on the interview questions asked. The next step was to identify any time when a respondent made a specific decision to change or develop something in their course. Each decision was then broken down into what course component was changed or developed, why it was changed, how it was changed, and what material was used to make that change or develop that course component. If the respondent did not mention one or more of these details, it was addressed in a follow up interview.

Results

Four categories of results were found, 1) what types course components instructors tend to change or adopt, 2) why instructors change or adopt these course components once they decide to or adopt them 3) how instructors go about making these changes and adopting these course components, and 4) where instructors get course components from when making changes to their courses.

What course components do faculty change?

When transportation engineering faculty members were asked about creating and changing course components in their classes, they talked most about lecture components, with 23 respondents mentioning developing or changing lecture components. Lecture course components include lecture slides, notes, and lecture style. Lecture notes were either developed from scratch when the respondent first taught the class, or they received course notes from a colleague who taught the course before them. Thirteen of the 24 respondents interviewed mention getting course notes from a colleague who taught the course before them.

The next most common component that respondents changed was in class activities, with 16 respondents mentioning creating or changing them. In class activities that were mentioned by respondents included group discussions, in class problems and group activities. A specific example from a respondent was taking a break in lecture, splitting students up into groups, giving the students a problem, and then having the students work them out on their own and share their findings and opinions with the class. Another example mentioned was having students read a current news article relating to the course, and then having a course discussion on the article.

Less commonly mentioned changes to course components included exams, homework, and labs, mentioned by 7, 8 and 5 respondents, respectively.

Why do they change course components?

When asked about changing course components, or what course components they adopted into their courses, respondents mentioned three reasons for making changes; 1) including active learning elements, 2) incorporating real world and contemporary course components, and 3) the clarity of the course components for students.

The most commonly mentioned reason for change was including active learning elements into their courses. Of the 24 interviewees, 17 mentioned implementing active learning activities in their classroom, or modifying course components to include more active learning. For the purposes of this research, the term active learning was considered as when a respondent explicitly mentioned the term active learning, mentioned moving away from older or more traditional teaching practices, or using course components and practices to improve student engagement. Examples of the different determinations of active learning use in classrooms are shown in quotes from Respondent 7 and Respondent 23. Respondent 7 described explicitly the use of active learning course components in their classroom:

> That particular class runs three times a week, 50 minutes a class, but it's a little bit closer to what I would call active learning. So there's a mix of sort of traditional lecture, and then peer-to-peer learning and engagement. (Tenure track professor, public research university, 5 years teaching experience, taught this course 3 times.)

Respondent 23 described how they modified lecture course components to encourage more student participation during lectures:

> I want them to be taking notes and participating in the lecture. I'll do in class examples, I try to do one or two in class, where the class will try to solve a problem on their own and then we'll step through it together. Usually I go back and forth between talking about a concept and doing an example and another

> concept and then an example. (Tenure track professor, public research university, 5 years teaching experience, taught this course 3 times).

Another common reason for changing or adopting course components into classrooms was the incorporation of real world and contemporary course components. This reasoning was the second most commonly reported, with 16 of the 24 respondents mentioning the incorporation of these types of course components. Course components were considered real world if a respondent mentioned the material being real world, from industry, or used in practice. A contemporary course component is considered course component that is up to date, such as current design standards and manuals. The two quotes shown below differentiate between the use of real world and contemporary materials in curriculum planning. Respondent 14 described the incorporation of real world examples into their lectures:

> So what I try to with the lectures is I have one main concept per lecture, so we'll go through the theory behind it and then we'll do some example problems, we'll talk about how it's applied in real life and then we'll do a design problem they'll actually get to use the concepts in the field somewhere (Tenure track professor, public research university, 6 years teaching experience, 6 times teaching this course).

Respondent 1 described incorporating contemporary course components into their lectures when asked to present them in a different state than the original course component was prepared for:

> What I wanted was the standards for Tennessee for the height of a traffic signal for clearance, I got that information the manual and used it on the slides. I have been asked to go to Kansas City, MO, to go teach this class. I asked for their manual and tried to incorporate whatever information they have in their manual and incorporate that into my slides when I did the presentation there (Non tenure track professor, public research university, 5 years teaching experience, 20 times teaching course).

Lastly, respondents mention changing or adopting course components that provide clarity for the students. Respondents mention components not providing enough clarity for several reasons. One reason is what the material they had did not go into enough depth on the subject being covered. Another was that the material they had was overly complex and to be simplified in order to be presented to students at the level that they were teaching. Many respondents also mention that if students struggle on a certain topic or give them feedback that an aspect of the course is confusing, they would go back and attempt to make the information clearer. Clarity was the least commonly mentioned reason for change, with 13 of the 24 respondents mentioning clarity of course components. Respondent 14 discussed adjusting their lecture course components to provide clarity for students:

> Every year I try to go back and see my notes what's worked, what hasn't worked and how to make it better. Its more of my feeling, maybe on work assignments, things like that if students don't do well I'll go back and see how it was presented (Tenure track professor, public research university, 6 years teaching experience, 6 times teaching this course).

How do faculty change their courses?

When transportation engineering faculty members were asked how they go about changing course components, there were three main paths that were mentioned; 1) actively considering the component they wanted to change first, 2) considering the source of the component first, or 3) considering the course component they wanted to adopt first. With 18 of the 24 respondents mentioning changing course components in this manner, the most common path to change was for respondents to want to change aspects of a course component they were already using in their class. The respondents would identify gaps in the components they wanted to make changes to, then go out and look for a material to fill these gaps. These gaps could be additional information on a specific topic, or information on a topic that was not included in their course that they felt should be. A common example of this path to change was adjusting the presentation of course components they received from colleagues. Respondent 22 discussed changing the lecture course components they received from someone who taught the course before them:

> I had somebody else's notes. They got changed quite a bit but that was nice to have as a starting point. I changed order of presentation on certain things, the logic that one person sees in how you explain a concept to someone is not the same way that you see it or feel comfortable explaining it, so it was never a factual change, you just change what gets presented when, or what order you go through the textbook (Tenure track professor, public research university, 24 years teaching experience, 20 times teaching this course).

The next most common path to change, with 10 of the 24 respondents changing materials in this way, was for respondents to have a source of course components in mind, look into that source, and then decide to adopt those course components into their classroom. These sources of course components ranged from textbooks and design manuals, to course components from colleagues who teach or have taught a similar course.

Lastly, respondents mentioned seeing a course component and then deciding to use that course component in their class. There were two ways faculty discovered these course components, they either found the course components on their own, or had the course components presented to them. A common example of respondents discovering a course component on their own was finding either a news story or journal article, and then bringing those course components into their classroom. These components were then used for lectures, homework, or in class activities. When course components were presented to respondents, it occurred in two ways; either a colleague presented the course component to them, or they attended professional development or workshops. If respondents felt the course components that were presented to them were useful, and would fit into their classroom, they would implement the course component, or parts of the components, into their classroom. Respondent 7 describes going to a workshop, and then bringing components of those experiences into their lectures:

> I've attended a couple of teaching workshops over the last few years, mainly active learning based workshops. I like that pedagogy, I try to work elements of that into my classes and students seem to respond well to that (Tenure track professor, public research university, 5 years teaching experience, 3 times teaching this course).

When respondents mention adopting a course component into their classroom, often they do not use the component in their class exactly how they receive it. It was common for respondents to use pieces of components they receive, or to modify a course component to fit into their own lecture.

What sources do faculty use when changing or developing their courses?

When talking specifically about a time they changed or developed a course component, instructors borrowing course components from a colleague was mentioned 21 times. When instructors borrowed from a colleague, lecture components were mentioned 16 times, in class activities were mentioned 3 times, labs were mentioned twice.

Following course components from a colleague, the next most commonly used resource of course components was design standards and manuals. Of the 24 respondents, 20 mention the use of design standards and manuals. These design standards and manuals are materials that are used in industry by practicing engineers.

Another common resource for course components mentioned by respondents was textbooks. When developing and changing course components, the use of textbooks was mentioned by respondents 18 times. When instructors used textbooks as reference materials, the textbooks used were not always the textbooks required of the students to have for the course.

Another commonly mentioned resource was research based course components. When changing curriculum components in their courses, 9 respondents mention using research materials as a resource. Research based materials include materials from scholarly journals and conferences, as well as the instructors' own research project, or research projects conducted by colleagues.

Discussion

The four categories of results show that 1) transportation engineering instructors most commonly change lecture components, including lecture slides, lecture style, lecture notes and in class activities, 2) the most common reasons for changing course components were to include active learning elements, improve clarity of materials for students, and incorporate real world and contemporary components into their classrooms, 3) when transportation engineering faculty change their course components, they have three main paths to change; considering the component they want to change first, considering the source of component they want to incorporate first, or seeing a material and then deciding to adapt it into their course, and 4) the most commonly used resources for changing curriculum components were components from a colleague, design manuals and standards, textbooks, and research materials.

The four categories of results within this study were used to draw conclusions on how and why instructors change course components within their classes, make recommendations for future research to aide in the development and dissemination of research based instructional methods, and identify ways the results of this study can be used to improve the state of engineering education.

Based on the results of this study, transportation engineering instructors do not fully adopt materials they borrow. Instead, instructors adopt individual pieces of the materials they borrow, such as an in class activity, or a piece of information for a lecture slide. Instructors also tend to make modifications to materials they adopt into their classrooms. When borrowing materials, instructors often incorporated course components into their existing courses and materials, and had the subject for the course in mind when they began to look for materials.

Instructor focus on lecture materials

When asked about changing and creating course components, the respondents in this study most often spoke about lecture components. This suggests that instructors feel that when it comes to course planning, they consider lectures the most important course components. As stated earlier in this essay, prior studies have shown that lectures may not be the most effective means of teaching, and that students do not particularly enjoy or pay attention during lectures (Keyser, 2000). If instructors are focusing mostly on lectures, yet lectures are not particularly effective, they are potentially using time that could be spent on the use of research and evidence based teaching methods on methods that are less effective means of delivering information to students.

Instructors may also consider lectures the most important course component due to the fact that most of their time in the classroom is spent lecturing. If a large portion of in class time is dedicated to lecturing, then developing and preparing for lectures would naturally take up a significant amount of time.

This study may also help instructors understand course planning in a way that will allow for them to plan college courses more efficiently. As mentioned by Stark, instructors' greater awareness of their curriculum planning processes and decision making is useful in raising consciousness of their own planning decisions (Stark, 2000). Future research on the influence of different components of courses on student learning could bring to instructors' attention which course components should be considered the most important. If instructors were made aware of which course components are the most influential on student learning, perhaps the focus of curriculum planning could shift to developing and refining the more influential components.

While it appears that instructors consider lecture components the most important in classes, this may not be a decision that they are consciously making. Stark also found that simply interviewing instructors on their decision making practices increased their awareness of their own planning processes, therefore further research on the subject could be largely influential on instructors decision making (Stark, 2000). This could improve the state of engineering education by utilizing instructors' time spent planning courses, which is already very limited, by directing more of their attention to developing course components that are largely influential. This would give instructors the potential to have a larger impact on student learning with a shorter amount of time spent on preparation and development of course components. Well developed course components that are largely influential on student learning also have the potential to improve students' learning experiences by improving students' understanding.

Instructor interest in active learning

Based on the responses within this study, transportation engineering educators are interested in active learning techniques and incorporating active learning elements into their courses, mainly their lectures. These results are in line with Prince's (2004) results that found active and collaborative learning are well known research based instructional strategies, and commonly implemented amongst engineering instructors (Prince, 2004). These results also align with evidence from higher education literature that university instructors have an awareness of research based instructional methods, and are also aware of the benefits of using these methods over traditional lectures (Henderson & Dancy, 2007; Henderson, 2006).

Several instructors interviewed throughout this study mention that, while they do continue to use lectures in their courses, they want to move away from the traditional lecture style, and add more active learning elements into their classrooms. These results suggest that instructors are aware of the fact that traditional lectures are perhaps not the most successful way to teach a course. These results can be beneficial for the development and dissemination of curricular materials in several ways. The first way these results can be used to improve dissemination of materials is for future researchers to consider the development of research based instructional methods that are of a small enough size where they can be easily incorporated into existing lectures. The instructors in this study wanted to add more active learning elements into their classrooms, but were not looking to change their entire course, just add course components in places in their existing courses where they felt they needed them; therefore an instructional method that requires a complete redesign of a course is unlikely to be adopted by these respondents.

Another way these results can improve dissemination of materials is to utilize the fact that instructors are looking to incorporate active learning elements into their existing courses, meaning that they already have the subject and content in mind. Based on these findings, active learning materials that allow instructors to easily incorporate their own course content are more likely to be adopted by the respondents interviewed in this study. These results represent an opportunity for change within engineering education. Instructors are seeking active learning elements in an effort to move away from traditional lectures, and if researchers can provide materials that will fill these gaps, engineering education can begin move away from less effective traditional lecture style, and towards more engaging and innovative teaching styles. If this shift were to occur it would provide a better educational experience for students, as well as represent a return on investment on the funding of projects dedicated to the development of research based instructional strategies through higher adoption rates.

Course components that were not often discussed

When asked about creating and changing their course components within their classes, respondents in this study did not often discuss changing exams, homework, and lab activities. This suggests that instructors do not find the development of these course components as important as they do lecture components. Previous research shows that collaborative and group learning, such as lab assignments and homework assignments, is more engaging for students than traditional lectures (Keyser, 2000; Prince, 2004). By focusing on less effective lecture components over these proven collaborative components, instructors are underutilizing their time.

These results also show that instructors may consider these components more difficult to develop and modify than others, such as lecture components. If these components are more difficult and time consuming to develop, instructors are not likely to change them often once they are developed to their liking. Changing or developing a homework, lab assignment or exam problem requires not only a change of the problem, but developing a solution, as well as determining the amount of time the problem will take students to complete. Lectures, on the other hand, can be easily modified by adjusting a few slides, and can even be adjusted during class time if need be.

If instructors are not actively changing these course components, research efforts that focus on the development of these components may not be disseminated as well as course components that instructors are looking to change, such as lectures. Researchers attempting to develop these types of course components could also include measures of effectiveness of their components on student learning. This would increase awareness of the importance and effectiveness of these course components, while also providing evidence of the effectiveness of the methods and materials they are developing, which could in turn increase adoption rates.

Recommendations

Based on the results of this research we can make four recommendations for developers of instructional materials, and engineering education researchers:

First, those creating research based instructional strategies should focus on developing course components that can be easily adapted into already existing classes, easily modifiable, and can easily transfer to different subjects. Based on the results of this study, instructors modify course components they adopt, and tend to have a subject in mind when creating or changing course components, and addressing this in the development of research based instructional methods can improve adoptability of developed curricular materials.

Second, researchers should focus on developing research based instructional strategies that instructors can incorporate into lectures. Based on the results of this study, lectures are the most common course components instructors make changes to, and therefore there is a greater chance of instructors adopting a course component if it can fit within a lecture.

Third, researchers developing research based course components should focus on including active learning elements. Within this study, 77% of respondents were looking to change their course components to include more active learning elements, so it is apparent that instructors are aware of active learning, and they are in search of methods to incorporate that into their existing materials.

Lastly, future research should focus on a comparison course components that instructors consider the most influential on student learning within the classroom, and what course components actually have an affect on student learning. Additionally, future research should look at not only barriers to change, but address methods to overcome these barriers.

These recommendations can help those developing research based instructional methods to improve adoptability of the materials and methods that they develop, which can lead to change within engineering education. Improving the adoptability of research based instructional methods within engineering education will improve the state of engineering education by providing students across the US with research and evidence based teaching methods that are proven to have a positive impact on student learning.

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Chapter 3: Refinement and Dissemination of a Digital Platform for Sharing Transportation Education Materials

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Introduction

In an effort to improve engineering education in the United States, the National Science Foundation (NSF) has invested heavily in the Transforming Undergraduate Education in Science, Technology, Engineering, and Mathematics (STEM) program (TUES) by developing an abundance of curricular materials and teaching methods (National Science Foundation, 2010). While these materials and methods are evidence-based and shown to positively affect student learning and educational outcomes, they have been slow to be adopted or disseminated.

In an effort to improve curriculum sharing, there is currently a two-part study underway for the development and dissemination of a web based repository containing curriculum materials and best practices. These two efforts are in place to understand, facilitate, and encourage sharing of materials and best practices between educators. The first is the development and refinement of the web-based repository for curriculum materials; the second is a study on the curricular decision-making processes of transportation engineering educators.

The overarching goal of these two studies is to develop an effective web-based repository where engineering educators can readily share educational materials and best practices. The development and dissemination of this repository is dependent on two aspects - a successful, usable web-based system, and materials that educators are interested in. If the materials contained within the website are what the educators are looking for, yet the repository does not meet user expectations, it is likely that educators will seek other methods of gathering these materials. Alternatively, a well-designed repository will be of little use if the materials available are not appealing or applicable to the short-term or long-term needs of educators.

Much research has been done in the design and development of technical systems for human use (Gould & Lewis, 1985). In order to provide a usable web-based system, academic- and industry-established user-centered design practices were incorporated in the development of the repository system. This included an in-depth needs assessment phase where system stakeholders (e.g., professors who would use the system) were interviewed about their own educational materials-sharing practices. Iterative prototyping and usability testing was built on the data gathered from the needs assessment phase.

The purpose of this usability testing was to gain knowledge to develop a sustainable plan for a web-based dissemination repository of best practices and materials, as well as determine how that repository can be developed to maximize use and adoption of materials. This was accomplished through determining the methods faculty use to look for curriculum when developing or refining a course, the characteristics of the curriculum that affect adoption decisions, and additional information needed for the adopter to know about materials to encourage adoption.

Recognizing that the success of the repository depends on the potential users' perceived usefulness of the materials available in the repository, the decision-making research focused on identifying characteristics of materials that transportation education faculty members implement in their classrooms, reasons faculty members have for modifying materials, and what resources and materials faculty members draw from when modifying materials.

Literature Review: Diffusion of Innovations

The national interest for improving engineering education in the United States has led to abundance of educational materials and methods. While these materials and methods are proven to positively affect student experiences and learning, and to improve courses and curriculum, their sharing and use in practice is limited by the unwillingness of educators to adopt new materials or change their teaching practices (Borrego et al., 2010). An example of this abundance is the fact that there are over two hundred introductory-level transportation engineering courses offered by faculty at universities across the country, yet there is little evidence to suggest that materials and methods are shared between these educators. Rogers' Diffusion of Innovations Theory can help guide efforts to understand this lack of diffusion and ways to increase diffusion (Rogers, 2003).

An innovation is anything that can be considered new, such as a technological advancement or idea (Rogers, 2003). According to Rogers, the adoption of an innovation relies heavily on the potential user's perception of the following five components: *relative advantage, observability, trialability, compatibility* and *complexity. Relative advantage* describes the perception of a current innovation being better than the ideas that came before it. A potential user will find an innovation useful to them if they feel it is better than what came before; the actual usefulness of the innovation is not necessarily relevant. *Observability* describes the ability of potential users to see the benefits of an innovation. *Trialability* is the potential user's ability to partially adopt or test out an innovation before having to fully commit to adopting the innovation. *Complexity* is how difficult the use of an innovation is perceived to be. *Compatibility* is how well potential users feel the innovation fits with their values and norms (Rogers, 2003).

A technology is a design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired outcome (Rogers, 2003). Rogers' theory considers a technology to have two components: (1) a hardware aspect, consisting of the tool that embodies the technology as a material or physical object, and (2) a software aspect, consisting of the information base for the tool (Rogers, 2003).

Prior educational research involving Diffusion of Innovations (DI) theory has focused on the use of computer technology (Sahin, 2006), course management systems (Bennett & Bennett, 2003; McQuiggins, 2006) and online teaching materials (Shea et al., 2006). While these studies have found the adoption of technology in classrooms to be correlated to student achievements (Christensen et al., 2001) and teaching experience (Less, 2003), the focus tends to be on the hardware components of technologies and neglects the software components. Research on hardware has identified relationships between use of technologies and the characteristics of adopters (Blankenship, 2003; Isleem, 2003; Zayim et al., 2006), but it has not addressed the adopters' perspectives, which have been argued to be necessary to be considered in the development of innovations if they are to be disseminated (Aboelmaged, 2000; McQuiggins, 2006). Previous studies have also treated adoption as an isolated incident (Waarts, Van Everdingen, & Van Hillegersberg, 2002), unlike Rogers' Diffusion of Innovations approach that considers adoption a process that occurs over time (Rogers, 2003). This could be due to the fact that the technologies in the previous studies were not designed to change over time.

Many academic institutions have considered the use of an institutional repository to share scholarly materials within their university (Dubinsky, 2014). For example, a study at the University of Oklahoma interviewed professors on their knowledge, concerns, and possible use of an online repository at their institution (Brown & Abbas, 2010). While there is evidence that the use and amount of content within these repositories is growing, the growth appears slow, and there is little evidence of active faculty participation (Dubinsky, 2014).

Methods

Background: Project Design

Because there has been no research on a web-based repository of curriculum materials, results from prior studies discussed above are being used to inform the development of the web-based repository and the decision-making research. The project utilizes Rogers' components of adoption in several ways. Relative advantage is addressed through both of the studies. The usability testing allows for potential user feedback on the usefulness of the repository, while the decision-making research gains insight into how educators are currently sharing information with each other. Observability is included in this repository by providing users with information on the quality of the materials, such as user ratings or number of downloads. The usability testing is not only an effective method for developing a system that potential users find useful, but also increases awareness of such a system amongst transportation engineering educators. Trialability is included in the system by allowing users to view excerpts or previews of materials before they chose to adopt the material into their classroom. Since this is development-level material and not a technology that is directly used in the classroom, using the system does not necessarily require individual users to change their teaching practices. Complexity is addressed through usability testing, by allowing potential users to voice their concerns or expectations of the system during the development stages. Compatibility is included in both studies: follow-up questions on why or why not this system would be useful to the potential users are asked during the usability testing, while identifying the materials in the repository that potential users are interested in contributes to the decision-making research.

The two studies can be seen as the hardware and software components of a technology that Rogers describes. The decision-making research serves as informational background, while the web-based repository is the physical tool that allows users to access the information sought. Unlike previous studies, perspectives on the system by potential adopters and the quality of the materials provided as judged by the same potential adopters are both taken into consideration, and these considerations are made over time, rather than at one moment in time. By being web-based and dependent on how educators use the system, the repository also has the ability to evolve and change over time.

Usability Testing

In order to refine the design of this digital repository, educators participated in two rounds of usability testing. This allowed the designers to see how potential end users interact with the repository, as well as get user feedback on these interactions. The first round of usability testing consisted of four engineering educators from a public research university. Participants in this round of testing all teach a transportation engineering or related course. Two instructors are tenured faculty, and two teach part time while working in industry. For this round of testing, researchers traveled to the participants' institution to carry out the tests. Users were given an interactive PDF prototype of the repository and asked to perform certain tasks. While interacting with the repository, users were asked to state each step out loud: what they were expecting, the reasoning behind their choices, and when their expectations were not met. This round of testing was centered on file uploading, adding contacts, sharing materials with contacts, browsing for contacts, and downloading files. Figure 1 shows a screenshot of the repository prototype used in the first round of testing.

Figure 1: Screenshot of the repository prototype used in round one of usability testing

Using the results from the first round of testing, the prototype of the repository was refined and a second round of tests were administered. Improvements included refining the levels of categories used to organize materials to simplify content navigation and improve the user experience. The second round of usability testing involved two tenure track transportation engineering educators, as well as four graduate students who plan on entering into academic careers. This round of testing also occurred at a public research university. Again the researchers traveled to the instructors' institution to carry out the tests. This test was administered in the same way as the first round, but this time the tasks focused on inviting contacts, requesting connections, adding members to groups, and sharing content. Figure 2 shows a screenshot of the repository prototype used in the second round of usability testing.

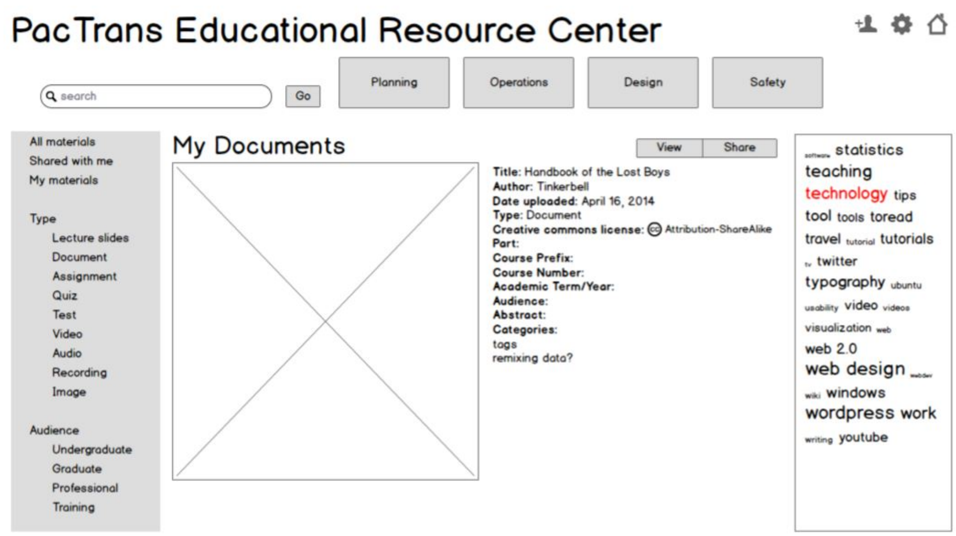

Figure 2: Screenshot of the repository prototypes used in the second round of usability testing

Decision-Making Research

For this study, the twenty-four engineering educators interviewed were instructors who teach transportation engineering or transportation-related courses. They broadly represented eighteen universities from thirteen states across the country. Seventeen of the universities are public research university, and one is a private university. The transportation educators chosen for this study were also identified as potential end users of the web-based repository under development.

The interview protocol was developed over several iterations. The initial protocol was focused mainly on a new course or newer course that the faculty had developed on his or her own. The focus was on newer courses so that the decision-making process was fresher in the minds of the participants. This interview protocol was initially administered to five participants, and the results were analyzed to see what kinds of themes would warrant additional interview questions. It was decided after the first round of interviews that sending the participants the interview protocol beforehand was beneficial. Furthermore, it was decided that asking participants to have a copy of their most recent course syllabus as a reference during the interview could lead to responses more oriented toward their decision-making thought process because it would serve a concrete reminder about choices that were made but were perhaps not given much consideration at the time. It was also noted that many instructors do not develop courses completely from scratch, so the protocol was changed to include any transportation-related course taught by the instructor.

The transcribed interviews were coded using the analysis software Dedoose (Dedoose Version 5.0.11) After each interview was transcribed, it was analyzed for any responses that related to faculty decision-making. Follow-up questions were developed to gain further detail on these responses, and these questions, along with the interview transcriptions, were sent to the participants prior to conducting a follow-up interview.

Results and Discussion

Usability Testing

The first round of user testing found that the initial version of the categorizing system for the materials did not meet the needs and expectations of the users. Results from this round of testing highlighted points of interaction that were difficult for users, including navigating complex engineering materials. As a result, the category hierarchy was changed and a set of filters was added that could be used in combination with the categories to allow users to further refine search results (see Figure 3). Some educators also had concerns over the security of their materials once they were uploaded to a repository like this one. This led to the development of user accounts with different levels of privacy for materials, such as an option to share materials with any user of the repository, or being able to choose specific users to share materials with.

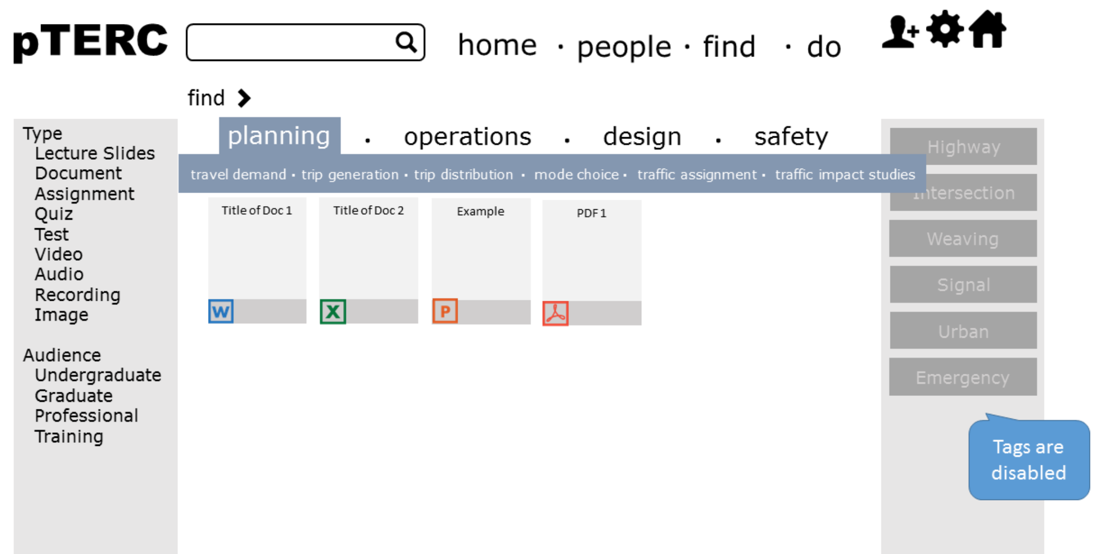

Figure 3. Screenshot of an updated user interface.

The second round of usability testing found that the contact and group management features met potential users' expectations. The security features that were included after the concerns that arose in the first round of testing yielded mixed reviews from the users in the second round. While most appreciated the increased security, there were concerns about the added complexity being a barrier to use and sharing. Some users also found symbols and links to be misleading or difficult to navigate. A possible solution for this would be labeling all links with words as opposed to symbols or pictures.

Decision-Making Research

The on-going decision-making research has identified several findings that can be used to further refine the web-based repository. First, we found that the type of materials most commonly created and changed are lecture materials, as opposed to homework or exams. *Lecture materials* included slides, notes, and lecture style. Second, we found that there were three major factors that influenced their decisions to use or change lecture materials: 1) active learning, 2) improving the clarity of materials for students, and 3) incorporating real world or contemporary materials. For the purposes of this research, *active learning* entailed explicit use of the term by the participant, moving away from older or more traditional teaching practices, and/or using materials and practices to improve student engagement. Materials were considered *real world* if labeled such by a participant, or if coming from industry or practice. *Contemporary* material was that which was up-to-date, such as current design standards and manuals.

Other preliminary findings include that when faculty members create or change materials, they most often gather materials from colleagues, textbooks, or design manuals and guides. When instructors borrow materials from colleagues they generally do not implement the materials as is, but rather make modifications to the materials or implement only portions of the materials. Educators are also looking for materials that they can include in their already existing materials, such as an individual lesson or activity instead of notes designed for an entire course.

Future Work

Usability testing combined with decision-making research has led to considerable progress towards the development of a successful web-based repository of curriculum materials and best practices. This research has aided in the design of the system, the end-users' expectations of this kind of system, and the characteristics of materials that should be included in this system.

The next step in this project is to complete a third round of usability testing. For this round, the information gathered in rounds one and two will be used to develop a functional website of the repository. While the static prototypes were useful during the early rounds of testing, they limited some user functionality, such as typing in search bars and text boxes. A functional webpage will alleviate any potential functionality issues that occur when using an interactive PDF prototype, making the webpage features the main focus of the testing. The functional system will also contain actual transportation course materials, as compared to the simulated materials that acted as placeholders to test the functionality of the system. This next round will get us one step closer to a final iteration of the repository.

Another important step is gathering of materials for the repository. The results from the decision-making research will be used to determine materials of value to educators. As discussed, these materials should include active learning elements, real world materials, and materials that are small enough to be included into an existing course, such as an individual lesson plan or lecture.

These two studies are expected to positively influence teaching practices in transportation engineering. Educators will be able to easily access transportation engineering curriculum materials and best practices, which can encourage dissemination, as well as reduce the replication of materials that already exist.

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We would like to thank the PacTrans Regional University Transportation Research Center for their financial support to conduct this project. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the PacTrans Regional University Transportation Research Center. We thank those professors who gave their time and thoughts to make this research possible.

Chapter 4: Conclusion

The research efforts described throughout these two articles address the dissemination, adoption and implementation of curricular materials from two different perspectives. The first effort, described in Chapter 2, gains insight into the curriculum decision making process of transportation engineering instructors, and the second, described in Chapter 3, is the development and refinement of a web based repository of curricular materials. The main goal of these efforts is to develop a web based repository that successfully allows engineering educators to share curricular materials.

The decision making research described in Chapter 2 identified a variety of results that can be used to further refine the web based repository. The first of these results being the types of course components that instructors change. When asked about creating and changing course components within their classes, transportation engineering faculty most often discussed creating and changing components of lectures. The next most common course component instructors mentioned creating and changing was in class activities. Less commonly mentioned changes to course components were exams, homework, and lab activities. This suggests that the instructors interviewed in this study consider lecture materials the most important course components. While lecture components may be an important aspect of the classroom, prior studies have shown that they are not the most effective. Students tend to not enjoy or pay close attention to lectures, and lectures tend to only promote lower level learning, therefore educators focusing on lectures over other aspects of the educational experience may under utilize instructors' time and impede educational reform (Keyser, 2000).

The decision making research also gained insight into why faculty members made changes to course components. Respondents most commonly mentioned changing course components or adopting materials into their courses to provide more active learning elements to their students. Another common reason for changing curriculum components was to incorporate real world and contemporary materials into their classes. This included providing materials that were up to date, and in alignment with resources engineers would use in practice, such as design manuals and guides. Lastly, but still very commonly mentioned, was providing greater clarity for the students. According to respondents, changes for clarity include greater level of detail, simplification of complex topics, or explanation of topics in a different manner if they felt students were struggling, or if students were giving negative feedback in certain areas.

Respondents changed course components mainly in three different ways. Instructors either actively considered the component they wanted to change first, considered the source of a component first, or considered the component they wanted to adopt first. The most common path was to consider the component they wanted to change first, meaning they had a component or topic in mind, then went searching for materials to support that change. Next most common path to change was to consider the source of the material first, meaning the first step in the process of creating or changing a component was to consult sources of materials, such as colleagues or textbooks. Lastly, respondents mention seeing or discovering a material, and then deciding that they wanted to incorporate that into their class. Respondents mentioned modifying materials before implementing them into their courses, and often borrowed materials they felt to be incorporated into their existing class materials.

The final takeaway from the decision making research in Chapter 2 was what sources faculty use when developing or changing course components. The most common source of curriculum components was their colleagues, and the most common materials to borrow from colleagues were lecture components. Following the borrowing of materials from colleagues, the next most common source of curriculum components was design standards and manuals. The next most commonly mentioned resource was textbooks.
The results of the usability testing described in Chapter 3 found potential points of difficulty for potential users of the systems, and highlighted areas where the potential users needs and expectations were not met. The usability testing led to a redesign of the categorization system of the materials contained within the repository. It also uncovered some users concerns of the security of their materials within the repository, which led to the inclusion of more security features. While navigation throughout the repository was improved in the second round of user testing, there were still some areas of confusion that will be addressed in further iterations.

Recommendations

The decision making research presented in Chapter 2 led to several recommendations for future researchers, curriculum developers, and engineering educators. The first recommendation is that those developing research based instructional strategies should focus on developing course components that can be easily incorporated by instructors into their existing courses, are easily modifiable, and can be transferred from one subject to another. This is based on the evidence from the study in Chapter 2 that instructors often have a subject or course in mind before searching for curricular materials.

The research in Chapter 2 also suggests that researchers should focus on developing research based instructional strategies that can be incorporated into lectures. When changing and creating materials, instructors most often focused on lectures, so instructional strategies that can be incorporated into lectures, or easily incorporated into a lecture based course, could increase the likelihood of adoption. Considering that lectures have been shown to be ineffective teaching methods (Keyser, 2000; Prince, 2004), incorporating research based instructional strategies into lectures could facilitate an increase in the effectiveness of lectures, and a shift from traditional lectures to more engaging and innovative ones.

When developing research based instructional strategies, researchers should also focus on developing active learning components that can be incorporated into existing courses, as opposed to entire courses or lesson plans. Instructors interviewed in the study presented in Chapter 2 often spoke of wanting to include more active learning elements into their classroom. This suggests that instructors are aware of active learning methods, and are seeking ways to include these methods into their classrooms.

Lastly, future research should focus on comparing what curriculum components instructors find the most important, and which curriculum components are most influential on student learning. This could increase awareness among curriculum planners as to which curriculum components have the largest effect on student learning.

If this system was to be successfully disseminated, adopted and implemented by transportation engineering educators, a similar system could be developed for other disciplines. While other disciplines could base a similar system off of this work, each discipline would require its own research to develop a system that meets the needs and expectations of their instructors. For example, transportation engineering educators have certain materials and resources that they commonly use, but a different discipline would likely have different resources that instructors look for that would need to be included in their system.

Future Work

The results of these efforts have led to a great deal of progress towards the successful dissemination and refinement of a web based repository of curriculum materials. The next steps toward this goal will be a third round of usability testing where the users will be testing a working prototype of the system, as opposed to the PDF prototypes that have been used in the prior tests.

Overall the results of these two efforts can be used simultaneously to provide a system that potential users want to use, and can use easily. Another crucial step moving forward is the gathering of curricular materials to contain within the repository. The information gathered from the decision making research in Chapter 2 will be used to determine which materials are considered useful to the potential users of this system. The results from Chapter 2 on how instructors search for materials will also be used to determine how materials can be searched for within the web based repository. These efforts to develop a system with the end users in mind can support dissemination of curricular materials amongst transportation engineering educators.

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