AN ABSTRACT OF THE THESIS OF

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Abstract approved:

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Decades of educational research has not reached and benefited most students due to the "implementation gap." The implementation gap is a term used to describe the divide between the number of research-based curricular materials created and the number that are broadly used in classrooms. A common approach to researching this gap is to look at the differences between users and developers. A different (and less commonly used) approach is to observe the involvement of instructors in the development of curricular materials. This level of involvement can provide a better understanding of the concerns of instructors during both development and implementation.

The purpose of this research is to describe the concerns of faculty who develop and implement their own research-based curricular materials over one academic year. In addition, the subjects of the concerns are analyzed and compared to previously identified barriers that hinder adoption.

A material-development workshop was held in which the video and audio recordings were used to determine the concerns cited by faculty. To gather concerns related to implementation, semi-structured interviews were conducted as near to implementation as faculty members' schedules allowed. The same group of faculty took part in both the workshop and

implementation interviews. Recordings were transcribed and coded using the constant comparative method and the Concerns Based Adoption Model (CBAM).

Management concerns were found to be similar in occurrence and subject for both the workshop (developers) and the interviews (users). Significant changes were found in the percentages of Consequence and Personal concerns cited between the workshop and the interviews. The subject of Consequence concerns remained consistent between development and use of the materials but the subject of Personal concerns changed with a greater focus on the implementer's confidence to correctly use and understand the materials was found during the interviews.

Despite using the same group of faculty during both the development and implementation of curricular-materials, adoption rates remained low and common barriers to adoption such as time and resources persisted. This suggests that the implementation gap is better explained by the differences in situations and not the differences in people (developers and implementers). An increase in Personal concerns is a prime example of how the situation affected instructors during implementation. This situational theory lays the foundation for approaching the implementation gap from a new direction and informs recommendations in designing workshops.

Concerns During Development and Implementation of Research-Based Curricular Materials

by

Grace C. Panther

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Dean of the Graduate School

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.

Grace C. Panther, Author

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Introduction

Engineering educators and researchers are challenged by the need to catalyze the adoption of research-based teaching practices and materials (Olson & Riordan, 2012). Increasing adoption of these practices is important due to their potential for benefiting students' understanding and furthering their opportunities for success. Additionally, these practices are thought to increase the retention of minority students and appeal to a more diverse range of students in general (Olson & Riordan, 2012).

Initially, it was thought that the main obstacle to adoption was a lack of awareness. More recent research has shown many instructors are aware of research-based teaching practices and still decide not to adopt them in their classrooms (Borrego, Froyd, & Hall, 2010). This lack of adoption has created an "implementation gap" causing most students to not benefit from the previous few decades of educational research. The implementation gap exists between the creation of research-based curricular materials and their widespread use in classrooms and has often been framed as differences between researchers and implementers. It has been proposed that by bringing researchers and implementers closer together in terms of their values, goals, and knowledge, the 'gap' can be narrowed. One commonly suggested method of doing this is by involving instructors in the development of curricular materials (Henderson & Dancy, 2007). Limited research has explored this co-development effort between researchers and instructors and how it can contribute to further understanding and closing the implementation gap.

Background

Implementation Gap

In a perfect world, spreading innovations would be a simple task where researchers could present their inventions, provide evidence that the innovation was valuable, and people would instantaneously start using it. But adoption is a much more complex problem and is often modeled as a progression through different stages in the innovation-decision process. For

example, Rogers' (2008) model begins with knowledge of the innovation (awareness) and progresses through persuasion (evidence), decision, implementation and finally the confirmation stage (on-going use of the adopted material).

The first stage of the innovation-decision process, awareness, has been well studied within engineering education and it has been found that faculty possess a general level of awareness about the innovations (Borrego et al., 2010). Though awareness continues to be a focus of researchers as a means to address the implementation gap, Cutler et. al. (2012) suggests shifting the focus to providing faculty with more information during implementation and resources for overcoming challenges.

The second stage in the innovation-decision process is to persuade people to use the innovation. One method of persuasion is to provide evidence of the benefits of the innovation. Within the educational setting, this evidence is often presented as assessment data but it has proven not to be a sufficient method to promote change and convince faculty to adopt innovations (Clark, Froyd, Merton, & Richardson, 2004; Fournier-Bonilla, Watson, Malavé, & Froyd, 2001). Despite this, many instructors still decide to try new curricular materials in their classroom but nearly one-third discontinue use after the first try (Henderson, Dancy, & Niewiadomska-Bugaj, 2012).

Deciding to use and implement the innovation, the third and fourth stages in the innovation-decision process, have been previously researched and is often referred to in terms of the barriers and challenges that prevent or limit the use of innovations. Addressing these barriers has the potential to increase adoption rates. Commonly found barriers that hinder adoption include a lack of departmental support, time, and student resistance (Borrego et al., 2010; Fournier-Bonilla et al., 2001; Henderson & Dancy, 2007). Time continues to be the most frequently cited barrier when adopting curricular materials and often refers to class time and instructor preparation time. Surprisingly, when instructors who teach Electrical or Computer Engineering courses were surveyed about barriers to adoption, resources were the least

frequently mentioned (Froyd, Borrego, Cutler, Henderson, & Prince, 2013). Furthermore, the complexity of an innovation has been shown to be a barrier when instructors decide what to use in their classrooms (Borrego et al., 2010).

Researchers have focused on studying developers and implementers as different groups. For example, research by Hazen et al. (2012) specifically talks about how to get educators to accept and use innovations, which implies that users and developers are two different groups. Furthermore, Henderson and Dancy (2011) propose that to increase the diffusion of innovations, faculty must act as meaningful participants. This further supports the idea that developers (researchers) and implementers (faculty) are often seen as two separate groups when trying to address the implementation gap. As a result of this research approach (separating developers from implementers), a list of 13 descriptive characteristics have emerged that support such a distinction (Bourrie, Cegielski, Jones-Farmer, & Sankar, 2014). These characteristics have been found to lead to successful dissemination of educational innovations. Of these 13 characteristics, Bourrie et al. (2014) identified three themes: faculty member's personal attributes (i.e. self-efficacy and innovativeness), faculty member's network (supportive community, professional social system etc), and thoughts regarding teaching (place value on teaching in addition to research). While Bourrie et al. (2014) has presented these as features that support adoption, they could also be viewed as possible barriers to adoption. For example, not having a supportive community that encourages the use of innovations could be seen as a barrier by an instructor.

Among the additional research showing that the implementation gap has been viewed as existing between two groups of people (developers and implementers), is the curriculum change literature in engineering education that states the need to identify and respond to sources of faculty resistance (Fournier-Bonilla et al., 2001). Fournier-Bonilla et al. (2001) state that time and energy are needed for initiating and sustaining change and that faculty must be aware of and respond to administrative issues as they arise. Their model provides a broader

perspective of change by focusing on behavior of the people involved unlike traditional models that focus only on the curriculum.

To overcome the obstacles found to inhibit or discourage adoption, it has been suggested to include instructors in the development of materials (Hazen, Wu, & Sankar, 2012; Henderson & Dancy, 2007; Henderson & Dancy, 2011). This is a logical solution when considering the implementation gap has often been viewed in terms of the differences between these two groups. One of the most rigorous and thoroughly supported models for describing the implementation gap in this way is the Concerns-Based Adoption Model (CBAM). Utilizing CBAM to focus on the beliefs and values of instructors is supported by research that stresses the importance of examining how instructors' thinking changes when adopting new practices and how this influences their beliefs and values, not just their practice (Siddiqui & Adams, 2013). Though educational diffusion research often utilizes Diffusion of Innovations theory (Rogers, 2008), which emphasizes the product, shifting the focus to the beliefs and attitudes of instructors could bring a new perspective to an on-going problem.

CBAM

The Concerns-Based Adoption Model (CBAM) was created in the 1970's and 1980's by researchers at the University of Texas at Austin based upon research in K-12 settings. The model is comprised of three components, Levels of Use (LoU), Stages of Concern (SoC), and Innovation Configurations (IC), that when used in combination can depict and predict instructors' adoption of classroom innovations. This model was designed to be used by leaders to forecast the support needed by instructors that will encourage and assist in implementation.

Specifically, the analysis conducted for this paper utilizes SoC as it focuses on instructors' beliefs and attitudes and how they change as instructors advance through the implementation process (Hall & Hord, 2006). Concerns are the fundamental components that construct the different SoC and can be divided into three main categories: Self Concerns (focused on the instructor's knowledge and attributes), Task Concerns (the focus shifts from the instructor to the use of the innovation), and Impact Concerns (emphasis is placed on how the innovation affects students

and how to improve upon the innovation) (Table 1). Moving to higher Stages of Concern is correlated to higher Levels of Use and thus an increase in adoption and effectiveness (Hall & Hord, 1987). In CBAM parlance, the implementation gap could be explained as a failure to advance through the first few Stages of Concern, which leads to low Levels of Use. For example, an instructor who is unable to understand aspects of an innovation (Personal concern) is likely to modify or not use the innovation, with both cases contributing to a lower Level of Use (potentially even non-use, the lowest Level of Use). Additionally, the previously mentioned barriers to adoption can be correlated with the different Stages of Concern. For example, a time barrier would be considered a Management concern if it relates to scheduling and organizing the use of the innovation in the classroom.

Table 1. Summary of CBAM's Stages of Concern. Adapted from Hall & Hord (2006).

Self Concerns	
Stage 0 Awareness	Participant is not concerned or involved with the innovation.
Stage 1 Informational	Participant is generally aware of the innovation but has not considered the demands or requirements of its use.
Stage 2 Personal	Participants' concerns are about their ability to meet the demands of the innovation. Barriers to implementation are considered in the realm of personal impacts.
Task Concerns	
Stage 3 Management	Participants' concerns are focused on efficiency, organizing, managing and scheduling. Barriers to implementation relate to physical constraints such as time and resources.
Impact Concerns	
Stage 4 Consequence	Participants are concerned with how the innovation will impact student understanding. Complexity of the innovation and assessment techniques are common barriers.
Stage 5 Collaboration	Participants are concerned about collaborating with others in their use of the innovation. Distance can be seen as a barrier.
Stage 6 Refocusing	Participants are concerned with how to improve the innovation for future use. These concerns often relate back to Consequence and Management concerns and their barriers.

Historically, CBAM has been utilized in the K-12 setting but it has also been applied to engineering education to provide a framework to study the implementation of new materials (Brown, Frye, Monfort, & Smith, 2011; Ross, Daugherty, & Custer, 2014; Turns, Eliot, Neal, & Linse, 2007). The emphasis of the Concerns-Based Adoption Model on individuals' perceptions can be misleading or incomplete when trying to explain adoption (Brown et al., 2011). Research has continued to focus on further developing the CBAM model to more closely align with the implementation process in undergraduate engineering education (Turns et al., 2007).

The Concerns-Based Adoption Model provides a way to describe how instructors experience development and implementation. The common barriers that hinder adoption can also be utilized to inform how development and implementation differ. Approaching the implementation gap by tracking the concerns of instructors as they develop and implement their own curricular materials will provide new insight into an ongoing problem within engineering education.

Purpose

The purpose of this research is to characterize the concerns of one group of faculty as they move between developing and implementing their own research-based curricular materials. Specifically, this study aims to answer the following questions:

Research Question 1: What concerns are most common during development and implementation?

Research Question 2: How do the concerns cited relate to previously identified barriers to adoption?

Research Question 3: How does the subject of the concerns compare between development and implementation?

Methods

This study follows the same group of instructors as they develop and implement research-based curricular materials in their Mechanics of Materials (aka solid mechanics) courses. Utilizing the same group of instructors for both parts of the project reduces individual differences that could impact the findings. Additionally, research suggests that instructors are more likely to implement materials they have personally developed since the materials will be more compatible and aligned to their individual situations and preferences.

Data collection for this research occurred in two phases. In the first phase participants were audio and video recorded during a summer material-development workshop. The second phase consisted of interviews that occurred during implementation of the developed materials. Further elaboration of how the data was collected and analyzed can be found in the following sections.

Data Collection

Participants

In total, 17 Mechanics of Materials instructors from 14 institutions volunteered to take part in a three-year material-development project. In selecting volunteers, it was decided that they must be interested in improving student understanding, willing to work in a collaborative environment, be effective communicators, and be teaching Mechanics of Materials (or a similar course) in the near future. These instructors were given the opportunity to opt out of the research portion of the workshop but all 17 instructors (100%) participated. Of the 17 instructors, six were female and eleven were male with teaching experience ranging from 0 (they would begin teaching the course the following year) to 30 years. A total of nine participants were from 2-year colleges while the other eight participants were from 4-year institutions. As part of the project, all of the participants agreed to implement at least one of the developed materials in their classrooms in the academic year following the summer workshop. Implementation support (e.g. answer questions or provide additional materials) was also emphasized and made available to all participants.

Workshop Design

The workshop focused on five prominent subject areas within Mechanics of Materials; Axial Loads, Bending Loads, Limitations/Assumptions/Uncertainties, Stress and Strain Elements, and Torsional Loads. Each participant was randomly assigned to one of the five different groups. The goal of the assignments was to distribute the varying levels of experience and to build new collaborations and a sense of shared community.

A 20-minute presentation introduced the organizers' research on student understanding of Mechanics of Materials to the participants. All participants were given a binder that summarized the research, which they were encouraged to review before starting to develop materials. Groups were asked to develop course materials that addressed one or more of the presented misconceptions. The number of constraints placed on the participants during development was kept to a minimum to allow for as much freedom and creativity as possible. Additionally, this was done to encourage participants to feel ownership of the materials by incorporating aspects they found important. Satisfaction surveys following the workshop indicated that all participants found their topic interesting and believed their developed materials to be valuable.

Participants were asked to create Innovation Configurations to help define how to appropriately use their developed innovation. For research purposes, "use" has been defined as using the materials in the way they were intended to be used. Innovation Configurations are important as most instructors do not use materials "as is" (Henderson and Dancy, 2011). The Innovation Configurations account for possible variations while maintaining the integrity of the activity, which in turn gives instructors a greater amount of flexibility and an increased potential for adoption. Creating Innovation Configurations also allowed participants to think specifically about what their innovation would look like when implemented and what acceptable alternatives were possible before modifications changed the material significantly enough that it was considered a different innovation. For example, some groups required student discussion

(i.e. use of the materials without student discussion would be considered “non-use” or “inappropriate use”), while others included it only as an acceptable alternative.

Implementation Interviews

Audio-recorded phone interviews with the participants were conducted during their implementation of the materials created at the workshop. These interviews took place as near to implementation as the participants’ schedules allowed. In total, ten interviews were conducted with six of the participants lasting on average between 15 and 30 minutes each. Because of the different lengths of the interviews and potential to contribute differing numbers of concerns, each of the participants’ concerns were individually tallied and then weighted to each contribute 1/6 of the total of all interview concerns. Of these interviews, four participants took part in pre and post implementation interviews while two participants participated in only a post implementation interview. All interviews are comparable and are therefore analyzed in the same way because they reflect the concerns of the group as a whole.

The interviews were semi-structured with a pre-determined list of questions (see Appendix A) to ensure consistency across interviews. The questions covered three main topics: how the innovation was used, instructor concerns, and the effectiveness of the activity. The semi-structured nature of the interviews allowed for additional follow-up and clarifying questions. The purpose of conducting interviews was to gain insight about the concerns of participants when they were experiencing implementation. These interviews provided an avenue for participants to share stories about how implementation went, which is one method used to encourage dialogue between parties and push the change closer to adoption (Merton, Clark, Richardson, & Froyd, 2001).

Data Analysis

The audio and video files from the workshop and implementation interviews were transcribed and analyzed independently, shortly after each data set was collected. The constant comparative method (Glaser, 1965) was applied during coding of the transcripts while CBAM’s SoC provided structure to the coding scheme.

Constant Comparative Method

The constant comparative method is one way to sift through data and identify common themes. This method of qualitative analysis stresses the importance of comparing the current code to previous codes in similar categories. The coding for this research was inspired by this method. For the first round of coding, pre-defined categories where utilized (Stages of Concern) and the second round of coding categories were built (which is more closely aligned with the constant comparative method). For this research, when a code was assigned, previously assigned codes and their subjects were then reviewed and compared to ensure consistency as well as to determine common themes within the individual Stages of Concern. This method does not expect two analysts to produce the same results but instead allows a greater amount of flexibility to aid in building theories (Glaser, 1965).

Coding

Within in the transcripts, phrases were labeled with concerns from CBAM's SoC followed by a brief description of the core subject of the conversation being held. In order for a phrase or segment of the transcript to be labeled with a concern, it had to reflect the core idea of the particular concern. These labels became known as codes and were assigned to phrases and interactions of varying length with a new code assigned anytime the speaker transitioned to a new concern or topic (Table 2). For example, a single sentence could have multiple codes if it referenced multiple concerns while a longer back-and-forth exchange between participants could be one code if the topic and concern remained static.

Table 2. Coded Transcript showing how codes were assigned

Transcript	Code	Description
Participant A: *I think it would be much better with discussion. I don't think it would be useless without it but I think if they got the wrong conclusion that could be problematic. So I think no feedback is unacceptable. Any other components of this exercise are critical? The pre and post assessments?*	Consequence concern	Discussion important for students especially if they get it wrong
Participant B: *Yeah so are there any, is there any variation on the ranking task? Is that optional? Could you do it without the assessment?*		
Participant C: *I like the assessment idea if someone had time.*	Management concern	do assessment if have time

To be coded as a concern, the participant had to be referring directly to the development of the innovation or drawing a parallel from their teaching experiences to the potential innovation. Conversations that generally referred to teaching experiences or other life events were not included in the coding of concerns. Different percentages of each transcript ended up being coded and largely depended upon how on-topic a group or individual remained. Additionally, concerns that did not clearly reference a particular stage were coded as Concern – Unclear. Examples of audio excerpts and their corresponding code according to CBAM can be found in Table 3.

Table 3. Example Coded Quotes showing the SoC code, description and the reasoning behind the code assignment

Excerpt	Code	Reasoning
"Do each of your students have one of those [manipulative]?"	Concern – Unclear – number of manipulatives (a physical object) per student	The instructor did not reference if they were concerned about the impact on students or the management or cost of creating manipulatives.
"Our lab time is like a bonus and it means they [students] get a little	Concern – Consequence – lab time a bonus, gives students extra time	The instructor referenced how lab time impacts students by giving them extra time

extra time."		
"I was thinking of like Styrofoam blocks or something that we can easier poke a toothpick in and/or stick in the side with that [poster] putty. Just essentially a blue square, a black square, a green square, a red square…"	Concern – Refocusing – Management – foam squares might work better	The instructor indicated a way to improve upon the activity by using foam blocks instead of the original material, a Rubrik's cube, which is the core essence of a Refocusing concern. His reasoning behind this change to make it easier to poke a toothpick in the material is reflective of a Management concern and no reference to how this change would affect student understanding (Consequence) is mentioned.

Codes were grouped based upon their SoC (Personal, Management, Consequence or Refocusing) in order to measure the frequency of each stage. The frequency of each stage is presented as a percentage of total concerns cited from each data set in order to normalize the differences in the number of total concerns cited. For example, if the workshop had a total of 100 concerns and 10 of those were Consequence concerns, then the percentage of Consequence concerns is 10%. Furthermore, if the interviews had 50 concerns total and 5 of those were Consequence concerns, then the percentage of Consequence concerns is 10%. (Note: Numbers have been simplified for example purposes and do not represent the actual data.) Using this method, both the workshop and interviews could have similar percentages of total concerns for any given SoC despite having a different number of total concerns. This was done because the workshop was greater in length time wise and thus had a greater number of concerns cited when compared to the interviews, which were shorter in length. The results focus on the largest differences in frequencies found between the data sets.

Further analysis of each SoC was conducted to determine common themes within each stage. This was done by assigning each coded excerpt with a one or two word summary of its subject. The constant comparative method was further applied to this part of the analysis by comparing the summaries. Once the summaries were completed, common themes were identified. Codes

were then sorted into these themes but not all codes fit within the specified themes and therefore were left with only a SoC code.

Results

Overview

As of the beginning of the summer of 2015, three instructors reported use of the materials created at the workshop, three instructors reported some version of use (though not the way they were intended to be used), and 11 instructors did not report their use of the materials.

A summary of the concerns cited during the workshop and interviews are presented in Figure 1.

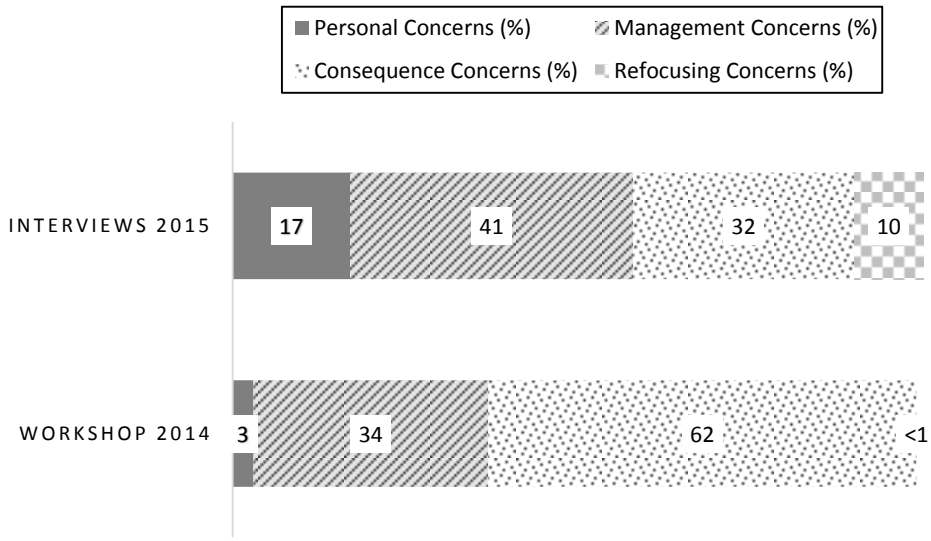

Figure 1. Summary of Concerns showing a decrease in Consequence concerns from the workshop to the interviews and an increase in Personal Concerns from the workshop to the interviews.

The frequency of Personal concerns changed from 3% of the total concerns cited during the workshop to 17% during the interviews. Management concerns remained fairly consistent between the workshop (34%) and the interviews (41%). A large change in Consequence concerns was found, decreasing from 62% during the workshop to 32% during the interviews. Refocusing concerns increased from <1% at the workshop to 10% during the interviews. Further dissection of each of these stages will be conducted to answer the research questions.

Personal Concerns

Personal concerns relate to the instructor's own abilities and attributes and were found to differ during the workshop (3%) in comparison to the interviews (17%). The subject of Personal concerns ranged from an instructor's ability to create assessments to the personal attributes they possessed. For example, the following quote from an interview shows how a participant was confused with one of the innovations. "So basically when I went through it, I felt confused by some of the material." This confusion ultimately led him to modify the activity in a way that made sense to him. The resulting modification could or could not be considered "use" as defined by the innovation configuration which directly impacts adoption (if it is considered non-use or inappropriate use by the Innovation Configuration, then the material would not be classified as "adopted").

This same participant would ask clarifying questions during the workshop anytime he felt confused or did not understand what someone was explaining but during implementation, he never reached out to the researchers for assistance. Despite the researchers emphasizing that they were available to assist during both the workshop and implementation, few participants actually sought help during implementation. Instead, they would modify or not use the innovation at all if they were unable to overcome their Personal concerns.

Personal concerns relate to the key characteristics of faculty who adopt innovations. It was found that within Personal concerns, participants often focused on their confidence and comfort level with an innovation (which is related to self-efficacy, one of the 13 faculty characteristics that encourage adoption). A large change in the frequency of Confidence Level concerns was found, going from 43% of Personal Concerns cited during the workshop to 58% during the interviews (Table 4).

Table 4. Summary of Personal Concerns showing a change in the overall frequency of concerns cited and an increase in Confidence Level concerns.

	Workshop 2014	**Interviews**
Personal Concerns - Total of All Concerns (%)	3	17
Confidence Level- % of Personal Concerns	43	58

Confidence Level

Participants more frequently cited Confidence concerns during implementation (58%) compared to the workshop (43%). Innovators and Implementers alike had similar Confidence concerns in nature, such as their personal effectiveness when using the innovation.

Workshop	Implementation
Show me how that[removing a piece of pool noodle to represent an element] would work, I don't think I entirely understand how that would [work]?	*I have to be able to understand it and teach it in a way that makes sense to me.*

In the workshop quote, a participant was struggling to understand an idea that another group member was discussing about how to cut out an element from a pool noodle. Cutting the element out of the pool noodle was one way the group was trying to demonstrate a concept to students but this participant did not understand how it would work. The participant sharing the idea goes on to explain in more detail what she meant, using a sketch to assist in her explanation. Similarly, during implementation, another participant voiced concern over being able to understand an innovation before using it in her classroom.

The quoted participants are unable to use or move forward with developing the material until their Personal concerns had been addressed. In order for these participants' thinking to progress to higher Stages of Concern, they must feel as if they comprehend what the innovation is about and make sense of it internally before they can consider how it would impact students (Consequence) or be used in the classroom (Management).

This type of concern surfaced multiple times throughout the workshop but more commonly during implementation. For example, one participant used one of the innovations in his classroom but did not utilize all of the original components due to a lack of understanding.

And so the Rubik's Cubes I didn't include, partly because as I was putting this together, I had myself, I had trouble coming to some understanding of the colors because the colors were used in multiple places.

The key phrase that signals a personal concern here is "…trouble coming to some understanding…" which indicates how the participant must first understand the innovation before using it in his classroom. This Personal concern shaped how the participant used the innovation in their classroom, modifying it to leave off any parts he found confusing. The Rubik's cube was a core component of the activity and therefore demonstrates how a Personal concern can lead to the non-use of an innovation.

From the interview examples one can see how Personal concerns can easily deter an instructor from using an innovation or modify it based upon their own understanding. Personal concerns appeared to have a less drastic effect during the workshop and were able to be worked through with the assistance of fellow participants.

Management Concerns

Management concerns, which focus on the use of the innovation, differed slightly in frequency between the implementer interviews (41%) and the workshop (34%) but this change was not one of the larger changes in frequencies found. When looking more closely at the Management concerns cited during the workshop and interviews, it was found that concerns covered a range of topics including group size, time, classroom layout, resources, vocabulary, and manipulative design. One of these topics is found in the following quote that took place during the workshop and demonstrates how organizational aspects of an innovation are considered during development.

> *The trouble is, if you are going to run stations, they don't all start at the same place. You are also assuming a room like this [tables that encourage group work] and not a lecture hall.*

This group was focused on how to implement a collective group of innovations simultaneously into a classroom. In this situation, participants were concerned about the layout of the classroom and how to have groups transition through the activities which are logistical issues

characteristic of Management SoC. These are both Management type concerns as they focus on the use of the innovation and not necessarily the impact they have on students (Consequence).

The following quote also pertains to organizing the innovation for implementation but is presented in the context of an interview.

> *And, um, shortened the size of it [referring to the student worksheet] so it didn't have to be a full page. It took up more like two thirds of a page or so. Um, to save paper.*

This quote shows how the instructor simply shortened the worksheet with their reasoning being to "save paper." This type of modification was done in strictly a management sense to save on resources and was not aimed at learning or student outcomes (which would be a Consequence concern). This specific type of concern never occurred during the workshop where resources were abundant.

Though all concerns are considered important, the next section of analysis of Management concerns focuses on Time and Resource concerns as they have a direct relationship to the barriers found that prevent or inhibit adoption and were the single most common subject of Management concerns. Resources comprised nearly one quarter of all Management concerns during the workshop and interviews and is similar to Time concerns percentage-wise (Table 5).

Table 5. Summary of Management Concerns indicating no change in frequency or subject of cited concerns.

	Workshop 2014	**Interviews**
Management Concerns - Total of All Concerns (%)	34	41
Time - % of Management Concerns	17	24
Resources - % of Management Concerns	24	24

Interestingly, the percentage of Management concerns that related to Time and Resources were very similar in both the workshop and interviews, comprising almost half of all Management concerns cited and did not change between the workshop and interviews.

Time

Management concerns that focused on time often referred to the amount of preparation time required by the instructor or the amount of class time the activity would take as depicted in the following examples.

Workshop	Implementation Interviews
I am just looking at this and wondering, how much time I would commit to this exercise? I think it is a full class period and I don't give that much to Saint Venant's [Principle].	*But that's clearly 45 minutes for axial and bending, 45 minutes for torsion and bending, and 45 minutes for axial torsion and bending. And, um, so that's three classes and it's a ... it's a pretty big chunk of time.*

In both quotes the participants are concerned about the amount of time an activity is going to take. In the workshop example, time is a concern as the participant does not devote that much time to cover Saint Venant's Principle. The implementation interview example is less direct in what their concern refers to beyond just a "big chunk of time." Both examples clearly indicate Management concerns since they are referring to how the innovation will fit into their class schedules with no mention about how the innovation could have an impact on students or their own abilities in using the innovation.

Resources

Resources were frequently cited in the context of what was available to individual instructors (i.e. smart boards, projectors, and lab techs) and also how to come up with additional resources to create the manipulatives (i.e. pool noodles, wood, or foam blocks). Both types of Resource concerns were cited during the workshop and implementation interviews.

Workshop	Implementation Interviews
I would say even like it would be better if we had one that was completely full [referring to wanting a solid foam cylinder, not hollow] but it is cheaper to get the pool noodles but ideally [it would be solid].	*So I gave them a sort of - or intended to give them a little fill in the blank handout that I could then collect and look at, but our copy machine broke. So, it was a little bit less organized than I would've liked.*

The participant during the workshop was focused on the ideal manipulative to use but was aware of potential resource issues (money) and settled on a hollow pool noodle instead. A

different type of resource became a stumbling block for one instructor during implementation when he was preparing to use the activity and discovered the copy machine was broken which prevented him from using a material he had intended to. His concern did not relate to the impact on students (Consequence) or his own image of preparedness (Personal), but the logistical smoothness of the exercise (Management).

From this exploration of Management concerns, it was shown how the resources available to individual participants can shape how they construct, organize, and utilize an innovation in their classrooms.

Consequence Concerns

Consequence concerns focus on how the innovation affects student outcomes and were found nearly twice as often in the workshop (62%) than the interviews (32%). This was the largest change in frequency found within the data set. Consequence concerns focused on a variety of topics including students' conceptual understanding, assessment (when to assess and what type of assessment to use), what students already know, clarity of an activity (this includes vocabulary use and wording of worksheets), and how teaching methods impact students. Example quotes will be used to further explore the subject of these concerns.

The following quote was extracted from the workshop and though it appears to be a Management concern at first since it focuses on organizing the activity. But it is ultimately a Consequence concern as it concentrates on designing the activity in a way that students are able to gain the intended content from the exercise.

> *I think it might, if it is not impossible, I think it is important to provide as much precision [in measuring] as possible to prevent students from justifying their predictions based on 'oh it is within the measurement error.' So if they really think it [the phenomena] is going to be the same and it [the manipulative] is not long [enough so] that the [measured] difference is very large, then they will say 'that is 3 inches this is 5 inches and they are about the same.'*

This participant was concerned about providing as much precision as possible when taking measurements during the activity so that the students would not be able to "justify" their predictions based on "measurement error." Though measurement error could be a teaching moment, the participant decided that the content of the activity was the main focus and did not want students to get side-tracked by extraneous details. This is a Consequence concern as it emphasizes how the design of the innovation can affect student understanding.

Similar to the previous example, during the interviews a participant indicated that having some incomplete guidance ("holes" as he called them) within the activity can be beneficial as it gets students thinking beyond the focus of the activity.

> *So I ... it's nice to have some holes like that, that they can fill, um, because I think that that actually gets them thinking a little bit more critically than me just saying, 'And here's north, east, south, west, and here's our coordinate system, and we're going to use these.' They actually said, 'We need a coordinate system,' and started doing that.*

Thinking critically was seen as an additional layer of the activity that the participant found to be important to student understanding. This instructor allowed the "holes" in the activity to give students a chance to make it their own and add components that would make the activity easier to understand and accomplish. Again, the focus is on student learning.

Though Consequence concerns include a wide range of topics, the focus remains on concerns that relate to barriers of use, which in this case are Assessment and Clarity of Activity. Assessment is important as it has been found that assessment data alone is not evidence enough to convince faculty to adopt innovations. Clarity of Activity correlates to the complexity of the activity, a known barrier to adoption.

Additionally, these two concerns comprised nearly 50% of all the Consequence concerns cited. Though the occurrence of Consequence concerns differed between the workshop and implementer interviews, Clarity of Activity and Assessment concerns were found to represent

similar percentages of the total of Consequence concerns cited (Table 6). These similar percentages indicate that the subject of Consequence concerns remained consistent between the workshop and interviews despite a change in the frequency of concerns cited.

Table 6. Summary of Consequence Concerns showing a decrease in the frequency of concerns cited and no change in the barrier-related concerns.

	Workshop 2014	**Interviews**
Consequence Concerns - Total of All Concerns (%)	62	32
Assessment - % of Consequence Concerns	10	17
Clarity of Activity - % of Consequence Concerns	32	31

Assessment Concerns

Consequence concerns that focused on Assessment during the workshop and interviews were similar in subject. They typically revolved around the timing of assessment, the type of assessment (formal vs. informal), and the purpose of assessing. The following quotes show how pre-assessments were thought of during the workshop and how assessment occurred during implementation.

Workshop	Implementer Interviews
It would be a good pre assessment if some students are having that problem you could address it. Once you understand it, it doesn't seem so complicated.	*I was looking for their descriptions of the type of stress they were observing, or maybe the type of strain they were observing, and how that related to...to the stress distribution that they'd expect to cause that strain. Um, and then I was looking for them to describe how that varied along the length of the shaft, how that related to the applied direction of torque…*

Both quotes are focused on how the assessment will indicate student understanding. In the workshop quote, the participant is interested in utilizing a pre-assessment so that they can address any problems that a student has before getting to the actual activity. In essence, the instructor wants to make sure students have the foundational knowledge necessary to be successful in the upcoming activity. The interview quote shows how a participant used a more informal assessment technique by listening for key words that students use when going through the activity as the instructor walked around the classroom. Both of these concerns are clearly Consequence concerns as they focus on student knowledge.

Clarity of Activity

Clarity of Activity was another frequently cited type of Consequence concern and included issues such as use of vocabulary, wording and proper use of manipulatives. The percentage of this type of concern of all Consequence concerns did not change between the workshop and interviews. Clarity of Activity concerns were often a focus of the participants to ensure the activity was designed in such a way that it was clear to the students what was expected of them and that the intended concept was being portrayed in a concise manner. This recurring theme was present in both the workshop and implementer interviews and often involved key words such as “confuse,” “mess them up,” and “concise” which is seen in the following quotes.

Workshop	Implementer Interviews
So if we do round[manipulative shape], then we should make sure to only think about the square here so that we don't totally mess them [students] up. [discussing the shape of the manipulative and how it affects students]	*I just don't, on the first one [activity] I think the students were quite confused. They were trying to be good sports [during the activity], you could tell that.*

At the workshop, the participant was concerned about designing a manipulative in a way that would not confuse students. She was focused on the shape of the manipulative and where to draw the squares on a round pool noodle so that she does not “mess them up.” Similarly, a post-implementation interview shows how the participant found that the students were confused when they worked through an activity for the first time. Both quotes focus on students, the basis of a Consequence concern.

Though not confusing students was a frequent objective during the workshop, it continued to be a focus even after the participants used the innovations in their classrooms.

Refocusing Concerns

Refocusing concerns refer to how participants improve upon the designed activity or suggest what they consider would be a better alternative to the activity. A limited number of refocusing concerns were cited during the workshop (<1%) and a greater number cited during the interviews (10%). Refocusing concerns were divided into two main categories, Refocusing –

Consequence and Refocusing – Management. The labeling refers to the subject of the Refocusing concern. Those that referenced improvements to benefit student understanding were put into the Consequence category while those that focused on organization, wording, and use of the innovation were placed in the Management category. These categories were utilized as they closely align with the barriers that instructors face when implementing curricular materials. It was found that the Refocusing concerns were evenly split between these two categories.

The following quote an example of a Refocusing – Consequence concern. This quote was part of a post-implementation interview.

> *Well I figured I would mention that the language could be too full. Students need to work on their language and vocabulary but I do think some of the language in there could be cleaned up and maybe some more pictures so they could see exactly what is being asked of them I guess.*

Though the participant comes across as being hesitant to make suggestions for change, he makes a suggestion on how to improve the student worksheet so that it is easier for students to understand and follow. He recognizes that language and vocabulary are something that students need to work on but at the same time, these things can cause issues with students if not presented in a clear and concise manner. Additionally, he suggests pictures to go along with the words so that students can visualize what is being asked of them. The participant is actively engaged in how to improve the innovation by offering suggestions which clearly indicates a Refocusing concern.

Refocusing concerns also came in the form of how to better organize and plan for the activity. In particular, one participant thought it would be helpful if the activity clearly stated how it fits into the class as a whole.

> *I think we could, as part of the project, we could clarify that a little bit better, where this sits in to a larger lesson plan.*

Though this quote utilizes the words “we” and “as part of the project” which both suggest a collaborative effort, this is ultimately a Refocusing concern as it is centered around improving the activity. This quote is representative of other participants’ concerns as knowing where the activity fits into the bigger picture of the class would enable instructors a quick reference to know if the activity would be suitable for the topic they were currently teaching without having to delve into the details of the activity. This has a potential to enable instructors to save time when looking for an activity to use in class. Time was a frequently cited Management concern and therefore any means to reduce preparation time are well noted.

Summary of Results

A summary of the results can be found in Table 7.

Table 7. Summary of Results indicating a change in frequency and barriers amongst the Stages of Concern.

	Overall Change in Frequency	Change Subject (Barriers)
Personal Concerns	NO	YES
Management Concerns	NO	NO
Consequence Concerns	YES	NO
Refocusing Concerns	NO	N/A

Personal concerns changed in subject between the workshop and interviews, which differed from Management concerns where no considerable changes in frequency or subjects were found. Consequence concerns were less frequent during the interviews compared to the workshop but the subjects remained consistent. Refocusing concerns increased during the interviews and were sorted into two main categories but due to the limited number of concerns cited during the workshop, the subjects could not be compared.

Discussion

Based on the higher Stages of Concern cited during the workshop, it was expected that a majority of instructors would implement the created innovations in their classrooms since higher Stages of Concern are correlated with higher Levels of Use and adoption (Hall & Hord, 1987). Additionally, by taking part in the development of the activities, it would make intuitive sense that most barriers would be addressed as participants designed activities for their own use. Once the implementer interviews were conducted though, it became apparent that few of the participants used the innovations in their classrooms. For this research, "use" is defined as using the innovation how it was designed and intended for implementation. Furthermore, analysis of the subject of the participants' concerns revealed that barriers preventing use remained in place during implementation (Borrego et al., 2010; Bourrie et al., 2014; Clark et al., 2004; Henderson & Dancy, 2007).

This anomaly can be explained by considering the differing circumstances the participants found themselves in as developers and implementers. The workshop was a unique environment in which resources and support were abundant. The stark contrast between this collaborative environment and that of participants' offices, often not a shared space, is noticeable in the concerns of the instructors. During the workshop, when participants were faced with a roadblock, they were able to voice their concerns and receive feedback from colleagues who had a vested interest in the success of the innovation. This was not the case during implementation and seeking feedback often required a phone call or email and a waiting period, which proved to be prohibitive for most participants. From the first year of data collection for this project, participants rarely reached out in search of assistance during implementation, although assistance from the researchers was offered on multiple occasions.

Circumstances surrounding the workshop and implementation affected the obligations of the participants and ultimately their concerns. Participants had fewer obligations during the workshop due to it being summer vacation and a majority of participants were not teaching courses. This changed to a higher obligation, "survival mode" mentality during implementation

since it was the academic year and instructors were teaching 3-5 classes each. Personal accountability also became more important during implementation as there were no workshop participants nearby to fall back on when things were confusing or difficult. These situational differences are reflected in the Personal concerns, which increased during implementation and were the only SoC that saw a significant change in the subject of concerns cited. During the interviews participants mentioned their own level of confidence (which relate to faculty characteristics that encourage adoption (Bourrie et al., 2014)) when using the innovation far more often. A situational difference explains this shift in confidence levels and is attributed to working with colleagues during development but being an authority figure during implementation. Additionally, participants did not seek the support of their group members or the researchers when progressing through the use of the materials but instead held themselves personally accountable to fully understand how each component of the innovation worked. The necessity of this higher level of personal accountability during implementation when compared to the co-development effort is further reflected in the lower-than-expected adoption rates. Lower adoption rates can also be partially attributed to the time span between development and implementation, often six or more months, which is supported by the increase of Personal concerns as the enthusiasm and ideas surrounding the development of the materials had waned without the support and inspiration of the collaborative setting.

Despite the level of support that participants were offered during the workshop and implementation in the form of collaborations and resources (a previously identified barrier to adoption), Management concerns showed no change in frequency or subject. It was expected that Management concerns would be addressed during development since each participant was aware of their own implementation environment. Even though the developers considered and tried to address potential Management concerns (see pages 16 and 17 for example quotes demonstrating this), limited adoption occurred. Again, this can be attributed to the situational differences. Situational variables, both the expected and unexpected, proved difficult for instructors to overcome and allowed Management concerns to persist. A prime example of this

is found in the quote about the copier machine breaking (pg. 18), an unexpected event that left the instructor lacking a critical resource that would enable implementation. Though this instructor undoubtedly was still concerned about students and their learning (Consequence), he was forced to focus on resolving his immediate concerns (Management).

Consequence concerns were strongly supported by the format of the workshop and played a less significant role during implementation. The workshop focused on addressing student misconceptions and therefore led to the natural occurrence of Consequence concerns. Many of the Consequence concerns during the workshop were also found to arise from the resolution of Management concerns (Panther, Montfort, & Brown, 2015). This was not true during implementation where most of the Management concerns went unresolved. This contributed to the lower incident of implementation Consequence concerns, further supporting the presence of a situational difference.

The context of the workshop (collaboratively developing new curricular materials) was not one in which Refocusing concerns would be abundant since the materials had not been implemented yet so they could not be refocused. This was reflected in the results. It was surprising to see Refocusing concerns during the interviews since it was the first round of implementation (Refocusing concerns are the highest SoC and associated with high Levels of Use (Hall & Hord, 1987)). This finding is explained by the instructors' shared interests, which drew them to the workshop to begin with. These shared interests focus on teaching, collaborating and improving student understanding. These suggest that higher-level concerns can be supported by particular environments (e.g. collaborative groups with shared interests), and suppressed by others (e.g. just-in-time preparation of course delivery).

In characterizing the concerns of instructors during both development and implementation of curricular materials, it has been found that situational differences affect the expression of the stage and subject of instructor concerns. Considering these situational differences and their

impacts on adoption during development and implementation can lead to further understanding of the implementation gap.

Conclusion

The research findings suggest the need to re-frame the problem of diffusion within engineering education. Though differences between researchers and instructors exist and are relevant, situational changes appear to have a greater impact on adoption than is accounted for in the current ways of thinking. This is important since instructors often learn about innovations during workshops and conferences, both which are highly collective and collaborative environments, and differ greatly in comparison to their individual offices.

The key differences suggested by this research were found to involve the environment (and situational context) surrounding development and implementation. Despite the best intentions of the participants and the agreement to implement the created materials in their classrooms, adoption levels remained low. Barriers to adoption persisted such as a lack of time and resources. To address these barriers, it is commonly suggested (and a key part of CBAM) to provide follow-up support after conferences and workshops to ensure instructors have the knowledge and resources necessary to go about implementation. Though this solution was offered to the participants, few used this option (it is also cost-prohibitive and therefore not a sustainable solution long-term). Therefore, it is suggested that to minimize the situational differences and their accompanying barriers, workshops should be conducted in a manner more similar to the implementation environment so the resources available during both are consistent (e.g. a virtual meeting where instructors participate from their offices (or classroom), the same environment in which implementation will occur).

Another potential solution to align workshops more closely to that of implementation is to have instructors work individually during workshops instead of in groups. By doing this, instructors could create materials that they are most interested in while not having to make any compromises with group members. Instructors would be encouraged to discuss the materials

they are working on with others at their table and to assist each other when obstacles arose. This would still allow a collaborative environment to form while also letting individuals create materials specific to their needs.

The evidence presented supporting a situational approach also supports the need for an increase in personal accountability during the adoption of the created materials. One potential solution to this issue is to have instructors team teach when they are using a material for the first time. This method would hold the instructors accountable to each other and allow the instructors someone else to converse with during course preparation and therefore has the potential to ease some of the Personal concerns identified during implementation.

Providing instructors with a set amount of time for course development that is separate from course delivery could also assist in easing both Personal and Management concerns and further support the adoption and implementation of research-based course materials and methods. This recommendation would need to be a specific part of the instructors' job description and be allotted a percentage of how they spend their time (for example, instead of 50% teaching, this could be reduced to 40% teaching and 10% course development). Easing instructors' teaching loads to focus on developing the courses they teach could have benefits for not only the instructor but also greatly benefit students, as they would be exposed to a greater number of research-based materials and methods.

Additionally, the findings suggest that overcoming Management concerns that relate to common barriers to adoption could be a more difficult issue to address and could signify a greater issue beyond the implementation gap such as a need for institutional reform, new policies, or accreditation standards.

As research continues on the implementation gap and knowledge accumulates, re-framing of the implementation gap can provide additional insight into solving educational innovation adoption issues. Furthermore, this can ultimately impact students and their understanding, creating engineers that are more prepared to enter the workforce and be globally competitive.

Future Work

Future work will focus on gathering and analyzing the data from Year 2 and Year 3 of this project, which could further support the development of a situational approach to the implementation gap.

In determining how the situated approach helps to explain the implementation gap, this theory needs to be applied to a larger group of participants and to other disciplines. In doing so, the situated approach can be tested to see if the findings here are further supported in a larger context and beyond engineering specific materials.

A situational approach to the implementation gap also provides another angle to examine how barriers to adoption are considered and overcome by instructors. Specifically, a situational approach could bring to light intricacies previously overlooked by previous theories and aid in increasing instructors' rates of adoption.

Limitations

Limitations to the research presented do exist, such as the relatively small number of workshop participants, but the findings are still valid and warrant additional research into how to address these situational changes.

Unlike the workshop, participants were specifically asked about their concerns during the interviews, which could have been confusing, as CBAM is not widely known amongst instructors in general. Therefore, instructors' definition of a concern may not accurately reflect the definition of a concern within the Stags of Concern.

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APPENDIX

Appendix A: Implementation Interview Protocol

1. How was the kit used?

- What did we provide/what did they provide?
- Ideas, physical materials, skills, etc.
- What did they **specifically** do during class?

2. What were your concerns going in to and coming out of the exercise?

- Logistical considerations?
- Learning goals?
- Personal skill?

3. How effective would you consider the exercise given what you had hoped for?

- How did you measure this?
- What were you comparing this against?
- Why did you want this?