

# Factors That Influence Dissemination in Engineering Education

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**Abstract**—Although the need for new educational materials and methods in engineering education is increasing, the process of disseminating (making target groups become aware of, accept, and use) these innovations remains a challenge. A literature review shows that few studies have thoroughly investigated this area. The purpose of this article is to identify factors that may affect the adoption and use of educational innovations used in engineering education and to offer advice to educators on how they may better disseminate their materials. This study uses extant theories related to diffusion and acceptance of innovation as the basis for identifying factors that may impact the dissemination of educational innovations. These factors are tested via a Delphi study employing 21 subject-matter experts and content analysis of 410 research abstracts. The results suggest nine factors that are most important for facilitating acceptance and use of educational engineering innovations. In particular, new materials should be designed such that they demonstrate an obvious relative advantage over existing materials, are compatible with and adaptable to existing pedagogy, lack complexity, and are generally easy to use. Management support and availability of resources are found to be important environmental conditions that facilitate acceptance; logistical issues and cultural differences are the chief impediments.

**Index Terms**—Content analysis, Delphi study, diffusion, dissemination, innovation, technology acceptance.

## I. INTRODUCTION

RESEARCH and innovation in engineering is important in keeping any developed nation competitive. This is evident when one considers that the vast majority of newly created jobs in a developed economy are a direct or indirect result of advances in areas such as engineering and technology [1]. This relationship between engineering education and jobs is demonstrated when firms such as General Electric locate the majority of their new research and development not in Niskayuna, NY, but instead in Bangalore, India; Shanghai, China; Munich, Germany; and Rio de Janeiro, Brazil—countries that are rich in human capital knowledgeable in engineering [2]. Thus, attracting, engaging, and properly training future engineering professionals is a research topic in need of more investigation [3], [4].

One way in which educators seek to attract and retain future talent is by utilizing educational innovations in the classroom (e.g., [5]). Unfortunately, disseminating these educational innovations to educators is recognized as a challenging process that requires a focused effort [6]. The term *educational innovation* encompasses any new instructional material, strategy, or

pedagogy. Examples of such educational innovations that are considered in this study include Web-enabled remote laboratories, computer-facilitated networking, project-based service learning, and interactive case-based learning. Educational innovation dissemination is defined as the process to make target groups become aware of, accept, and use these educational innovations [7]. Indeed, many have called for further investigation regarding how to facilitate acceptance and use of these innovations (e.g., [1], [8], and [9]). For example, the National Science Board [10], the National Science Foundation (NSF) [11], and the National Academy of Engineering (NAE) [12] have all published reports that emphasize the importance of transforming the education of future engineers and motivating educators to accept and use new instructional materials in order to adequately prepare students for future employment in engineering fields. NSF's Transforming Undergraduate Education in STEM (TUES) program changed its name from the earlier Course, Curriculum, and Laboratory Improvement (CCLI) program to show that the new program expects innovators to design for dissemination rather than design the product first and then think about dissemination later. Therefore, it is important to identify the factors that affect dissemination of engineering education innovations. Inasmuch, this research effort was formulated to answer the following question: What factors are important in the adoption and use of innovations in engineering education? This paper also discusses the lessons that developers of these educational innovations may learn by becoming aware of these factors.

This research effort is a triangulation of two studies that investigate factors that either facilitate or impede the acceptance and use of innovations in engineering education. This paper begins with a brief review of literature in education dissemination and reference theories on which to ground the study. This literature also provides the basis of the factors examined in this study. The method employed for the study is then described, where 21 researchers funded by the NSF's CCLI or TUES grants rated the importance of a number of factors identified in the aforementioned literature to the dissemination of their innovations. Next, the content analysis methodology used in the second study to examine 410 research abstracts for the purpose of identifying and categorizing the challenges associated with dissemination is discussed. The results of both studies are then presented and compared to draw conclusions regarding which variables are most important to dissemination. This paper closes with a discussion of implications for those who create educational innovations.

## II. LITERATURE REVIEW

The actual adoption and use of educational innovations requires a long-term effort [13]. Thus, a variety of researchers and

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educators have worked toward the improvement of dissemination [8], [14]–[18]. These studies have investigated factors that both facilitate and inhibit dissemination of educational materials. For example, the concerns-based adoption model (CBAM) addresses teacher and school-level responses to many types of educational innovations. It identifies factors that encourage the use of an innovation, such as school-based consultants [19] and observable student success [20]. Additional research suggests that support from school administrators and other governing agencies facilitates dissemination of educational innovations [21]. This is evident in Lichtenstein *et al.*'s [13] investigation into the barriers to dissemination of teaching materials, which found that the support from school administration was a key indicator of dissemination success. In addition, Owen and Stupans [22] highlight the importance of university engagement and wider stakeholder involvement in the curriculum dissemination of pharmaceutical education.

Although studies such as these and others have identified some of the factors that influence dissemination (e.g., [23]–[27]), most of the existing studies in this area investigate only a small number of variables, and some of these studies may not be familiar to those in the engineering education community. Thus, engineering education innovators are left without a complete understanding of the many variables that are likely to influence dissemination. Without this bigger picture, innovators are unable to thoroughly understand how best to create and distribute educational innovations for maximum effectiveness. In addition, much of the existing literature is conceptual in nature (e.g., [3], [8], and [28]–[30]). As such, limited empirical support exists for the variables that are suggested in extant literature. This research aims toward filling this gap not only by compiling a listing of variables that are posited to affect acceptance and use of educational innovations, but also by using empirical methods to determine which factors may be the most important to consider.

#### A. Theoretical Basis for Examining Dissemination

There is a vast amount of research related to the mechanisms that affect the process by which individuals or organizations adopt innovations [31], [32]. A review of the literature in this area indicates that innovation diffusion theory, which is grounded in the reference discipline of sociology, is among the most widely utilized research paradigms [33], [34]. Previous research within the domain of classical diffusion theory indicates that characteristics perceived to be specific to an innovation may provide a basis for explaining differences that facilitate its adoption. Although classical diffusion theory provides a sound foundation for the investigation of many topics, previous research suggests that consulting additional theories is often prudent when examining the complexities of innovation diffusion and adoption [35], [36]. Thus, the technology acceptance model (TAM) and additional reference theories were also considered in this study.

The TAM is one of the most widely applied theoretical models for explaining why an individual accepts or rejects an innovation, particularly in the management information systems literature [37]. Based on the theory of planned behavior and the theory of reasoned action [38], [39], the TAM suggests

that users generally intend to adopt an innovation if they consider it to be useful and easy to use. After being introduced in 1986, the TAM has been tested in many empirical settings and has evolved continually over time. Scholars have extended the model by combining the TAM with other theoretical models to introduce a variety of factors relevant to their research artifacts of interest (e.g., [40]–[44]). Besides its noted application to information systems research, the TAM also has been used often in education research [45]–[48]. Lee *et al.* [37] assimilate and summarize the historical TAM and other diffusion-related research to comprise a listing of frequently used variables that these studies employ.

Because the ultimate goal of educational innovation dissemination is the acceptance and use of the innovation, this study examines the relevance of 21 variables related to the theories discussed in the preceding review of the literature. Table I contains the list of 21 variables (as summarized by Lee *et al.* [37]) in alphabetical order. The right-hand column provides the operational definition as it applies to the problem of disseminating innovations in engineering education. In viewing the list, it should be noted that factors from a variety of related theories, such as diffusion of innovation [44], theory of planned behavior [38], and the TAM [49], are listed. The list also contains factors that reflect variables suggested by CBAM, such as anxiety in use [19], self-efficacy [19], [20], user support [20], and management support [19]. Because this listing of variables is derived from multiple, complementary theories that address diffusion and acceptance of innovation, the variables listed in Table I represent a logical starting point for examining dissemination of educational innovations in engineering.

### III. METHOD

This research effort is a triangulation of two studies (Delphi method and content analysis) that investigate factors that either facilitate or impede the acceptance and use of innovations in engineering education.

#### A. Study 1

The Delphi process generally consists of a panel of experts who are given a series of questionnaires interspersed with feedback from the researchers such that they may be provided the opportunity to modify previous responses [61]. Although individual Delphi studies may follow varying procedures, four characteristics are common to most studies that employ this method [62]. First, a panel of subject matter experts is selected. The panel is initially solicited individually to allow for unbiased responses. Second, the method employs an iterative process to give each participant the opportunity to improve his or her responses as feedback is garnered from the process. Third, feedback regarding responses is controlled to give each participant a synopsis of the responses given by other participants. Finally, the responses are compiled to allow for analysis and interpretation of data. As discussed next, this study followed these procedures to gather and interpret meaningful data.

Twenty-one principal investigators from different TUES or CCLI research projects participated in the two-round Delphi study. These investigators represented many STEM education disciplines, but the majority were associated with engineering or

TABLE I  
VARIABLES THAT MAY AFFECT DISSEMINATION (ADAPTED FROM LEE *et al.* [37])

Variable	Origin	Contextual Definition
Accessibility	Karahanna and Limayem [50]	The degree of simplicity in gaining access to the educational innovation and all of its required components
Aid Social Presence	Fulk <i>et al.</i> [51]	The degree to which the educational innovation permits users to experience others as being psychologically present
Anxiety in Use (-)	Simonson <i>et al.</i> [52]	The concerns that people have when facing use of educational innovation
Attitude to System	Ajzen and Fishbein [53]	The opinion that a person holds about the educational innovation
Compatibility	Rogers [44]	The consistency of the educational innovation with current pedagogy
Complexity (-)	Rogers [44]	The perceived difficulty of use of the educational innovation
Demonstrable	Rogers [44]	The easiness of predicting and explaining the results of the educational innovation
Enhance Image	Rogers [44]	The level of increased social status received by using the educational innovation
Enhance Visibility	Rogers [44]	The observability of the educational innovation
Facilitating Conditions	Taylor and Todd [43]	The degree of availability of resources necessary to facilitate dissemination of educational innovation
Innovativeness	Agarwal and Karahanna [54]	An individual's willingness to try out any educational innovation
Management Support	Igbaria <i>et al.</i> [55]	The degree of support provided by institutional authorities (i.e. government, school administration, etc.) toward facilitating dissemination of educational innovation
Perceived Enjoyment	Davis <i>et al.</i> [49]	An individual's perception of how enjoyable it is to use the educational innovation
Playfulness	Webster and Martocchio [56]	The degree of interaction between the individual and the educational innovation
Relative Advantage	Rogers [44]	The degree to which the educational innovation is perceived as being better than its precursor
Relevant to Job	Thompson <i>et al.</i> [57]	The ability of the educational innovation to enhance the educator's performance
Self-Efficacy/User Support	Igbaria <i>et al.</i> [58]	The degree of support from the educators and the students toward the educational innovation
Social Pressure	Fishbein and Ajzen [39]	An individual's perception of what people who are important to him or her think of his or her use of the educational innovation
Trialability	Rogers [44]	The extent to which individuals are able to try the educational innovation before they actually adopt it
Usability	Card <i>et al.</i> [59]	The effectiveness of use regarding the educational innovation
Voluntary	Moore and Benbasat [60]	The degree to which use of the educational innovation is perceived as being voluntary

(-) next to a variable denotes that it inhibits dissemination

computer science. Each investigator had been granted funding under the NSF TUES or CCLI programs to create educational innovations and was willing to participate in the discussion group. As such, each of these individuals was deemed to be a valuable participant for this study. The participants signed up to attend the session, and there was no incentive provided to them to attend. The group was first given an introduction to the dissemination problem and a brief presentation on two sample dissemination efforts from engineering and physics. Then, the 21 variables identified by Lee *et al.* [37] were presented to the participants. In the first round of the Delphi, participants were asked to rate individually, without conferring, each of the 21 variables as to how important they may be to dissemination. Using a paper form, participants were asked to rate the importance of each variable using a three-point scale with the options of most important, moderately important, or less important.

Once the participants had an individual opportunity to rate the variables, they were formed into seven small groups to discuss their responses. After group discussion of the individual responses, the members of each group were asked to come to a consensus and rate each variable in the second round of the Delphi. Each group was provided ample time to discuss the

variables and compile their listing. The session facilitators were available to address any concerns. The groups were also asked to identify any additional variables they believed might affect dissemination. The researchers explained that the rating sheets would be used in future research; the participants willingly provided the completed sheets to the researchers for analysis and publication.

### B. Study 2

A content analysis method was employed in the second study. At the 2011 TUES Principal Investigators Conference in Washington, DC, 410 research posters were presented. Each poster described the various attributes of a CCLI or TUES-funded research effort. Although projects represented all areas of STEM education research, nearly half of the projects were in the areas of engineering and computer science. An overwhelming majority (95%) of the projects were funded under the NSF CCLI program, whereas 5% were funded under the NSF TUES program.

Upon reviewing the project abstracts, it was noted that the "challenges" sections of the posters seemed to be heavily

focused on describing problems related to dissemination. Because these posters captured discussion from funded innovation developers regarding actual problems encountered in their dissemination efforts, these abstracts provide a rich source of data that may be useful in examining this study's research question.

Content analysis is a research technique for revealing meaning within a communication medium [63] and has been used in recent engineering education literature where large amounts of qualitative data were examined (e.g., [64]–[66]). In this study, procedures for problem-driven content analysis suggested by Krippendorff [67] were used. The unit of analysis was any factor mentioned or alluded to by a TUES or CCLI researcher in their description of research challenges that seemed to affect dissemination. Each challenge was represented by an independent text segment (words, sentence, or paragraph) that describes the problem.

MaxQDA, a qualitative data analysis package that assists in organizing and recalling textual data, was employed to code and analyze the data. Recording instructions were created, which directed that the coder first identify anything in the text that was thought to reflect a problem with dissemination. After all problems were identified, a classical coding procedure was employed using an *a priori* categorization scheme (the 21 dissemination variables). To conduct this procedure, the coder matched each of the text segments with its corresponding variable in accordance with the operational definitions established in the literature review (Table I). Any text segment whose proper categorization seemed questionable to the coder was discussed with other members of the team until consensus was reached. Any text segment not readily associated with a variable was identified as "other." Upon completion of the initial coding, the research team met to discuss each of these other factors. The text segments that did not align with existing variables were discussed by the research team and used to create additional problem categories. Discussion as to how these additional categories were inferred and how they were defined is addressed later in Section IV.

Adherence to strict coding standards enhanced the reliability of the results. In order to maintain consistency, the coding stage of the content analysis was conducted by only one of the authors. This individual identified relevant text segments and categorized the segments in accordance with the procedure outlined above. Next, an analysis for determining whether the coding met appropriate standards of reliability was conducted. Using a random number generator, a second research team member drew a sample of 20% of the 410 abstracts to analyze independently. This second coder followed the same procedure as the primary coder to identify and categorize the problems. Unanimous agreement was reached regarding the identification of the relevant dissemination problems. To measure intercoder reliability (matching the text segment to the problem category), Krippendorff's alpha coefficient for two observers and many nominal categories [67] was calculated. Krippendorff's alpha was 0.83, which is above the recommended minimum for drawing meaningful conclusions [67].

#### IV. RESULTS

The results of both studies are displayed in Table II, which is sorted in descending order by the number of times the variable

was rated most important by the group. The table provides the mean scores attributed to each variable by the individuals, a count of the number of times a group identified a variable as being "most important" and a count of the number of studies that were affected by each variable. The Delphi study participants identified one additional variable that was not originally included in the listing of variables to consider: adaptability. Although not initially considered in the listing of 21 variables, it must be noted that previous diffusion of innovation research has identified adaptability as being relevant to the adoption of innovations [44]. Because this was not identified prior to the individual round of variable ratings, only the group ratings are available for this variable. However, because the Delphi study was conducted prior to the content analysis effort, adaptability was included in the content analysis in addition to the original 21 variables.

As identified in Table II with three asterisks, the content analysis uncovered additional variables that seem to affect dissemination. In accordance with the content analysis method, challenges not relevant to the 21 variables in the original listing were coded as "other." Initially, there were 74 segments coded as such. The investigators used a process of abductive inference to identify additional variables and categorize these additional text segments. Upon close examination of these text segments, further review of dissemination-related literature, and much discussion between this study's investigators, consensus was reached that four additional variables seemingly emerge as barriers to dissemination. These are: 1) logistical issues; 2) cultural differences; 3) resistance to change; and 4) teacher/student turnover. The additional variables identified in this study are defined in Table III.

#### V. DISCUSSION

The results of both studies yield generally similar results. Some variables emerged as being more relevant to the dissemination problem than others. In this section, the procedure followed to determine which variables emerged as being most important to dissemination is explained. Then, practical implications are discussed.

Using the results from both studies, the data were sorted using two levels: 1) number of groups indicating a particular variable was the most important, and then 2) number of text segments assigned to that variable. This sorting process facilitated the ranking of variables with regard to one another. This process separated the variables into two distinct groupings, which are labeled as: a) most important, and b) less important. After close examination of the data distributions and discussion among the research team members, the following criteria were established to categorize the variables. A variable was considered to be most important if it was rated by four or more of the Delphi groups as being most important or if 20 or more of the studies considered in the content analysis identified the variable as presenting a problem to dissemination. Any variable not meeting these criteria was then categorized as less important. This protocol resulted in the top one-third of variables to be considered as most important. In the remainder of this paper, only the variables found to be most important are discussed.

TABLE II  
RESULTS

Variable	Mean Individual Rating*	Count of Groups Rated Most Important (n = 7)	Count of Projects Affected by Variable (n = 410)
Relative Advantage	2.6	7	28
Usability	2.9	5	24
Adaptability**	-	5	11
Management Support	2.5	4	18
Complexity	2.4	4	34
Relevant to Job	2.6	3	8
Accessibility	2.3	3	12
Facilitating Conditions	2.3	3	58
Self-Efficacy/User Support	2.4	2	6
Compatibility	2.2	2	21
Trialability	2.2	2	1
Innovativeness	2.4	1	2
Demonstrable	2.2	0	18
Attitude toward System	2.2	0	17
Perceived Enjoyment	2.2	0	0
Social Pressure	1.9	0	1
Anxiety in Use	2.0	0	1
Voluntary	1.8	0	3
Playfulness	1.8	0	3
Enhance Visibility	2.1	0	3
Enhance Image	1.5	0	0
Aid Social Presence	1.4	0	0
Logistical Issues***	-	-	32
Cultural Differences***	-	-	21
Resistance to Change***	-	-	11
Teacher/Student Turnover***	-	-	10

\*Scale from 1–3 where 3 = most important, 2 = moderately important, and 1 = less important  
\*\*Additional variable identified by Delphi study participants  
\*\*\*Additional variable identified by the content analysis

TABLE III  
ADDITIONAL VARIABLES

Variable	Explanation and Definition
Adaptability*	The ability of the educational innovation to be tailored, without great effort, to fulfill varying educational needs; differs from compatibility in that compatibility is concerned with how the innovation integrates into curriculum “as is,” whereas adaptability allows the user to modify the innovation as deemed necessary
Logistical Issues (-)	Any problem within or between stakeholders regarding scheduling, communication, or participation; usually due to geographic or time separation of resources or participants
Cultural Differences (-)	The varying intrinsic and extrinsic attributes within and between dissemination groups; accounts for the belief differences between different teachers, schools, ethnicities, and locations; i.e., learning style preferences differ between students with varying cultural values [68]
Teacher/Student Turnover (-)	Frequency and degree of change in the teaching staff and student population
Resistance to Change (-)	Any situation where educators resist change from current practices

(-) next to a variable denotes that it inhibits dissemination

\* Although not initially considered in the listing of 21 variables, it must be noted that previous diffusion of innovation research has identified adaptability as being relevant to the adoption of innovations [44]

### A. Most Important Variables to Dissemination

Table IV describes the most important variables. Also provided are examples of text segments selected from the poster

abstracts describing each variable in order to clarify the definition, while demonstrating its practical significance to the dissemination problem. In all, 72% of all of the problems identified in the content analysis were related to these nine most important

TABLE IV  
MOST IMPORTANT VARIABLES

Variable (groups rated most important : number of studies)	Example from content
Relative Advantage (7:28)	A pure PBL-based approach seems to demand a lot of students' time, that's one of the reasons why a guided PBL seems to be more practical in settings similar to us
Usability (5:24)	Developing easy to use Evo Connections and modifying existing labs so that connections to evolution are more explicit have proved to be more challenging than anticipated
Adaptability (5:11)	...to implement the proposed course to maximally benefit all the participating students, the strategies need to be flexible or customized to suit the needs of each individual student
Complexity (-) (4:34)	The complexity and open-ended nature of some of the medical device projects have been challenging to some students
Management Support (4:18)	Some institutions experienced implementation challenges due to resistance from curriculum committees and other factors
Facilitating Conditions (3:58)	The major challenge has been developing the game on a limited budget
Compatibility (2:21)	The specific equipment choices and the challenges of getting all the parts of the system to work together was more challenging than expected
Logistical Issues (-) (*:32)	The primary challenge has been working with large number of lead personnel who were located at six different colleges around the country
Cultural Differences (-) (*:21)	The one unexpected challenge was the difficulty in one community (Economics) to accept methods that are used in the other (Engineering), such as the use of numerical methods to resolve problems that are not tractable with analytical techniques

\* Variable not rated in Delphi study

(-) next to a variable denotes that this inhibits dissemination

variables. For innovators, the results suggest that it is important to improve the characteristics of the innovation itself; design considerations should include *relative advantage*, *compatibility*, *usability*, *complexity*, and *adaptability*. Innovators also need to consider variables relevant to the education/dissemination environment, to include *management support*, *facilitating conditions*, *logistical issues*, and *cultural differences*, before spending time and resources to develop the innovation. These factors were also found to be important by the researchers who presented at the 2011 NAE Forum on Characterizing the Impact and Diffusion of Transformative Engineering Education Innovation. They identified factors such as complexity, compatibility, relative advantage, and time and resource constraints as being important to dissemination [69], [70].

### B. Considerations for Innovators Regarding the Innovation Design

The results suggest that designing for dissemination may be important to ensuring that educators adopt and use an educational innovation; dissemination should not be an afterthought. To begin, including mechanisms that facilitate *adaptability* into the design of the innovation helps potential users to be able to tailor the innovation to their unique needs. Because every teacher, student, and classroom is different, building adaptability into the innovation allows for dissemination to a wider audience. Similarly, the results suggest that new materials must be *compatible* with existing pedagogy. It was uncovered that some educational innovations, although relevant, were simply not a good fit given the current design of the targeted course. Compatibility differs from adaptability in that compatibility is concerned with how the innovation is integrated by an educator "as is," whereas adaptability allows the user to modify the innovation to fit his or her specific needs. However, the ideas of

compatibility and adaptability need not be mutually exclusive. In fact, designing for both compatibility and adaptability may help to create an innovation that is relevant to both the targeted audience and those in related fields. Understanding the current pedagogical trends and contemporary issues of their field will help developers create innovations that are both compatible with existing programs and easily adaptable for additional uses.

*Usability* is another important variable to consider. The results suggest that it is necessary for the innovation to be easy for both teachers and students to use. Likewise, *complexity* of the innovation is something that should be avoided. In the content analysis, it was often mentioned that students felt that some of the innovations were unnecessarily complex. To overcome these problems of usability and complexity, the TUES and CCLI researchers suggested that engaging faculty and students during development is often helpful. Because this feedback process makes users feel that they are part of the project rather than simply having the innovation imposed on them, this type of user involvement has been shown to increase the user's self-efficacy, which may increase perceived usability while decreasing perceived complexity [16]. By employing this feedback in the design process, developers can create the innovation with better usability and less complexity. However, it must be noted that decreased complexity may entail less adaptability. This tradeoff should be considered by innovators, and future research is encouraged to determine how to design with both considerations in mind.

The results suggest that it is most important to create materials that possess a clear, *relative advantage* over materials that are currently in use. Indeed, this need for relative advantage was cited by every group in the Delphi study as being a most important variable. This implies that material developers must have a firm grasp on current materials/methods being employed. If not, how can developers understand if their materials are any better

than what is currently in use? In addition, by thoroughly understanding current methods and materials, developers can better understand the shortcomings of current pedagogy and design new methods and materials accordingly.

### C. Considerations for Innovators Regarding the Dissemination Environment

Although design considerations are surely important, addressing factors that affect the dissemination environment has been shown to be equally, if not more important, to dissemination [71]. In this regard, the results show that the resources required for dissemination are a primary concern. *Facilitating conditions* were cited 58 times in the content analysis, which is more than any other variable. Although time and manpower were noted as facilitating conditions that are important to dissemination, the need for funding was the most cited condition encompassed by this variable. Not only is adequate funding important to develop the innovation, but it was also found that distribution of the innovation could be costly. Innovators should anticipate the costs associated with dissemination and communicate with potential users when they create materials so as to keep costs within a predetermined amount and facilitate acceptance by the intended audience.

The results suggest that support from department, college, and university leadership is also important to facilitating dissemination. The content analysis revealed many instances where a champion from administration could either facilitate or hinder the dissemination process. This finding is congruent with the findings of Owen and Stupans [22], who highlight the importance of university engagement and wider stakeholder involvement in curriculum dissemination. Previous research also points out that university engagement through the dissemination process could benefit not only the change initiative, the students, and the faculty, but even society as a whole, because it raises public awareness of the need for more innovations in higher education [72]. Thus, innovators need to be in continuous communication with administrators throughout the design and dissemination process so as to acquire sufficient *management support*.

*Logistical issues* are also a barrier for dissemination. Geographical distance, varying time zones, and different schedules of implementers appear to inhibit the collaboration and coaching required for some educational innovations to be effectively used. Innovators should find means to overcome the logistical issues inherent in the dissemination of the educational innovation. Solutions could entail the use of tools such as asynchronous chat, video conferencing, or use of collaboration Web sites.

Logistical issues may also be compounded by the presence of *cultural differences* between different schools, teachers, and students, which were found to be another barrier to dissemination. For example, one of the research abstracts noted a challenge when implementing materials at an institution for which the innovation was not originally intended. In order to facilitate adoption, the innovators noted that they should have involved colleagues from other institutions in the development process

so they could understand different cultural norms, anticipate potential problems, and effectively implement the innovation. This provides further support for the importance of building adaptability into educational innovations.

## VI. LIMITATIONS AND FUTURE RESEARCH

Dissemination is a complex process. Use of an *a priori* categorization scheme based on the literature for both the Delphi and content analysis may have explored only a single dimension of the dissemination process. However, meaningful conclusions were still derived, and the study identified important variables for innovators to consider. Further research should not only seek to confirm these results, but also find and test additional variables that may be relevant to dissemination. Variables such as “quality of initial information about innovation” may have to be considered since it may serve to reduce the amount of original assessment that potential users believe they need to do as part of their adoption/adaptation decisions.

Although the results of both studies provided generally similar results, there were some points of divergence. For example, facilitating conditions was only rated by three of the seven groups as being most important, whereas it was the most cited dissemination problem in the content analysis. Similarly, compatibility was only rated by two of the seven groups as being most important. However, it was cited in 21 projects as being a problem. Finally, demonstrability and user attitude toward the innovation were cited in 18 and 17 projects, respectively; no groups rated these as most important. These conflicting results suggest that there may be other issues that moderate the effect of these factors that were not accounted for in this study, such as academic discipline, type of innovation, type of academic institution, or other. Although the qualitative methods used in this study may not be adequate for testing moderation, future research could employ quantitative means to test for such effects.

In this study, the dissemination problem was viewed from the perspective of innovation developers. However, dissemination is an effort that requires contributions from multiple stakeholders to include grant providers, school administrators, students, and educators. Future research could investigate factors that should be considered by each of these stakeholders to facilitate dissemination. Finally, this study was focused primarily on educational innovations in engineering education. However, because the data used in this study were derived from experts and textual content spanning multiple STEM areas, these results may also generalize to other STEM educational innovations. Future research should investigate whether or not such generalization is appropriate.

## VII. CONCLUSION

Educators, researchers, and institutions devote time and resources to develop educational innovations, many of which are not adopted widely. This research sought to investigate ways in which creators of these innovations can better facilitate dissemination. Using extant theories as a basis to identify the factors that may affect the acceptance and use of educational innovations, this study serves as a preliminary effort to investigate how to effectively facilitate dissemination. The results of this

study suggest that innovators should consider such design considerations as *relative advantage*, *compatibility*, *usability*, *complexity*, and *adaptability*. Although minding these design considerations is important, as the findings of both this study and past studies suggest, this is only a part of the solution [71]. Innovators should also be aware of issues relevant to the dissemination environment, such as *management support*, *facilitating conditions*, *logistical issues*, and *cultural differences* when developing educational innovations. The findings of this research effort offer guidance for those in engineering education to better disseminate educational innovations. Additional research in the area of dissemination is encouraged so that innovators better understand the most important factors in dissemination before embarking on their research efforts.

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