AC 2011-1635: UNDERSTANDING FACULTY AND PRACTITIONER INVOLVEMENT IN A CAPSTONE INTERDISCIPLINARY DESIGN EXPERIENCE

Shane A. Brown, Washington State University

Dr. Brown is an Assistant Professor in the Department of Civil and Environmental Engineering at Washington State University. His research includes understanding how and why faculty adopt curricular innovations using Diffusions of Innovation Theory and the Concerns Based Adoption Model.

Nadia Frye, Washington State University

Nadia Frye is currently working on her PH.D. in Civil Engineering at Washington State University focusing on Engineering Education research.

Devlin B. Montfort, Washington State University
Paul M. Smith, The Pennsylvania State University

Dr. Smith is a Professor of Forest Products Marketing at Penn State University. He received a B.S. in Forestry, University of Montana, M.S. in Forest Products, University of Idaho and Ph.D. in Forest Products Marketing, Virginia Tech. He also serves as adjunct Professor at Washington State University's Wood Materials & Engineering Lab and Institute for Sustainable Design.

Dr. Smith's recent research interests include: Trade Show Use/Effectiveness; Value Analysis; Product-Market Development; Branding; Content Analysis of Advertising; and Pennsylvania's Hardwood Industries.

Understanding Faculty and Practitioner Involvement in a Capstone Interdisciplinary Design Experience

Introduction

Engineering education innovations are continually being developed and promulgated in the higher education engineering community. It is the hope of the engineering education community as a whole that these innovations will lead to an overall transformation of engineering education that will have a positive impact on students, programs and the professional engineering community. The push for this change is widespread ranging from individual engineering education professors to the National Science Foundation.

One of the ways in which engineering education innovators are attempting to transform engineering education is through implementation of interdisciplinary capstone design courses. Interdisciplinary capstone design courses provide students from different fields with the opportunity to work directly with other design students and professionals to develop a real world, authentic project. Studies have shown that engineering departments across the nation are attempting to implement interdisciplinary capstone design courses into their curriculum[1].

The Interdisciplinary Design Experience (IDeX) is an interdisciplinary academic program developed to provide real world experience with innovative sustainable design projects to engineering, architecture and construction management undergraduate and Masters level students. The two-semester course incorporates students, faculty and practicing professionals into a design studio where they produce a complete design ready to be implemented by a client. IDeX was developed in 2009 at Washington State University and is currently in its second year of implementation. The program is self-funded through a contract with the client, which allows a low student-to-faculty ratio and provides access to advanced technology being used by industry professionals. IDeX would be considered an interdisciplinary capstone design course, but is unique from many courses of this type in that it incorporates graduate-level students who often complete a thesis project relating to some aspect of the course. The first semester of the course introduces students to sustainable design, prepares them to work in interdisciplinary groups, lays the ground work for their designs and provides the technical skills needed to complete professional design projects. Short sessions, ranging from one class to two weeks of classes, are taught by external faculty and visiting professionals to increases students' understanding of the concepts and tools utilized in the design project. The second semester completes the design project for the client. Students present their work for evaluation at different stages to groups of faculty, practicing professionals and liaisons from the client. At the end of the year a complete design project is submitted to the client.

Developers of engineering education innovations like IDeX – large, complex programs to be implemented at the university level – want to be able to understand the phenomenon of adoption and how their innovation will be affected during the adoption process. Engineering education innovators have utilized adoption frameworks, such as Diffusion of Innovations (DI) and the Concerns Based Adoption Model (CBAM) to produce reliable, generalizable results[3, 4, 5, 6]. However, even in its second year of implementation, IDeX continues to evolve and be adapted in order to better suit the students, faculty, clients and even the college in which it is based, and it remains a diverse and complex program. The process of change and re-invention of an innovation is an interesting phenomenon in adoption research that challenges well-established adoption frameworks[6].

Literature Review

Previous Work in Engineering Education

Both DI and CBAM have been utilized to understand adoption of innovations in engineering education. Borrego, Froyd and Hall did a study using DI to examine adoption of seven engineering education innovations in universities across the United States[1]. The research team surveyed engineering department heads about their awareness of each of seven innovations using four criteria as follows (adapted from Borrego et al.)[1]:

1. Each innovation needed to be easily distinguished from the others in the study;
2. Previous research had to show that each innovation had a positive impact on student learning;
3. No innovation could have universal adoption; and
4. Each innovation needed to be wide spread enough to have been implemented diversely.

This study found that most department heads were aware of the innovations, but the innovations were only adopted at a rate near 50 percent, and "financial resources, faculty time and attitudes, and student satisfaction and learning" were major factors when considering adoption[1]. The authors also called for future research to study the complex and intricate way in which groups of faculty and administrators affect adoption decisions in engineering departments[1].

Turns et al. utilized CBAM when examining the teaching concerns of engineering educators[7]. The study used accounts of interviews between engineering faculty and a teaching consultant about their teaching experiences to better understand faculty concerns about their teaching. A wide variety of concerns were identified within the CBAM framework, but the authors concluded that CBAM could not explain all of the faculty concerns[7]. Turns et al. referred to one of the conceptual foundations of CBAM, Fuller's Self-Task-Impact Model[2], to generally characterize some of the concerns that could not be explained by CBAM[7]. The research by Turns et al. shows a need to look more closely at CBAM and develop means to explain adoption concerns and decisions when CBAM cannot[7].

Conceptual Models for Changing Innovations

Rogers presents the concept of re-invention in order to explain the evolution of an innovation during the adoption process[6]. Beyond noting that re-invention is not necessarily bad and listing potential causes for re-invention, Rogers mostly presents re-invention as a theoretical challenge to understanding the adoption process. Re-invention is not included as something to be measured and defined by the DI framework[6]. It may be that Rogers' view of re-invention as a challenge is based on the flexibility of DI theory's means of describing innovations. Instead of rigidly defining an innovation based on ostensibly objective characteristics, Rogers defines innovations based on how potential adopters perceive them[6]. In particular, adoption is largely controlled by potential adopters perceptions of the following five characteristics:

1. *Relative Advantage* is the increased strengths or weaknesses of an innovation in comparison to any ideas previously presented to or utilized by potential adopters.
2. *Compatibility* is the extent to which an innovation agrees with beliefs, ideas or experiences of potential adopters.
3. *Complexity* is how complicated or difficult to use an innovation may seem to potential adopters.
4. *Trialability* is the extent to which a potential adopter may experiment with or test an innovation previous to adoption.
5. *Observability* is the extent to which effects of an innovation are apparent to potential adopters.

CBAM consists of three components, Stages of Concern (SoC), Levels of Use (LoU) and Innovation Configurations (IC). Stages of Concern are used to determine how potential adopters are thinking of an innovation and changing their conceptions of the innovation[3]. Levels of Use evaluate how the potential adopter is utilizing the innovation[4]. Instruments were developed with CBAM to determine an adopter's LoU and SoC. These instruments focus on one individual's thoughts and experiences of the implementation and adoption of an innovation controlled by that individual. The IDeX program, however, is facilitated by several faculty members and practicing professionals, which requires implementation and adoption decisions to be made by the group. The intricacy of an innovation like IDeX limits the applicability of SoC and LoU because they have not been tested and validated to be applied to complex and rapidly changing innovations.

Innovation Configurations can be utilized more freely by the implementer to characterize these types of programs and still used to identify Stages of Concern and Levels of Use. For example, an Innovation Configuration should identify how someone is using an innovation, how they have changed the innovation and how they plan to change it in the future, which ties directly to Levels of Use and makes identifying those levels simple[4, 5]. Innovation Configurations also provides an understanding of how each individual operationalizes a complex interaction innovation like IDeX. Innovation Configurations look at the way a specific user has adopted, adapted and is using an innovation[5].

Purpose

The purpose of this research is to apply CBAM and DI theory to the particularly challenging case of a complex and changing innovation by using the constructs in those theories, Innovation Configurations and the characteristics of an innovation, respectively, that most apply this case.

Methodology

The focus of this research was faculty and practicing professional participation in IDeX. All of the faculty and professionals participating in IDeX currently were invited to participate in the interviews, and all but one of those people responded. A total of six faculty members plus two clients were interviewed in the Fall of 2010. Two faculty members are in architecture, three are in civil engineering and one is an environmental engineering faculty member. All six faculty members participated in some way in the program. Two of the faculty members were involved with the program from its inception and are considered in this research to be *Developers*. Four faculty members became involved with IDeX at different points after its inception and will be termed *Implementers*. Four faculty members are directly involved in the teaching aspect of the program. The other two faculty members teach associated classes and participate in certain IDeX components like the design review sessions. In addition, two client liaisons were interviewed and termed *Clients*. One of these people was involved with the business aspect of the contract with the program, but both were involved in the technical aspects of the contract. Figure 1 summarizes these groups, and provides the pseudonyms used to refer to each interviewee.

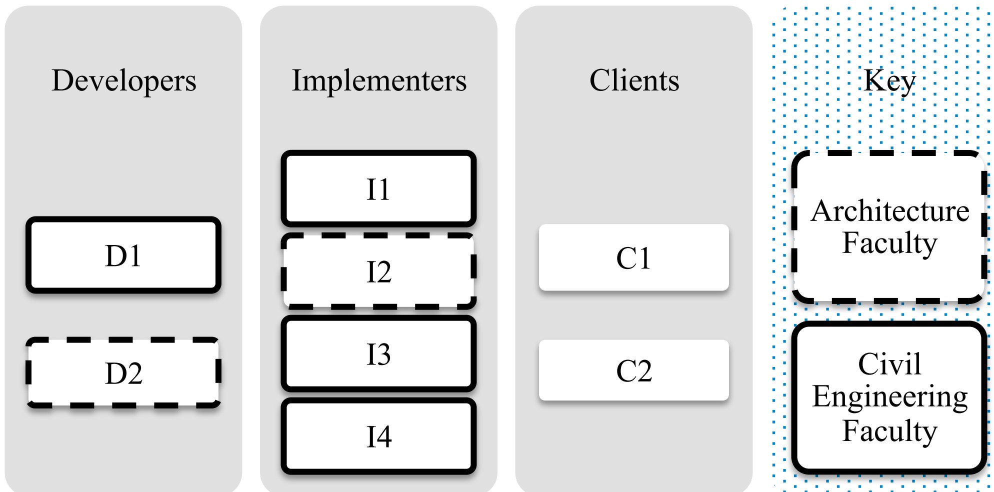

Figure 1. Interviewee classification.

Qualitative interview protocols were developed by the research team and utilized to analyze the perceptions faculty and professionals have regarding IDeX. The questions were based on experiences participants have had with the program in both its 2009-2010 and 2010-2011 courses. A small team of faculty, the *Developers*, also worked on the development of the course and were therefore asked additional questions about their experiences in development. The interviews were developed utilizing the DI and CBAM frameworks and a summary of the concepts and the relevant corresponding DI and CBAM components is provided in Table 1. Each interview was coded for the interviewee's perceptions through the lenses of the DI and CBAM frameworks.

Results

Although all five characteristics were included in the interview methodology, only Relative Advantage and Compatibility were consistently important in the participants' responses to IDeX. Relative advantage was often implied by faculty members' desire to develop research projects from the designs and ideas developed in IDeX and is illustrated by I3's response to the question regarding their reasons for participating in IDeX, "And I also am really interested in, just as a research topic, in sustainability, sustainable design, and we really [want] to focus on that…" Compatibility was often implied in the tie between interviewees' perceptions of the goals and advantages of the program and their description of the program. Examples of Compatibility are given in Table 2. The participants described their goals and the programs' advantages in four distinct ways: collaboration, sustainability, interdisciplinary interaction and economic advantage.

D2, for example, spoke of teaching students to collaborate with their peers early on in the design process as one of his goals, and as one of the goals of the IDeX program. This compatibility based on a focus on "collaboration" was common among the interviewees. As shown in Table 2, participants' also perceived compatibility between their goals and the IDeX program based on the importance of teaching students about sustainability (see interviewee D2 for examples), interdisciplinary interaction (see interviewee I2 for examples) and economic advantages to the sponsoring clients (see interviewee C1 for examples).

<table>
<tr><th>Interview Concepts</th><th>DI Components</th><th>CBAM Components</th></tr>
<tr><td>Asked to give their description of the program</td><td></td><td rowspan="6">Innovation Configuration</td></tr>
<tr><td>Asked about their perception of the effects of the program on themselves, students, faculty and practicing professionals</td><td>Relative Advantage
Complexity</td></tr>
<tr><td>Asked about their perception of the goals and advantages of the program</td><td>Relative Advantage
Compatibility
Complexity</td></tr>
<tr><td>Asked about their perception of the weaknesses of the program</td><td>Compatibility
Complexity</td></tr>
<tr><td>Asked about their involvement with the program and level of satisfaction with involvement</td><td>Compatibility
Complexity</td></tr>
<tr><td>Asked about their reasons for participation</td><td>Relative Advantage
Compatibility
Observability
Trialability</td></tr>
</table>

Table 1. Interview concepts.

The Innovation Configuration of each of the interviewees was examined and it was determined that there was a large variance in the dimensions of the Innovation Configurations. These large differences seemed to be based on the different interactions participants had with IDeX. A summary of these differences is given in Table 3. Interviewees varied in the amount of in-classroom participation from daily to quarterly participation. Some interviewees had full classes of students that participated in IDeX; one had a few students from a class participate in IDeX; and two did not teach students that participated in IDeX. Three of the interviewees were only involved in the evaluation portions of IDeX (e.g. the design review sessions), while the rest were also active in educating the students in IDeX. Of the interviewees that had students participating in IDeX, four taught students directly in IDeX while two taught students in classes outside of IDeX but associated with it in some way.

Interviewee	Goals for Participation in IDeX	Description of the IDeX Program
D2	Collaboration • *"One is early-on teaching students…this model of collaboration…"* Sustainability • *"…this is a fantastic tool to teach the students about green design."*	Collaboration • *"…to help teach the students that they need to be collaborating from the outset…"* Sustainability • *"…to challenge in particular with problems that work to sustainability and the environment."*
I1	Interdisciplinary Interaction • *"…gets them interacting with other disciplines…"*	Interdisciplinary Integration • *"IDeX is about trying to get people from different disciplines and different personalities, almost to integrate together, to work well with each other…"*
C1	Economic Advantage • *"Other benefits I see here are actual economic benefits for the sponsoring agency."*	Economic Advantage • *"…I would probably emphasize the jobs aspect of it and the economic development aspect of it…"*

Table 2. Interviewee examples of DI characteristic – "*Compatibility*".

In order to better understand the effect of the interviewees' interaction with the class and their Innovation Configurations, the interviewees' use of the class has been classified as:

1. *Direct* – Working with students enrolled in IDeX within the IDeX classroom regularly,
2. *Limited Direct* – Working with students enrolled in IDeX within the IDeX classroom on a limited basis and working with students participating in IDeX through an associated course on a more regular basis,
3. *Secondary* – Working with IDeX and the participating students, but not directly involved in the teaching of IDeX,
4. *Limited Secondary* – Working with students participating in IDeX through an associated course, but not directly involved in the teaching of IDeX.

Examples of the Innovation Configurations of the interviewees from their descriptions of IDeX are given in Table 4. Each description has been summarized with short statements and supporting quotes.

Interviewee	Participation Time	Number of Students Involved	Participation Type	Student Participation Type	Use Classification
D1	Daily	All	Education	In IDeX	Direct
D2	Weekly	All	Education	In Auxiliary Class	Limited Direct
I1	Daily	All	Education	In IDeX	Direct
I2	Daily	All	Education	In IDeX	Direct
I3	Daily	All	Education	In IDeX	Direct
I4	Quarterly	Few	Evaluation	In Auxiliary Class	Limited Secondary
C1	Monthly	No Students	Evaluation	No Students	Secondary
C2	Monthly	No Students	Evaluation	No Students	Secondary

Table 3. Summary of interviewee Innovation Configuration factors.

Interviewee	IDeX Description	DI Components Reflected in Description	Use Classification
D1	**Interdisciplinary problems** • "…IDeX is…a … space…to work on interdisciplinary problems in the built environment…" **Sustainability** • "…problems… that have challenging bends towards sustainability…" **Application of Education** • " …to a student…it provides an opportunity to practice the engineering that they're learning…" **Improve Communication Skills** • "… it's an opportunity to improve communication skills…" **Learn about other disciplines** • "… it's an opportunity to… learn about other disciplines and what their roles are in the design process." **Professionals Interacting with University** • "…to a professional who's out there in practice…it's an opportunity for them …to interact with the university from a standpoint of both a teaching and a research basis…" **Faculty Learning About Sustainability and its Research Areas** • "To other faculty … it's an opportunity for them to … learn about the issues around sustainable design and green and clean technology …and where the researchable topic areas are within this component."	Relative Advantage Compatibility	Direct

Table 4. Innovation Configurations and influencing factors (continued on next page).

I3	**Interdisciplinary Design Class** • "…it's an interdisciplinary design class so we bring in students from different disciplines." **Real Design Project** • "Usually… we have been able to acquire a project, a real design project that the students work on throughout the year." **Interact and Communicate with Different Disciplines** • "So I just see it as a way for students to learn how to interact with different disciplines, which has been a problem in practice, to be able to communicate with engineers be able to communicate with architects…" **Learn to Cross Discipline Barriers** • "And this class gives them the ability to learn how to go across those discipline barriers before they go into practice."	Compatibility	Direct
C1	**Learn the Big Picture** • "It's an opportunity for different disciplines to learn the big picture…" **Learn How to Use Technical Resources** • "…learn… how to leverage other technical resources." **Increase Interdisciplinary Interaction** • "… we'll have more and more interaction between disciplines." **Use Sustainable Technology** • "… I would emphasize some of the… more technical details like the specific pervious concrete for instance as a solution for some storm water things … or energy retrofits for buildings to save energy…" **Increase Economic Development** • "…I would probably emphasize the jobs aspect of it and the economic development aspect of it…"	Relative Advantage Compatibility	Secondary

Table 4. Innovation Configurations and influencing factors (continued from previous page).

Discussion

The variance in Innovation Configurations bring to light challenges in using the DI and CBAM frameworks to look at complex, advanced engineering education innovations like IDeX. Because each of the interviewees had a different Innovation Configuration, it shows that they each operationalize IDeX differently. It seems that this is related to the fact that IDeX is not a static innovation. Instead, it is constantly changing as a result of the users' inputs, and because of the different ways in which the users interact with the program. The way each person perceives IDeX contributes to the way it evolves and each time IDeX evolves the users' perceptions of it change. This leads to a continuous loop of perceptions influencing changes which, in turn, influence perceptions of the program. This continuing evolution of the program limits the effectiveness of using Innovation Configurations solely as developed to understand users' adoption decisions because the reasoning behind the decisions will change as the program changes. It also limits the effectiveness of using DI's characteristics of an innovation for similar reasons. As the users are able to influence the evolution of IDeX they will be able to increase their Compatibility with the program and the Relative Advantages it offers them. Even though the characteristics continue to apply, the components of each characteristic will change as the program changes.

There is another challenge to using Innovation Configurations simply as developed in CBAM and brought to light by the variance in Innovation Configuration. Innovation Configurations are designed to be different for different people because each person can use or implement an innovation in their own. However, this is not actually the case for IDeX. The program is administered and implemented by the previously outlined group of faculty and clients. As a result, IDeX cannot be implemented in different ways by each person because it is only one instance of implementation. All modifications to the program must be made through group decisions. Since there is only one instance of the program, CBAM would tell us that all of the users should have the same Innovation Configuration, but our study found that the Innovation Configurations of the users were actually quite varied and were potentially affected by a wide range of factors external to the innovation itself. One of the major influences on the Innovation Configurations was the diverse use and participation experiences of the adopters. The users were able to be involved in a variety of different ways which contributed to altering their Innovation Configuration.

Conclusions

Diffusions of Innovation and the Concerns Based Adoption Model are useful frameworks for understanding adoption of engineering education innovations, but there are some challenges to using them. Some innovations being developed in engineering education – like the IDeX program or other program and curricular innovations – are large, complex and adaptable. To understand adoption in such diverse and evolving innovations we must develop an understanding of the way change during the adoption of an innovation affects the adoption decisions of current and potential users. For example, in the case where innovations are programs, like IDeX, which are meant to be implemented by a group of people, CBAM and DI theory's emphasis on the individuals' perceptions can be misleading, or at least incomplete.

There are some limitations to this research in the small sample size of participants in IDeX, and that it was limited to one interdisciplinary capstone design course that does have some unique features in comparison to other similar programs. Despite these limitations, this research lays the groundwork to examine these frameworks more closely in order to develop an understanding of the effects of innovation change on adoption of engineering education innovations. A high resolution, longitudinal study that included more adopters of a larger number of engineering education innovations could map the Innovation Configurations of the adopters and increase the understanding of the effects of change.

Future Research

There will be follow up interviews with the current adopters of IDeX along with a more in-depth look at all of the characteristics of these frameworks that inform adoption in changing engineering education innovations. Follow up interviews with the current adopters of IDeX will increase understanding of how adopters operationalize IDeX over time and how that affects their adoption decision. The research team is also developing a survey to examine characteristics that would potentially inform adoption decisions by faculty and practicing professionals not currently involved in IDeX. Broadening the pool of potential adopters could help create a more robust understanding of the way change affects adoption in engineering education and specifically in interdisciplinary capstone design courses.

Each participant operationalized IDeX, a dynamic innovation based on user inputs, according to their role in and perceptions of IDeX. This continuous evolution of perceptual change limits the effectiveness of current Innovation Configuration models to adequately describe IDeX in terms of an innovation to be adopted and diffused into engineering curricula. Additional research is necessary to better understand and describe dynamic engineering education innovations and to determine means by which successful outcomes may be replicated.

References

1. Borrego, M., Froyd, J. E., & Hall, T. S. (2010). Diffusion of Engineering Education Innovations: A Survey of Awareness and Adoption Rates in U.S. Engineering Departments. *Journal of Engineering Education*, July, 185-207.
2. Fuller, F. (1969). Concerns of teachers: A developmental conceptualization*. American Educational Research Journal*, 1969. 207-226.
3. George, A. A., Hall, G. E., Stiegelbauer, S. M. (2006). *Measuring Implementation in Schools: The Stages of Concern Questionnaire*. Austin, TX: SEDL.
4. Hall, G. E., Dirksen, D. J., George, A. A. (2006). *Measuring Implementation in Schools: Levels of Use*. Austin, TX: SEDL.
5. Hord, S. M., Stiegelbauer, S. M., Hall, G. E., George, A. A. (2006). *Measuring Implementation in Schools: Innovation Configurations*. Austin, TX: SEDL.
6. Rogers, E. M. (2003) *Diffusions of Innovations*. New York, NY: Free Press.
7. Turns, J., Eliot, M., Neal, R., Linse, A. (2007). Investigating the Teaching Concerns of Engineering Educators. *Journal of Engineering Education*, October, 295-308.