



## **Examining the Innovation-Decision Process: A Preliminary Study of the AIChE Concept Warehouse**

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# Examining the Innovation-Decision Process: A Preliminary Study of the AIChE Concept Warehouse

## Introduction

Transportability is a widespread goal of education materials development. If an educational innovation is effective in one environment, many developers want to share it with other instructors and institutions to have a larger impact and improve education more broadly. Additionally, funding agencies like the National Science Foundation require a “broader impact” component in all grant proposals.

One aspect commonly missing when an innovation is shared is a reflective, evidence-based description of the process as the educational innovation moves from the home institution to other institutions with different faculty, different students and a different culture. In analogy to molecular diffusion, E.M. Rogers put forth a theory, *Diffusion of Innovations*, that offers one framework with which to examine this process. In this context, Rogers describes diffusion as “the process in which an innovation is communicated through certain channels over time among the members of a social system. (p. 5)”<sup>1</sup> We focus on one aspect of diffusion, the innovation-decision process, which describes five stages the potential user goes through as they decide whether to adopt a new innovation: knowledge, persuasion, decision, implementation, and confirmation.<sup>1</sup>

Conceptual learning is critical to developing problem solving skills in chemical engineering. Many engineering educators and industry partners emphasize the need for students to apply their knowledge to new and challenging problems.<sup>2</sup> In order to do so, students must learn with understanding.<sup>3</sup> A lack of conceptual understanding has been shown to severely restrict students’ ability to solve new problems, since they do not have the functional understanding to use their knowledge in new situations.<sup>4</sup> However, science and engineering classrooms often reward students more for rote learning than for conceptual understanding.<sup>5, 6</sup> There is clearly a need for more emphasis on conceptual understanding and concept-based instruction.

We report on the first year investigation of the innovation decision-process of faculty who have considered adopting the AIChE Concept Warehouse, a cyber-enabled site for facilitating conceptual learning in Chemical Engineering. We ask the following research questions:

1. Why do early adopters choose to implement the AIChE Concept Warehouse and how do they use the tool?
2. What factors contribute to the innovation-decision process and how can we minimize negative factors?
3. What ways can we increase awareness?

For the purposes of this study, we count someone as “using” the tool if it has enabled him/her to teach in a way that he/she wouldn’t otherwise have employed.

## Background

Transportability is a broad topic that is difficult to research and assess. The ultimate question in this type of research is what works, with whom, where and in what conditions? It is concerned

with both the overall diffusion of an innovation as well as the details of that process in assessing changes and effectiveness. Often developers of curricular interventions provide suggestions for implementation and support; however, one aspect commonly missing is more reflective and evidence-based description of the implementation process as technical and pedagogical innovations spread to a wide variety of institutions with different faculty, different students and different cultures.

The need for more systematic understanding has recently been emphasized at the national level. Funding agencies like the National Science Foundation (NSF) require a “broader impact” component in all grant proposals.<sup>7</sup> Transportability is specifically emphasized in the new Transforming Undergraduate Education, in Science, Technology, Engineering and Mathematics (TUES) Program, which requires transportability as a main component for funding of proposals.<sup>8</sup> In this paper, we investigate the transportability and initial diffusion of the AIChE Concept Warehouse.

### ***The AIChE Concept Warehouse***

#### ***Overview***

The AIChE Concept Warehouse, a cyber-enabled infrastructure for conceptual questions, was developed with the goal of creating a community of learning within the discipline of chemical engineering (ChE) focused on concept-based instruction. This tool can be used throughout the core ChE curriculum (Material and Energy Balances, Thermodynamics, Transport Phenomena, Kinetics and Reactor Design, and Materials Science). Currently the AIChE Concept Warehouse has more than 1,600 concept questions (ConcepTests) and 10 Concept Inventories available for searching, viewing, and using in courses through the user interfaces. Student and instructor interfaces are available for the community at <http://cw.edudiv.org>, and university faculty can obtain an account through this site. There are currently over 80 institutions and over 180 accounts registered with the AIChE Concept Warehouse.

A screen shot of the AIChE Concept Warehouse ConcepTest search page is shown in Figure 1. The overall objective of this tool is to lower the activation barrier for using conceptual instruction and assessment so that many more chemical engineering faculty incorporate concept-based learning into their classes. Concept-based instruction (e.g., ConcepTests, concept inventories) often depends on high quality concept questions. These questions can be time consuming and difficult to construct, posing one of the biggest barriers keeping faculty from implementing this type of pedagogy.<sup>9, 10</sup>

In order to maximize compatibility and minimize complexity, an effort was made to design the instructor interface to match with the current practices of new users, or potential adopters, to be familiar and user-friendly. One way of accomplishing this design objective was to predict and accommodate different ways users might leverage the AIChE Concept Warehouse. The next subsection presents the different predicted modes of use for potential adopters.

HOME
CONCEPTTESTS
CONCEPT INVENTORIES
INSTRUCTIONAL TOOLS
CLASSES
PROFILE
SUPPORT

ABOUT
SEARCH
MANAGE TESTS
STATISTICS
NEW QUESTION

Class : Design F2011

Classes

☐ Energy Balances  
☐ Fluid Dynamics  
☐ General Chemistry  
☐ Heat Transfer  
☐ Mass Transfer  
☐ Material Balances  
☐ Materials Science  
☐ Other  
☐ Reaction Engineering  
☒ Thermodynamics  
☐ Workshop

Misconceptions

Topics

Surface Features

My Questions

Unused (self)

Type

Suggestions

[Advanced Search](#)

Showing 1-50 of 688 results (in 0s)
Results per page: 50

☐ ID:1 Modified Throttling Valve

An **ideal gas** flows steadily through the piping system and valve shown below. The inlet pressure and temperature are  $P_1$  and  $T_1$ ...

Contributor: Bill Brooks  
Author: Ron Miller  
Type: Multiple Choice  
Rating: ★★★★★

Class: Energy Balances  
Thermodynamics

☐ ID:13 Thermite Reaction

Consider a completely insulated, closed system of fixed volume. The exothermic thermite reaction takes place in the system. What happens to the system's energy?

Contributor: Bill Brooks  
Author: John Falconer  
Type: Multiple Choice  
Rating: ★★★★★

Class: Energy Balances  
Thermodynamics

☐ ID:14 Exothermic Reaction in Adiabatic SS Flow Reactor

The exothermic reaction  $A \rightarrow B$  reaches an equilibrium conversion of 25% in an adiabatic steady state flow reactor. Which of the following will likely increase conversion?

Contributor: John Falconer  
Type: Multiple Choice  
Rating: ★★★★★

Class: Thermodynamics  
Reaction Engineering

**Figure 1.** Screenshot of the ConcepTest search page of the AIChE Concept Warehouse

### Modes of Use

There are four ways that the developers originally foresaw new users implementing the AIChE Concept Warehouse in their classes. These four modes of use are supported in the AIChE Concept Warehouse through Quick Start guides written as step-by-step instructions. In addition there are video walkthroughs for a subset of activities that users can engage in while using the AIChE Concept Warehouse. These guides are intended for new users to facilitate their initial use. In addition, faculty may actively contribute by adding their own questions to the database.

Table 1 gives a summary of these modes of use. At all levels of use, instructors can create a class as well as find and select a set of concept questions to create a ConcepTest.

1. *Offline* refers to not using the web based infrastructure which includes features such as housing aggregate and tabulated data provided by students. Examples of this include faculty downloading questions, either as a Microsoft Word document or PowerPoint

slides, used on a homework set, test, quiz, or in class with an external clicker system. This form of use does not expose students to the site. Even at the basic level of using offline, instructors already using peer instruction or active learning with concept questions need only make minor changes to current practices and the AICHe Concept Warehouse may save them preparation time.

2. *Online* refers to using the website infrastructure and features. A major benefit of this mode of use is the ability to view results from assignments, which are presented aggregated, tabulated, and archived for later use and are available for download in Microsoft Excel format. If an instructor wants to use more of the features available online, instead of downloading questions they can integrate the use of clickers or have students log in and answer ConcepTests and inventories on their laptops or smart phones (either in-class or for homework). If instructors solicit responses via laptops or smartphones, they can prompt short answer explanations and confidence follow-ups in addition to the multiple choice answers. Such written reflection is perceived by students as helpful.<sup>11</sup> These more involved features require students to interface with the website.

**Table 1.** Predicted modes of use of the AICHe Concept Warehouse and their description

Mode of Use		Description
<b>Offline</b>		Download questions via Microsoft Word or PowerPoint to use on homework, tests, or with external clicker systems
<b>Online*</b>	Homework	Used online outside of class through student interface as homework
	In-Class, with Laptops or Cell Phones	Used in class allowing short answer explanations and confidence follow-up
	In-Class, with Turning Point Clickers	Used in class with Turning Point clickers using the AICHe Concept Warehouse java applet

\* requires students to interface with the site

### ***Diffusion of Innovations***

In this paper we use *Diffusion of innovations*, a theory put forth by E.M. Rogers in his first book on the topic in 1962.<sup>1</sup> Diffusion of innovations has been used as a theoretical framework for decades and has accounted for more than 5,000 publications in the field. According to Rogers “diffusion is the process in which an innovation is communicated through certain channels over time among the members of a social system. (p. 5)”<sup>1</sup> Characteristics that contribute to the rate at which an innovation is adopted include relative advantage, compatibility, complexity, observability and triability, described in Table 2. The innovation-decision process used by an individual in consideration of adopting an innovation consists of five stages “(1) from first *knowledge* of an innovation, (2) to forming an *attitude* toward the innovation, (3) to a *decision* to adopt or reject, (4) to *implementation* of the new idea, and to (5) *confirmation* of this decision. (p. 990)”<sup>12</sup>

**Table 2.** Attributes of an innovation described by Rogers<sup>1</sup>

Attribute	Description
Relative advantage	“the degree to which an innovation is perceived as better than the idea it supersedes. (p. 229)”
Compatibility	“the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters. (p.240)”
Complexity	“the degree to which an innovation is perceived as relatively difficult to understand and use. (p. 257)”
Observability	“the degree to which the results of an innovation are visible to others. (p. 258)”
Triability	“the degree to which an innovation may be experimented with on a limited basis. (p. 257)”

Borrego et al. used diffusion of innovations as a framework to survey department chairs and investigate faculty awareness and adoption of a wide variety of research-based instructional strategies in engineering education.<sup>13</sup> They found three major types of factors that contribute to the decision to adopt innovations:<sup>13</sup>

- The most prevalent type of factor was resources (e.g., funding, computers, classroom and laboratory space, etc.).
- Faculty member related issues occurred as the second most common type of factor, and included: time for preparation, management of labor-intensive innovations, culture of the faculty members' environment, "resistance to change, marginalization of teaching in promotion and tenure, and skepticism regarding evidence of improved student learning. (p. 199)"<sup>13</sup>
- The third type of factor, student-related aspects, included advantages of innovations, such as improved student learning and improved student satisfaction and barriers such as student resistance.

In addition, they emphasize "the importance of disciplinary networks and opinion leaders who are similar to (i.e., practicing in the same discipline as) potential adopters. (p. 200)"<sup>13</sup>

Studies in other disciplines have findings that are likely applicable for engineering education. For example, Henderson et al. investigated the innovation-decision process of faculty considering research-based instructional strategies for introductory physics and, through a multi-variable analysis, illustrated the varying needs of faculty as they go through different stages of the innovation-decision process.<sup>14</sup> In particular, discontinuation was found to be where a large percent of faculty left the innovation-decision process, indicating that "more attention needs to be given to developing ways to support faculty to be successful in their implementations, (p. 11)"<sup>14</sup> particularly during initial implementation. Henderson et al. suggest that one reason faculty are likely to leave the innovation-decision process is that they are not made fully aware of potential issues.<sup>14</sup> In our case, likely issues include time required to learn how to use the tool,<sup>15</sup> student resistance,<sup>16</sup> and technical difficulties.<sup>17</sup> Similar to physics, Borrego et al. investigated the innovation-decision process in engineering education and highlighted word of mouth, workshops, and literature as the most common diffusion channel to raise awareness.<sup>18</sup> Diffusion of Innovations was also used to investigate the diffusion of the Engineering Education Coalitions' SUCCEED program.<sup>19</sup> In another engineering education context, Montfort et al. investigated the adoption of a Capstone Assessment Instrument through interviews finding that specific university context and perceptions greatly affected adoption decisions.<sup>20</sup> Similar to Montfort et al., in this study we investigate early adopters through qualitative interviews.

### **Theoretical Framework**

In this paper we use the framework of *Diffusion of innovations*. Through interviews we are specifically investigating the initial stages of the innovation-decision process. We use Rogers' attributes of an innovation and the stages of the innovation-decision process to frame the initial diffusion of the AIChE Concept Warehouse. Through this investigation we discuss methods we have used to promote knowledge of the innovation and their influence, as well as suggested methods by early adopters. In addition we developed a list of adopter and innovation attributes that likely contribute to attitude formation, initial decision to adopt this innovation, and continued use. We also identify barriers to adoption.

## **Methodology**

This investigation was a qualitative interview study. As such, it had a relatively small number of participants and flexibility in interview questions.<sup>21</sup> The purpose was to gather a lot of information from a small number of early adopters in order to gain an in-depth understanding of their experience with the AIChE Concept Warehouse and their path as they began and progressed through the initial stages of the innovation-decision process.

### ***Participants and Setting***

Ten faculty members were interviewed in this study. Seven of these participants had attended the 2012 ASEE Summer School Workshop, which was the first introduction for six of them. Three participants were beta testers that tested the website when it was in the early stages of development. One participant heard about it from a colleague but did not attend the Workshop and was not a beta tester. Participants in this preliminary investigation come from a wide range of institutions and teaching experience. Besides the individual users at institutions, there were also two clusters of users; two participants at one university team taught a course and two participants at a second university taught the same course sequence with one of them teaching the first course in the sequence and the other teaching the second course in the sequence. Institutions included public and private universities with several also being Flagship and Land-grant universities. Eight of the participants had the rank of assistant professor and had 7 or less years of teaching experience. One is an associate professor and one is a full professor. Most of the participants taught the same course with class sizes ranging from approximately 20 to approximately 240 students.

Participants were selected as follows. An initial list of 28 faculty members who were AIChE Concept Warehouse users was constructed. The initial list consisted of faculty with a variety of use patterns who were perceived to represent a wide range of the adoption categories described by Rogers. Factors that were taken into account when choosing this initial list included: number of log-ins and log-in date, number of downloads, use of AIChE Concept Warehouse online capabilities, and if they had written their own questions. An example of a perceived early adopter that had continued use was someone who showed a high log in count as well as multiple Microsoft PowerPoint or Word downloads. They also had a log in date and/or an online assignment within a week from the time the list was made, and/or created their own questions to use in the Warehouse. These characteristics indicated that the participant had returned to the AIChE Concept Warehouse on a regular basis and was interested in implementing different forms of ConcepTests. On the other side of the spectrum, a potential participant who had attended the 2012 ASEE Summer School Workshop, logged in at least once but not since the workshop, had minimal or no downloads and no online assignments was perceived to be in the category of someone who had knowledge of the tool but chose not to adopt it. While there appeared to be a variety of use patterns represented by the initial list of potential participants, the authors expected that categorization of use could only be completed post-interview.

Seventy-one percent of the initial list of potential participants had attended the 2012 ASEE Summer School Workshop in which the AIChE Concept Warehouse was introduced to new faculty. Potential participants who attended the ASEE Summer School Workshop were chosen for several reasons. First, they were given an introduction to the AIChE Concept Warehouse and

how to implement it in class. Also, because the ASEE Summer School was presented at least one month prior to typical university terms and semesters starting, it gave potential participants time to explore and integrate the Concept Warehouse into the upcoming term/semester. The remaining potential participants were identified belonged to at least one of the following groups: faculty members that were part of clusters of users within universities, faculty members that had already submitted signed informed consent forms, and faculty members that appeared to fit well into one of the adoption categories.

An email requesting participation was sent to each of the faculty members on the initial list. Ten of the 28 faculty members on the initial list responded and participated in this study.

### ***Data Sources, Collection, & Analysis***

The primary data source for this study was semi-structured interviews with participants, which provided information about the ways adopters of the AIChE Concept Warehouse perceived and implemented the tool. Three additional data sources included surveys completed by participants as part of an AIChE Concept Warehouse introductory workshop at ASEE Summer School, initial AIChE Concept Warehouse applications, and general usage data from the AIChE Concept Warehouse.

Semi-structured interviews were conducted using an initial list of questions as a guide. Interview questions were designed around Rogers' perceived attributes of an innovation, along with the five stages of the Innovation-Decision process. Groups of questions, roughly in the order asked, asked and how they relate to these two categories are shown in Table 3.

**Table 3.** Groups of interview questions and how they relate to Rogers' perceived attributes of innovation and stages of the innovation-decision process

<b>Perceived Attributes of Innovations</b>	<b>Stages of the Innovation-Decision Process</b>	<b>Example Questions</b>
Compatibility, Relative Advantage		Describe your teaching philosophy. What, if any, experiences influenced that? Describe your classroom.
Complexity	Knowledge, Persuasion	How did you hear about the AIChE Concept Warehouse? What do you remember about the CW from the ASEE Summer School workshop?
Complexity, Trialability	Persuasion	What aspects did you like or not like about the CW? Was it fairly accessible? Complicated?
	Decision, Implementation	Describe your experience with the CW. Walk me through your initial/typical use of the CW.
	Knowledge	How have you shared the CW with other faculty? Do you have any suggestions as to how to alert faculty of this tool?
	Confirmation	Do you plan to use/continue using the CW?

Questions devoted to teaching philosophy and the experiences that influenced that philosophy were asked to gain a better understanding of the culture and background of each interview participant. These questions would help determine if the Concept Warehouse was an innovation that the participant would value and how compatible it was with their current practices.



Logistical questions such as participant's classroom environment, class size, and available resources were also asked to help determine the compatibility of incorporating the AICHE Concept Warehouse into the established curricula. Participants were also asked what aspects they liked or did not like about the CW, if they found it fairly accessible or complicated, as well as what could be done to make use easier. These questions targeted how complex participants perceived the CW to be and what areas needed improvement to mitigate those complexities.

A subset of the questions was asked explicitly of all participants. Some questions were not asked if they were addressed as part of the answer to another question. Interviews were conducted by two graduate student researchers. Participants were informed that the interview would take no more than one hour of their time and interviews averaged approximately 50 minutes. At the beginning of the interview, participants were told what the purpose of the interview was and that they should feel comfortable giving any comments or criticism. All interviews were audio recorded and transcribed. Based on their self-described usage pattern, participants were grouped according to the Diffusion of Innovations adoption categories described earlier. An emergent thematic coding process was performed on all transcripts.

We used participants' surveys completed after attendance of an introductory workshop for additional information about their innovation-decision path and initial applications for the AICHE Concept Warehouse to provide a richer description of the participants' initial perception of the tool and to inform ways to increase awareness of the tool. General usage data was used for identifying potential participants and included the following information: number of logins to the website, number questions downloaded from the website, and whether users had added and/or assigned questions through the website. In addition, the total number of AICHE Concept Warehouse accounts over time was used to compare the effectiveness of different distribution channels for making faculty aware of the tool.

## **Results & Discussion**

Nine of the ten participants had used the AICHE Concept Warehouse in at least one of their classes. The remaining participant did not have the opportunity to teach the term following introduction but indicated the intent to use the tool.

It was too early in the decision process to really conclude that participants were past the confirmation stage. Many had recognized the benefits of using the AICHE Concept Warehouse and had promoted it to fellow faculty, but had not had the chance to fully integrate it and make it a part of their "ongoing routine." However, participants were asked (or had expressed themselves) if they planned on continuing to use the Concept Warehouse. This question addressed the "continued adoption" portion of the confirmation stage. All participants indicated that they were going to use or continue using the AICHE Concept Warehouse in future classes.

### ***Research Question 1: Why do early adopters choose to implement the AICHE Concept Warehouse and how do they use the tool?***

#### ***Why Early Adopters Chose to Implement the AICHE Concept Warehouse***

We asked participants about their teaching philosophy, how they heard about the AICHE Concept Warehouse and their motivation for learning about the tool. In some cases their reasoning for initially implementing the Concept Warehouse was stated clearly. For example, one participant

described her/his search for something different, for something that would actively engage her/his students, expressed in the following statement.

“I’ve traditionally...always lectured...sort of PowerPoint and chalkboard, sort of talking to the students. For [this] class, um, I kind of felt like I didn’t want to do that, I didn’t want...them to just be sitting back and listening to me talk”

S/he went on to describe the benefit of attending the ASEE Summer School, and specifically her/his familiarity with and motivation to use the Concept Warehouse, “I was aware of it before and kind of played around with it, but uh really tried to use it a little more this semester.” Some participants simply described the Concept Warehouse as something that “seemed like a great idea.” In other cases, participants cited previous experience with pedagogy as a contributing factor to their implantation of the Concept Warehouse, such as the following statement from one participant, “I was already familiar with the ConcepTests and maybe that might have been a part of it.”

Two participants explicitly expressed that class size was a factor to implementation. One of these participants voiced:

“I just found that, especially most rooms I teach in, for a class set size, there's no way for me to engage those students in those kinds of activities. But with...[the] concept warehouse, or clickers or laptops, then you know, they can be held accountable for actually entering an answer.”

Later on in the interview, s/he continued by giving an example of a colleague,

“So then other people I think come to it, like...for example, [s/he] has 60 students in her class, and she's like, how am I going to, I need some other way to manage it. So it's probably, I mean everyone's got their own motivation for why they would take something like this on.”

Another participant expressed their current implementation strategy would be able to scale up to a larger class size.

In other cases, reasoning was less explicit. However, several themes are likely related to the participants’ motivation to use the Concept Warehouse. All participants expressed an interest in active learning pedagogies. Many of them came from schools and departments that fostered a culture of active learning. In addition, all but one of the participants discussed their seemingly comfortable use of technology both inside and outside of the classroom. One participant was self-described as “more of a paper and pencil person.” This individual was at an institution where another more technically savvy colleague was also using the tool, and acknowledged “If [s/he] had not been available I would not have used it.”

### *How They Use It*

Early adopters, participants who had used the AICHE Concept Warehouse in class, were asked to describe their experience implementing the tool. This was done in order to gain a better

understanding of which delivery features of the Concept Warehouse were being used. This would provide information on what support materials would be needed but more importantly allow developers an insight into the diverse cultures and teaching practices being used by faculty from various types of institutions.

There were variations in how early adopters prepared for implementation. The preparation of each adopter may have influenced how they chose to use it, the barriers they encountered and ultimately how it fit into their current practices. One adopter “spent a couple of marathon nights...generating a giant pool of everything...that would be relevant to turning those into slides and then putting them with the right lecture later.” Others would write or search for questions 10-15 minutes before class started. These variations address relative advantage and compatibility of the tool.

Interviews revealed there are a variety of ways that faculty are using the AICHe Concept Warehouse outside the four modes previously shown in Table 1. Table 4 presents a summary of the modes of use implemented by the early adopters.

**Table 4.** Summary of the different modes of implementation used by participants

Mode of Use	Description	# of Adopters
Offline	In class quizzes, assignments and/or exam questions	2
	Microsoft PowerPoint with clickers and cellphones	1
	Screen capture of questions incorporated into Microsoft PowerPoint with clickers	1
Online	In class with laptops, cellphones and clickers	3
	In class with laptops, cellphones and clickers with short answer written explanations	2

Five of the early adopters used the online features of AICHe Concept Warehouse in class with the remainder using it offline in different ways. The implementation mode that required the least infrastructure was a simple pencil and paper method. One adopter described her/his use with the following statement: “I am using this as little in-class exercises. On paper and pencil...so that is how I am using it. I am not projecting it as a PowerPoint on the board. Each student gets their own piece of paper with the problem on it.” In another adopter’s unexpected example of offline use, s/he took screen shots of the questions and incorporated the screen shots into her/his lecture Microsoft PowerPoint slides in order to have them “be more consistent with the...rest of the style of the presentation” and administered them with i>clickers. This type of use was not captured in the usage data nor was it well supported; however, it has inspired the development of a screen capture image button that will create a higher quality image. Clickers were used both online (Turning Point Technology clickers) and offline (i>clickers). One online adopter used the “display results” feature and described her/his implementation as follows:

“I would go to class and then, what I’d try to do is lecture past that point, where I felt like I had explained something and my hope is that, okay now everyone is going to get it right, and then ask a question, a conceptual question, that maybe is phrased a little bit differently or might...even be perceived as being a little bit

tricky, but if you understood the concept, it should be something you could get...and then challenge the students to answer it, and after a couple of minutes stopping it, showing the results, which were sometimes surprising for me as it was for the students...just that there was a question I thought everyone would get right and it would be 50/50, half the class would get it right, half the class would get it wrong... so then, we would use that as kind of a discussion point.”

This example portrays how using a feature only available online gave the adopter the immediate opportunity to refocus her/his lecture and learning environment. This adopter also found a way to incorporate the tool to serve other needs by using the Concept Warehouse to administer surveys in order to get immediate feedback from students, which was not foreseen by developers.

Placement and number of ConcepTests differed between adopters. One adopter used it at the very beginning of class as a quiz for the reading that was associated for that day in an effort to get students to read the textbook. Another adopter used ConcepTests throughout the class period and had a bank of questions available for use at the end of class time permitting. Others had entire recitations dedicated to ConcepTests. Two adopters stated they used the Concept Warehouse more heavily towards the beginning of the term/semester and less as the term/semester went on due to time and/or difficulty of material. The amount of ConcepTests used per day ranged from one to eight.

Many of the adopters wrote their own questions and expressed interest in sharing them with other faculty. This interest aligns with the goal of the AIChE Concept Warehouse of creating a community of learning.

***Research Question 2: What factors contribute to the innovation-decision process and how can we minimize negative factors?***

Through emergent coding of the interviews, many factors stood out as clear themes that spanned participants. As previously mentioned, most participants cited word of mouth as the perceived most effective way to raise awareness of the tool. Most participants perceived use of the tool and the conceptual questions from it to be beneficial to their courses, illustrated by the following themes and representative quotes:

- Made teaching easier – “just having these around made it so I didn’t worry as much about, the timing of the material”
- Improve student engagement learning – “In general I think this is a new approach to help students to learn... I think that it works. It makes students engage in the course.”

All participants noted positive design features of the AIChE Concept Warehouse website which afforded flexibility in implementation and use. Some participants suggested ways in which the user interface could be improved to be more familiar and user-friendly. Participants also noted the quality of questions as an important factor in their decision to use the tool. Some cited it as better than other resources they had previously used, while a couple noted hesitation and need to carefully evaluate questions to avoid “tricky” questions. In addition, participants appreciated the large bank of questions for most classes. However, the quantity of questions combined with the lack of filtering options for a subset of courses represented a major barrier. For example, one participant expressed frustration with the time it took to find the right questions in the large

number of results “I would say most of the time I would spend searching it. It would seem like sometimes, like probably with anything, if you have a good key word that is helpful, but sometimes, you know. Like vapor liquid equilibrium will get you 150 questions that are related.”

Most participants also noted that there were not questions available for Process Control, Engineering Economics and some special electives courses. This was a barrier for their colleagues that taught those courses. One participant noted in reference to Process Control, “We have a new professor teaching that, uh, for one of the first or second times now and [s/he]’d be interested in using it, but that seems to be one of those classes that no one has a lot of information for.”

Along with the lack of filtering options and the overwhelming number of questions, participants experienced a variety of technical difficulties both with the AIChE Concept Warehouse and with technological infrastructure at the university. These technical difficulties related to the following aspects: browser compatibility, downloading issues, wireless capacity issues, question management, and browser caching issues.

Despite the barriers noted, the beta testers noticed improvement with time, with statements such as “I have this impression that it keeps improving as it goes on.”

In order to minimize the negative factors, we are currently developing filtering categories for the classes that do not currently have topic sorting options. In addition, we are always trying to increase the number of questions available for courses such as Process Control, Separations, and Engineering Economics. We encourage any faculty who would like to contribute to contact the corresponding author.

### ***Research Question 3: What ways can we increase awareness?***

Awareness, or knowledge, of an innovation is a key component to transportability and adoption. Developers of the AIChE Concept Warehouse have used different communication channels to alert faculty of this tool including conferences, emails, workshops, and by word of mouth. Participants were asked about the communication channel(s) in which they were made aware of the AIChE Concept Warehouse as well as what they thought would be the best and worst ways to inform other faculty.

#### ***Channels Used by AIChE Concept Warehouse Developers***

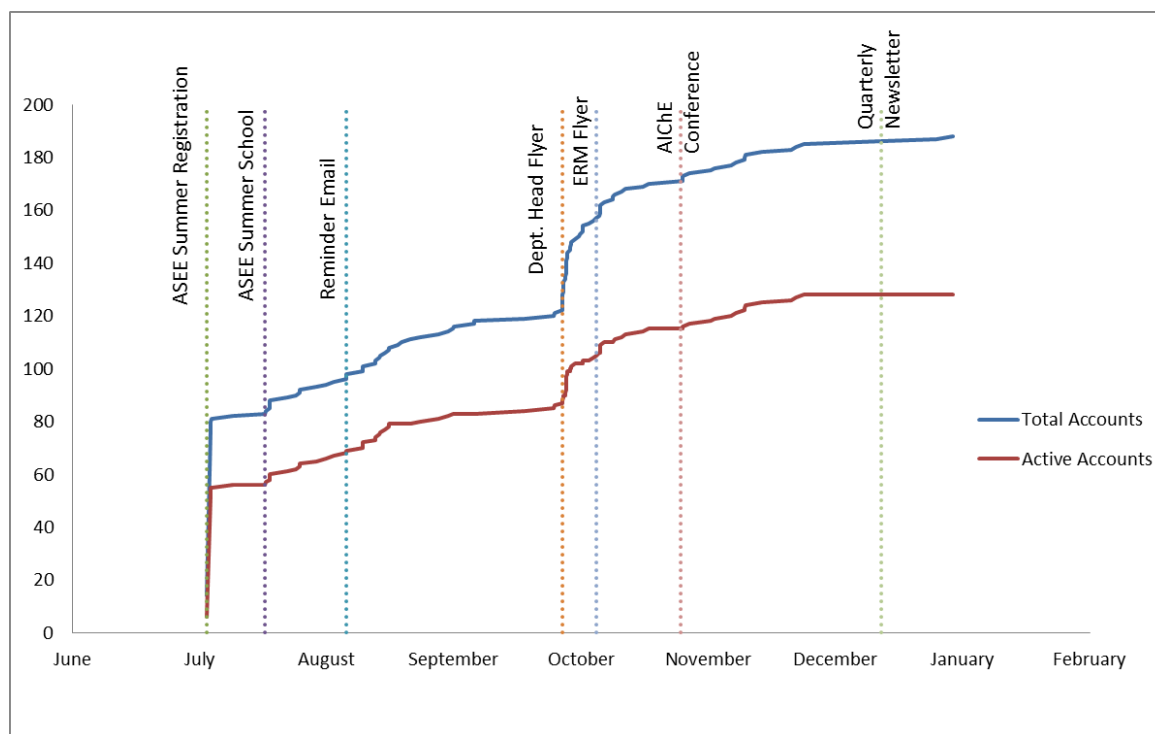
Beta testers were made aware of the AIChE Concept Warehouse through conferences and word of mouth approximately one year before the 2012 ASEE Summer School Workshop. Roughly one month after the Workshop, an email was sent reminding attendees of the support features available for the Concept Warehouse. A series of flyers were sent to chemical engineering department heads and the Educational Research and Methods (ERM) Division of ASEE two months later. One month following a presentation was given at the 2012 AIChE National Conference and a quarterly newsletter was sent to users of the Concept Warehouse towards the end of the term/semester in hopes of making faculty aware of the tool before the start of the next term/semester. Table 5 is a summary of the number of accounts created after each of these different communication events occurred.

**Table 5.** Number of accounts added after each awareness instance

	Communication Channel	# of Accounts Added	% of Total
Beta Testers	Interpersonal, Presentation	13	7%
ASEE Summer School	Workshop	82	44%
Workshop Reminder	Email	26	14%
Department Head Flyer	Email	35	19%
ERM Flyer	Email	14	7%
AIChE Conference	Presentation	15	8%
Quarterly Newsletter	Email	3	2%
	TOTAL	188	

There is a large increase in the number of accounts created after the ASEE Summer School Workshop. The AIChE Concept Warehouse was made publicly available during the Workshop and pre-registered Workshop attendees were automatically issued accounts. One participant expressed that the Workshop gave her/him confidence to make a technological modification in her/his teaching.

The reminder email and the quarterly newsletter reached current users and pre-registered workshop attendees. The chemical engineering department head email and an email to the ERM mailing list contained a promotional flyer and reached new potential adopters. Figure 2 presents the increase in user accounts, with lines marking each of these communication instances. The greatest increase in accounts came after the ASEE Summer School Workshop held in July 2012.



**Figure 2.** Plot of total and active accounts created since the 2012 ASEE Summer School Registration

A chi squared test was used to compare logins per active user (an active user was defined as someone who logged in more than five times) between the group of users that signed up during the 2012 ASEE Summer School Workshop and those who had signed up as a result of an email. The Workshop group had a statistically significant higher logins per active user than the email group ( $p=0.044$ ). This result suggests that while emails may be effective in creating awareness, more extensive engagement through the workshop better promotes use. However, in interpreting this result the following factors should be kept in mind: the Workshop group had approximately 2 months more time than the email users to login, and the Workshop group also was introduced to the AIChE Concept Warehouse before the start of a term/semester while the email users were informed during the term/semester. In addition, as was discovered from the interviews, the number of logins does not directly correlate with the level of use, as one user logged in for two “marathon sessions” (not active by our definition).

#### *Suggested Best and Worst Ways to Inform Faculty*

The communication channel that most participants voiced was a good way to inform other faculty of this new tool was by word of mouth, or as one participant suggested, “find advocates at particular schools...” Comparable to this would be finding opinion leaders at a wide variety of universities. Suggestions included campus visits and more workshops. Two participants suggested contacting the university technology support offices or centers for teaching and learning.

There were several participants who discouraged using email as a way to inform other faculty about the AIChE Concept Warehouse. One participant said “When I get emails, one that I am not expecting... I just hit ‘read’ and delete it. Um, so, maybe 5-10% of those get through if you broadcast it.” Another stated, “... I just get so many emails that I ignore most of them,... you know, that don’t need an immediate response and that’s the only danger I think you run with sending out flyers or sending out emails is there will be a lot of people that just never read it.”

One participant acknowledged discipline-specific journals like *Chemical Engineering Education* and *Chemical Engineering Progress* as possible channels to use to alert faculty. However, another participant suggested not relying on *Chemical Engineering Education* because it would only reach faculty who are already like know about the tool.

#### **Conclusions & Implications**

This preliminary investigation suggests that workshops are an effective method to both raise awareness for an innovations such as the AIChE Concept Warehouse, as well as promote adoption of it. Like many other studies, word of mouth was perceived to be the most effective communication channel by participants. Email was perceived to be ineffective for promoting awareness and adoption; however, the email communication associated with the AIChE Concept Warehouse appeared to be reasonably effective for increasing awareness.

Early adopters of the Concept Warehouse were found to use the tool in a variety of ways, which was afforded by several noted design features. Early adopters, while appreciating the quantity and quality of questions for most classes, sometimes found it frustrating to narrow their question set to a smaller, more manageable group. This barrier will be minimized with ongoing

development, including additional filtering options for existing courses. Finally, we hope to develop sets of ConcepTests for Process Control, Separations, and Engineering Economics.

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