AC 2012-4310: PRELIMINARY DEVELOPMENT OF THE AICHE CONCEPT WAREHOUSE

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Milo Koretsky is a professor of chemical engineering at Oregon State University. He currently has research activity in areas related to thin film materials processing and engineering education. He is interested in integrating technology into effective educational practices and in promoting the use of higher level cognitive skills in engineering problem solving. Koretsky is a six-time Intel Faculty Fellow and has won awards for his work in engineering education at the university and national levels.
Preliminary Development of the AIChE Concept Warehouse

Introduction

The AIChE Concept Warehouse is being developed with the goal of creating a community of learning within the discipline of chemical engineering (ChE) focused on concept-based instruction. Many engineering educators and industry partners emphasize the need for students to apply their knowledge to new and challenging problems.\(^1\) In order to do so, our students must learn with understanding.\(^2\) 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.\(^3\) However, science and engineering classrooms often reward students more for rote learning than for conceptual understanding.\(^4, 5\) There is clearly a need for more emphasis on conceptual understanding and concept-based instruction.

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.\(^6, 7\) The AIChE Concept Warehouse decreases this barrier by housing questions pertinent to courses throughout the core chemical engineering (ChE) curriculum (Material and Energy Balances, Thermodynamics, Transport Phenomena, Kinetics and Reactor Design, Process Control, and Materials Science). This cyber-enabled infrastructure is maintained through the Education Division of the American Institute of Chemical Engineers (AIChE), the discipline’s major professional society. With careful and intentioned design to promote widespread use, this tool has the potential to catalyze the use of concept-based pedagogy throughout the chemical engineering education community. In this paper we present a description of the current status and available features, which should prove useful for educators who are interested in incorporating concept-based instruction into their courses. Similarly, a description of the design and development process is included to provide potential designers with a useful reference to inform future design processes. In addition, we report on initial deployment, community building activities, and future plans for the AIChE Concept Warehouse.

Concept-based Pedagogy

Concept-based pedagogies have been studied in the physics education research community for decades and provide a model that engineering education researchers have been adopting. Two concept-based pedagogical tools have dramatically reshaped how conceptual teaching and learning are viewed in college physics classrooms: ConcepTests\(^8\) and concept inventories.\(^3\) Both of these tools require high quality concept questions in order to be effective. High quality concept questions are typically multiple choice, conceptually challenging, and require little to no calculation so students cannot rely on equations to reach an answer. In the following, we provide a brief description of ConcepTests and concept inventories. In addition, we discuss a framework, Diffusion Theory, used to inform development and promote widespread adoption.

ConcepTests & Active Learning

In his book Peer Instruction, Mazur describes the use of ConcepTests to engage students in conceptual learning during lecture.\(^8\) ConcepTests consist of one or a small number of concept questions. ConcepTests can be used with peer instruction in class. The process includes...
structured questioning in which all students respond independently. Students then discuss their answers in small groups and respond again individually. Peer instruction encourages students to reflect on conceptual problems, think through the arguments being developed, and put them into their own words. It also provides both student and instructor with feedback regarding student understanding of the concept being tested.

Studies of more than 5,000 science and engineering students have found that classes using active learning methods such as peer instruction had double the conceptual learning gains\(^9\) and 25\% higher pass rate\(^10\) than traditional lecture. Deslauriers et al. compared the performance of two sections of students studying electromagnetic waves; the section taught by an inexperienced postdoctoral fellow using active learning techniques outperformed, by 2.5 standard deviations, the section taught by an experienced professor with a record of high evaluations.\(^11\) The use of ConcepTests and peer instruction has recently been reported in chemical engineering, with similar positive results.\(^{12-14}\)

**Concept Inventories**

While ConcepTests are used to facilitate active learning, concept inventories are one tool used to evaluate and demonstrate the effectiveness of active learning. The first concept inventory, the Force Concept Inventory (FCI),\(^3,15\) provided a reliable and valid instrument to measure students’ fundamental conceptual understanding of Newtonian mechanics. Concept inventories are valid and reliable instruments that consist of high quality concept questions. Validity is a measure of how well a concept inventory measures the intended concepts, as evaluated by experts, student observations, or other means within a single population of students or a variety of populations.\(^16\) Reliability is a measure of the degree to which repeated administrations of a concept inventory produce the same results.\(^16\) Concept inventories are used as an objective pre/post measure of an intervention and have been used to inform instruction by identifying student misconceptions. Since development of the FCI, concept inventories have been created in a variety of engineering subjects, including statics,\(^17\) dynamics,\(^18\) and fluid mechanics\(^19\) among others.

A set of concept inventories pertinent to chemical engineering have also been developed. One of these, the Thermal and Transport Concept Inventory (TTCI),\(^20,21\) covers concepts in heat transfer, fluid mechanics, and thermodynamics. Research used to develop the TTCI also informed the construction of the Heat and Energy Concept Inventory,\(^22\) which was used to show the effectiveness of inquiry-based activities on repairing misconceptions in heat transfer and thermodynamics.\(^23\) The Materials Concept Inventory has been used to assess conceptual gains in introductory materials engineering courses.\(^24\) Other concept inventories in chemical engineering that have been used to assess student learning include, the Engineering Thermodynamics Concept Inventory,\(^25\) and the Material and Energy Balances Concept Inventory.\(^26\)

**Design for Diffusion**

Although significant effort has been made in engineering education research to identify best practices in teaching, such as the cases discussed above, widespread adoption of best practices can be met with resistance and is often slow.\(^27\) For widespread use, a bridge needs to be formed between innovation and general practice. The intent of the *AIChE Concept Warehouse* is to provide such a bridge between chemical engineering researchers developing concept inventories and ConcepTests and chemical engineering educational practitioners in the classroom.
Diffusion theory provides a useful framework to inform the development process and identify the design elements that will better enable widespread adoption. Diffusion, defined by Rogers, is “the process in which an innovation is communicated through certain channels over time among the members of a social system.” Diffusion theory classifies the perceived attributes of an innovation that most impact the rate at which it is adopted. These attributes, described in Table 1, are being attended to both in initial design and throughout development.

**The AIChe Concept Warehouse – January 2012 Status**

Currently, the AIChe Concept Warehouse has more than 1,200 concept questions available for searching, viewing, and using in courses through the user interfaces. Student and instructor interfaces are available at [http://cw.edudiv.org](http://cw.edudiv.org) for the community, and university faculty can obtain an account through this site. A third interface, for administration purposes, includes moderator and testing functions such as adding news bulletins, organizational information, and debugging. The administrator interface will not be described in detail in this paper.

**Adding Questions & Concept Inventories**

One relative advantage of the AIChe Concept Warehouse is the availability of quality concept questions for core chemical engineering courses. A substantial effort has been made to populate the database with questions during the initial development period. Figure 1 shows the total number of questions available in the first year of development.

Questions have been incorporated from the authors’ personal lists, ConcepTest PowerPoint files from [www.learncheme.com](http://www.learncheme.com), and Materials Science PowerPoint files provided by Stephen Krause (ASU). Complete concept inventories are also available including each of three portions of the Thermal and Transport Concept Inventory (fluids, thermodynamics, and heat transfer), the Heat and Energy Concept Inventory, and the Materials Concept Inventory. These questions and concept inventories are accessible via the user-friendly interfaces that have been developed.

### Table 1. Attributes of an innovation described by Rogers

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative advantage</td>
<td>“the degree to which an innovation is perceived as better than the idea it supersedes.” (p229)</td>
</tr>
<tr>
<td>Compatibility</td>
<td>“the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters.” (p240)</td>
</tr>
<tr>
<td>Complexity</td>
<td>“the degree to which an innovation is perceived as relatively difficult to understand and use.” (p257)</td>
</tr>
<tr>
<td>Observability</td>
<td>“the degree to which the results of an innovation are visible to others.” (p258)</td>
</tr>
<tr>
<td>Triability</td>
<td>“the degree to which an innovation may be experimented with on a limited basis.” (p257)</td>
</tr>
</tbody>
</table>

**Figure 1.** Number of questions added to the AIChe Concept Warehouse during the initial development period.
**Instructor Interface**

The instructor interface is organized into seven main sections, accessible by their corresponding tabs: Home, ConcepTests, Concept Inventories, Classes, Profile, Review, and Resources. Table 2 provides a description of the functions available to instructors in the *AIChE Concept Warehouse*, organized by submenu sections within each tab.

<table>
<thead>
<tr>
<th>Tab</th>
<th>Submenu Sections</th>
<th>Description of Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home</td>
<td></td>
<td>View a brief summary of the latest changes, including: highlights of <em>AIChE Concept Warehouse</em> news, added questions, new tutorials and comments about submitted questions.</td>
</tr>
<tr>
<td>ConcepTests</td>
<td>Search</td>
<td>View, filter, and search for questions. Then, select question(s) for use in class.</td>
</tr>
<tr>
<td></td>
<td>Manage Tests</td>
<td>Organize, group, download (MS Power Point, MS Word), or assign (via projection in-class or sent to student laptops or smartphones) ConcepTests. Confidence and short answer explanation prompts can be added to questions during assignment.</td>
</tr>
<tr>
<td></td>
<td>Statistics</td>
<td>View information after questions have been answered, including all or a subset of options: question title and text, question images, percent correct, answer choice distribution, average confidence, number of students answered, and pedagogy recommendation.</td>
</tr>
<tr>
<td></td>
<td>New Question</td>
<td>Add new questions. Question information can include: question title, question and answer images, answer options, comments for faculty, and applicable research data. Question types include: multiple choice – single right answer or multiple right answer, short answer, and ranking. Questions can also be tagged by class, misconception, topic, and textbook.</td>
</tr>
<tr>
<td>Concept Inventories</td>
<td>Browse</td>
<td>View available concept inventories and select for use in class. Additional concept inventory information is available for viewing, such as: research data, development history, list of individual questions and an answer key.</td>
</tr>
<tr>
<td></td>
<td>Manage Inventories</td>
<td>Assign concept inventories (via projection in-class or sent to student laptops or smartphones), either in complete form or subsections. Confidence and short answer explanation prompts can be added to questions during assignment.</td>
</tr>
<tr>
<td></td>
<td>Statistics</td>
<td>View information after concept inventory questions have been answered, including all or a subset of options: question name, question text, question image, percent correct, answer distribution, average confidence, and number of students answered.</td>
</tr>
<tr>
<td>Classes</td>
<td>Class List</td>
<td>Create and delete personal classes and associate personal classes with general classes.</td>
</tr>
<tr>
<td></td>
<td>Manage Class</td>
<td>Manage the class roster and grade sheet. Add students to or remove them from the class roster. View and download the grade sheet, which includes student responses to questions (correct/incorrect, written responses, written explanations, confidence)</td>
</tr>
<tr>
<td>Profile</td>
<td>Preferences</td>
<td>Set personal preferences such as: show or hide tooltips, show or hide answer option comments, and show or hide the correct answer indicator in question previews.</td>
</tr>
<tr>
<td></td>
<td>Demographic Information</td>
<td>Report institution, schedule type, approximate first year teaching, and approximate first year using active learning.</td>
</tr>
<tr>
<td></td>
<td>My Clicker</td>
<td>Select clicker type, download clicker integration application, and register clicker receiver.</td>
</tr>
<tr>
<td></td>
<td>User Agreement</td>
<td>Displays the end user license agreement (EULA). Accepting the EULA is a required prerequisite to use of the <em>AIChE Concept Warehouse</em> and is displayed upon initial log-in.</td>
</tr>
<tr>
<td>Review</td>
<td>Under development</td>
<td></td>
</tr>
<tr>
<td>Resources</td>
<td>Intro to Pedagogy</td>
<td>View a collection of journal articles and videos to facilitate the integration of concept-based pedagogy into their classes.</td>
</tr>
<tr>
<td></td>
<td>Tutorials</td>
<td>Watch videos to help instructors use the <em>AIChE Concept Warehouse</em>.</td>
</tr>
<tr>
<td></td>
<td>FAQ</td>
<td>Find videos to help instructors use the <em>AIChE Concept Warehouse</em>.</td>
</tr>
<tr>
<td></td>
<td>Chat Forum</td>
<td>Interact with other community members through a bulletin board.</td>
</tr>
<tr>
<td></td>
<td>Helpful Links</td>
<td>Links to external resources on concept-based pedagogy, and active learning.</td>
</tr>
<tr>
<td></td>
<td>News Archive</td>
<td>View the full history of the news about the <em>AIChE Concept Warehouse</em>.</td>
</tr>
</tbody>
</table>
In order to maximize compatibility and minimize complexity, an effort was made to design the instructor interface to match with the current practices of potential adopters, 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 remainder of this section presents a few potential scenarios of how an instructor might engage, how they fit into the community, and the features that enable them.

If an instructor would like to participate at a basic level they can simply find and select a set of concept questions to download (via MS Word or PowerPoint). They will have access to easily search through the concept questions currently available, and can use these questions on homework, on tests, or with external clicker systems as they please. In this way, instructors already using peer instruction or active learning with concept questions need only minor changes to current practices and the *AIChe Concept Warehouse* may even save them valuable preparation time. They also need not expose their students to the site or be involved farther themselves.

If an instructor wants to use more of the features available, 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 smartphones (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. These more involved features require students to interface with the site; the student interface is described in the next section.

For faculty, the results from assignments are aggregated, tabulated and archived for later use. They are also downloadable in MS Excel format. Finally, for the engineering education research community, usage data can be used to inform ConcepTest and concept inventory development. For example, data from student selections could be used for item testing, a critical step in concept inventory development. This synergy will allow the question pool for use in concept inventories to greatly expand.

In addition, instructors may actively contribute by adding their own questions to the database. They can create multiple choice, multiple correct multiple choice, ranking, and short answer questions. These questions can then be associated with classes, the misconceptions they are testing, textbooks, and topics. Comments can also be left for instructors when they are searching for or deciding on using questions. These comments can include information about the correct answer, a distractor, or the use of the question.

**Student Interface**

Having only three tabs, the student interface is much simpler than the instructor interface. The tabs, submenu sections, and function descriptions are presented in Table 3. The questions tab, shown in Figure 2, shows the highest priority concept-based assignment for a selected class. It is in the questions tab that students can answer questions from in-class activities or homework assignments. Also depicted in Figure 2, is the student view of three question components: a multiple choice question, a short answer follow-up, and a confidence follow-up. A sample (incorrect) student answer is also shown.
Table 3. Summary of AIChE Concept Warehouse Student functions organized by tab and sub menu sections

<table>
<thead>
<tr>
<th>Tab</th>
<th>Submenu Sections</th>
<th>Description of Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home</td>
<td></td>
<td>Alerts students to the number of concept-based assignments with unanswered questions, categorized by class.</td>
</tr>
<tr>
<td>Questions</td>
<td></td>
<td>View the highest priority concept-based assignment for a selected class. Students can answer questions from in-class activities or homework assignments.</td>
</tr>
<tr>
<td>Profile</td>
<td>Demographics</td>
<td>Report voluntary demographic information (e.g., birth year, first year at the university, gender, race, and major).</td>
</tr>
<tr>
<td></td>
<td>Informed consent</td>
<td>Students can allow or deny the use of their response data for research purposes.</td>
</tr>
<tr>
<td></td>
<td>Clicker registration</td>
<td>Aligns clicker responses with the student’s account.</td>
</tr>
</tbody>
</table>

Figure 2. Screenshot of a student’s answer from the questions tab from the student interface
To obtain an account, students provide their email address and click the “log in” button, while leaving the password field empty. A link is then emailed to the provided email address that allows students to create a password. The same process is used to reset forgotten passwords. Student email addresses and passwords are encrypted; therefore password reminders cannot be sent. After an account is setup, students can log in for the first time and are greeted with a prompt to provide voluntary user information and an opportunity to provide informed consent to allow their anonymized responses to be incorporated into aggregate usage information for research purposes, as shown in the profile tab in Table 3.

Technology use in the classroom, in the form of laptops, tablet PCs, and clickers has been well documented. The use of internet-capable cell phones is also emerging as a learning tool, seen in a recent study on active learning and as evidenced by audience response system companies releasing cell phone applications as an alternative to purchasing separate hardware. The student interface was designed with these considerations in mind and is enabled by the software structure detailed in the next section.

**The AICHE Concept Warehouse – Design & Development**

**Software Structure**

The AICHE Concept Warehouse software structure is based on a synergy between a web-based user interface (programmed using PHP 5.3) and a commercial database (MySQL 5.1). Advantages of this combination are presented in Figure 3. The AICHE Concept Warehouse is being developed on both Windows and Linux platforms to accommodate developer preferences, institutional constraints, and provide ease of portability. Instructor and student usernames and passwords, along with any links between student and instructor accounts are all encrypted.

**Advantages of web-based user interface**

- Can be used in Windows, Linux, Macintosh, and even a smartphone, with the incorporation of browser specific accommodations

**Combined advantages: Internet accessibility with centralized management**

- Updates can be implemented without requiring user action
- Accumulation and fast processing of data (both usage data and educational research data)
- Versions of questions can be tracked, commented on, changed, and iterated upon easily
- Facilitation of question data tagging which enables a variety of analysis perspectives
- Easy and fast searching because the commercial software is already optimized for speed

**Advantages of commercial database**

- Portability both within MySQL and between database software and amenability to future technical support

![Figure 3. Advantages of a web-based user interface and a commercial database](https://example.com/figure3)

*O'Reilly, **Bulger et al.
Development of the *AIChE Concept Warehouse* software structure leverages the development experience of two of the authors on another education-focused tool. This previously developed tool, the Web-based Interactive Science and Engineering (WISE) Learning Tool, also has a web-based user interface and is database driven. Other similarities include a concept question focus, the facilitation of active, concept-based pedagogies and efficient data collection. While there are some similarities, there are other key differences. The WISE Learning Tool was designed for individual instructors to manage and deliver questions to their own classes and track research data for their classes alone. With the WISE Learning Tool, the questions lacked the capability to be easily shared between instructors. In the *AIChE Concept Warehouse* instructors can still manage their own questions and classes; however, they can also share their questions with the community and search through and use any of questions others have added. Some research data in the *AIChE Concept Warehouse* is also automatically aggregated. Greater care has also been taken to make the user interface of the *AIChE Concept Warehouse* as simple as possible while offering necessary and useful features, to make it more compatible with the current practices of potential adopters.

**User Interface Design & Development**

While an underlying structure was being developed, design of the user interfaces was also underway. Initially the design team generated a list of functions that needed to be incorporated into the *AIChE Concept Warehouse*. Separate function lists were generated for each interface. Next, each function list was categorized and grouped into website sections. A similar design process is used for each section, which includes the following steps:

1. Developing a function list to be incorporated into the page
2. Creating a storyboard of a page that includes the listed section functions
3. Implementing the storyboard concept in a live webpage,
4. Design team testing of live webpages and modification to enhance functionality and usability.
5. External testing of live webpages and modification to enhance functionality and usability.

To illustrate the design process, we provide a detailed description of the evolution of the *question search* section starting from the function list and progressing to the latest version.

The initial function list for the question search section was comprised of three simple functions: (i) find questions, (ii) view a list of questions, and (iii) select questions for use. A storyboard was created in Microsoft PowerPoint which was intended to be familiar to a typical user and incorporate the ability to carry out the specified functions through various user input options (e.g., buttons, links, checkboxes, text input fields). In some cases, storyboards also incorporated features and functions that weren’t originally included in the function list.

The question search section storyboard, shown in Figure 4, was created in November 2010. To accomplish the first specified function, find questions, two aspects were incorporated (a) filtering options and (b) a keyword search, labeled accordingly with yellow shaded circles in Figure 4. Filtering would allow the user to check a filter option box, resulting in a question list that only contained questions pertinent to the checked filter option. The keyword search would be similar to a typical web search, and only return questions pertinent to the keywords used. Along with the
keyword search, an advanced search option was envisioned but not fully detailed in the storyboard.

The storyboard included a list of question previews, labeled (c) in Figure 4, as a way to view the information for multiple questions in a relatively compact, yet informative manner, accomplishing the second function. The four question previews in this storyboard are all identical and preview the “Throttling Valve” question, adapted from the TTCI. Question previews included: the question title, a question image if one was associated with the question, the first ~150 characters of the question text, the question author(s), the date the question was added to the AIChe Concept Warehouse, question type, statistical information, class association, concept association, and usage information.

Each question preview also included a button in the lower right corner which would allow a question to be added to the instructor’s personal list of questions, the list of questions that the instructor intended to use in his or her class. This button, one of which is labeled (d) in Figure 4, would afford the third required function, allowing the instructor to select questions for use.

After storyboards were designed, they were used as a basis to create active prototype pages with partial functionality. Access to these pages was limited to the design team. An initial page, prototype V1, for the question search section is shown in Figure 5, from February 2011.
Where navigation in the “Tests” submenu was limited and largely unspecified in the storyboard (Figure 4), prototype V1 (Figure 5) has four functional submenu links: manage sets, current set, build set, and results/statistics. These working submenu titles continued to change over the course of development. There were cosmetic differences between the storyboard and the prototype V1, and certain features illustrated in the storyboards were excluded in the initial prototype. In the question search section exclusions were advanced searching, search result sorting, and some of the question information. Other aspects included in the initial prototype were not in the original storyboards. For example, an overall rating for each question was included that was intended to serve as a rough rating of question quality based on user feedback. Along with research data and user comments, similar to those available at Amazon.com, the overall rating could serve as a metric for instructors to reference as they evaluated which questions to use in their classes.

The initial prototype pages were tested by the members of the design team and revised for user-friendliness and functionality. Figure 6 shows a later revision, prototype V2, of the question search section, dated August 2011.
In prototype V2, additional functionality was integrated. The question previews were transformed from a purely informational display to incorporate links to more complete question summary pages. These links are apparent in Figure 6 by the presence of underlined font in all of the question related text. Webpage naming and organization also evolved over time. The “Build Set” submenu became the “Search” submenu, a more appropriate name. User-friendliness was enhanced between prototype V1 and prototype V2 as well with modification of filter option organization. In prototype V1 there had been a main filtering options category, labeled “Filter By,” that would enable or disable filter categories. In order to filter by one of the options in a category, the user would need to first expand the “Filter By” list by clicking on the image of a warehouse crate next to the “Filter By” text. Next, the user would check the checkbox next to the category in the “Filter By” list, expand the category, and finally click on the check box next to the particular option. The design team recognized that there would be limited number of categories present, so for user-friendliness the extra clicks required to enable a category were removed and all filter categories were listed on the left side of the page, in prototype V2. A suggestions button was also added so that users could suggest filter categories. Main tab titles and submenu titles were also changed and rearranged between versions.

After prototype V2, semi-structured interviews were performed with two users of the WISE Learning Tool. Both interviewees are faculty members who have used the WISE Learning Tool.
in sophomore-level courses with large class sizes (more than 100 students). Both interviewees were junior faculty with less than 5 years in a faculty position. These semi-structured interviews included broad questions such as “Walk me through a typical day in which you used WISE?”, “What did you like about WISE?”, and “If you could, what would you change about WISE?” After asking broad questions about WISE, the interviewees were introduced to prototype V2 of the AIChE Concept Warehouse, allowed to briefly test it themselves and comment on different aspects of the prototype. Interviewers took notes during the interviews. Some of the issues the interviewees had experienced with the WISE Learning Tool had been addressed in the AIChE Concept Warehouse prototype V2. Other issues had not, and were later incorporated into the AIChE Concept Warehouse as a result of interviewee comments. The majority of the question search section was well-liked by the interviewees and, as a result, largely unmodified based on interviewee comments. However, the interviewees provided insightful recommendations for class management in general, a need for a user-friendly interface, and some comments on specific sections in the AIChE Concept Warehouse, including and “Manage Tests,” “Statistics,” and “New Question.”

After a limited amount of external testing, some minor changes were incorporated into prototype V3 of the question search section, shown in Figure 7. This prototype is the working version of the AIChE Concept Warehouse, dated December 2011.

![Image of AIChE Concept Warehouse](image)

**Figure 7.** Step 5 (in progress): Revision after initial external testing of the question search section of AIChE Concept Warehouse prototype V3, December 2011.

Text buttons were converted to icon buttons. To reduce page clutter, the question preview text is no longer underlined; it does still link to a complete question view, but the hyperlink is now indicated by a changing mouse pointer. In addition, checkboxes were added to each question.
preview so instructors can now select multiple questions at once and click a single add button to add all of the selected questions to their personal question list for use in class.

The *AIChe Concept Warehouse* will continue to be improved both through design team recommendations, beta tester feedback, and community involvement.

**The *AIChe Concept Warehouse* – Beta Testing**

Beta testing of the *AIChe Concept Warehouse* began in November 2011, and is currently underway. Beta testers have been and are still being recruited via the *AIChe Concept Warehouse* website. In addition, beta testers were recruited at the 2011 ASEE Annual Conference and the 2011 AIChE Annual Meeting, described in more detail in the Community Development section of this paper. After being recruited, potential beta testers go through the following process.

First, instructors are asked to fill out the online application form available at the *AIChe Concept Warehouse* website (http://cw.edudiv.org/). Currently seven beta testers have signed up to participate. The application form includes questions in five categories: general information about the applicant, teaching philosophy, course information, information about their computer system, and other. General information about the beta testers includes name, contact information, computer expertise and previous beta testing experience. The teaching philosophy category asks for a brief description of the applicant’s general teaching philosophy, information about their experience with concept-based pedagogy and specifically asks about previous experience using clickers. Information gathered in this category enables us to determine and provide the appropriate level of support throughout the beta testing process. The course information collected from beta testers helps prioritize question entry. Information about computer systems is used to ensure compatibility with an instructor’s hardware, software, and technological preferences, including operating system, presentation software, and web browser.

The next step in the beta testing process consists of the design team initiating discussions with the potential beta testers. This step allows for further evaluation of the suitability of potential beta testers for pre-release testing. So far, no beta testers have been eliminated based on a lack of suitability. This initial discussion also introduces potential beta testers to the *AIChe Concept Warehouse* prototype and affords development of a preliminary, personalized test plan.

Beta testers then implement their personalized test plan by using the *AIChe Concept Warehouse* as it best fits into their course(s). After use, follow-up interviews are conducted and surveys are given. Interviews and surveys serve two purposes. First, they provide feedback on the user interface and functionality of the tool. This feedback will be used to improve the *AIChe Concept Warehouse*. Second, the interviews and surveys inform the diffusion process. Specific questions in the interviews and surveys are designed to characterize the attributes of this innovation.

**Community Development Activities**

Involvement of chemical engineering educators is crucial for the success of the *AIChe Concept Warehouse*. In order to foster community engagement, two types of activities have either started or are planned for the future. These types of activities include professional society related activities (e.g., special sessions, posters, papers, and presentations) and independent department visits. In general, the activities are intended to help faculty interested in incorporating
educational methods and tools into their classrooms to encourage students to think more deeply about concepts central to chemical engineering.

At the 2011 American Society for Engineering Education (ASEE) Annual Conference, a special session, titled "Educational Methods and Tools to Encourage Conceptual Learning," was presented, also with an accompanying paper. This interactive special session had approximately 70 attendees and lasted 90 minutes. Seven presenters emphasized the need for concept-based pedagogy and described pedagogical and instructional tools that can be used to promote conceptual learning, and identify and repair misconceptions. In addition, a presenter discussed how technology can be used to enable concept-based pedagogy in the ever-changing classroom, highlighting the utility of the *AIChE Concept Warehouse*. Presentations ended with a reflection on the benefits and challenges of integrating concept-based pedagogy into classroom instruction. Activities were included throughout the presentations, which had participants get into pairs, reflect on what was discussed, and extend their understanding to consider when might be most appropriate to use different pedagogical tools and why some misconceptions are so deeply held. Participants also used an audience response system (Turning Technologies ResponseCard NXT clickers) to answer conceptual questions that were delivered via the *AIChE Concept Warehouse*. After the presentations, the special session concluded with a lively panel discussion of participant questions.

At the 2011 AIChE Annual Meeting, a workshop titled “Tools and Techniques for Conceptual Learning” was facilitated. This 2.5 hour workshop had five presenters and approximately 15 participants. It had presentations similar to the ASEE special session, with an emphasis on the need for concept-based pedagogy and a discussion of pedagogical tools, repair of misconceptions and classroom experiences. However, it ended with participants gaining hands-on experience using the AIChE Concept Warehouse. Participants went through an activity to develop their own concept questions, which led some to appreciate the difficulty in constructing a high quality concept questions. Participants were shown how to add questions to the AIChE Concept Warehouse, create ConcepTests, assign ConcepTests to their classes, and how to view student results. The contrast in attendance between the ASEE special session and the AIChE workshop is reflective of the challenge in attracting mainstream faculty to education reform.

In addition to the activities already completed, professional society related activities are planned for the future. One such activity is a 3-hour, two-part workshop at the ASEE Chemical Engineering Faculty Summer School in July, 2012. The goal of this workshop is to provide early career faculty members with the education methods and tools they will need to incorporate concept-based pedagogy into their classrooms. Pedagogical content will be similar to that of the ASEE special session and the AIChE workshop. The workshop will have many interactive components, including discussions, clicker and laptop content delivery and response, and scaffolded hands-on use of the *AIChE Concept Warehouse*. During scaffolded use, participants will develop conceptual questions, add them to the *AIChE Concept Warehouse*, and use them to practice a sample lesson using Peer Instruction. At the end of this workshop, participants will walk through the other resources and materials available on the website, and provide feedback regarding the workshop and the *AIChE Concept Warehouse*. 
Along with the professional society related activities, we intend to visit departments who are interested in adopting this tool. It is expected that these workshops will incorporate similar material as has been included in previous workshops; however, they will be tailored to the individual needs of the departments. If interested in hosting a department workshop, please contact the corresponding author.

**Future Plans**

Future plans include continued application development and testing, and community development activities. Iterative development and testing is focused on finalizing *AIChE Concept Warehouse* sections, incorporating additional concept questions and concept inventories, performing beta testing, and incorporating feedback from beta testers. Community development activities will primarily be in the form of workshops, introducing the *AIChE Concept Warehouse* to more members of the community. Planned workshops include the 2012 ASEE ChE Summer School and independent department visits.

As researchers improve current tools and develop new concept-based pedagogical tools, improvements and new additions will be integrated into the *AIChE Concept Warehouse*. For example, one improvement expected for concept inventories is the development of diagnostic models to interpret the results of concept inventories. These models can be incorporated into the *AIChE Concept Warehouse* to provide users with a more descriptive explanation of student understanding. New additions might include more scaffolding for the repair of misconceptions and additional approaches to facilitate conceptual learning.

In addition, we intend to study the longitudinal diffusion of this tool in order to inform the design, development, and diffusion of other engineering education best practices. It is expected that by carefully tracking the diffusion process and gather information regarding decisions to adopt this tool, we will be able to inform others trying to bridge the gap between engineering education researchers and practitioners.

**Summary & Implications for the Future**

In this paper, we have reported on the initial development and current status of the *AIChE Concept Warehouse*. This web accessible tool is currently in beta testing. It houses more than 1,200 concept questions, five concept inventories, and provides pedagogical scaffolding to promote the use of concept-based pedagogy throughout chemical engineering.

While the design of this tool and incorporation of questions provides a strong foundation, participation from the community is critical for success. We encourage the broader community of chemical engineering educators to participate.

If you would like to use it, please visit us at [http://cw.edudiv.org](http://cw.edudiv.org)

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