THE AIChE CONCEPT WAREHOUSE: A WEBSITE RESOURCE FOR CONCEPT-BASED INSTRUCTION

Milo D. Koretsky
Oregon State University • Corvallis, OR 97331-2702

Many engineering educators and industry partners emphasize the need for students to apply their knowledge to new and challenging problems. A lack of conceptual understanding has been shown to severely restrict students' ability to solve new problems since they do not have the foundational understanding to use their knowledge in new situations.[1] This problem is exacerbated by science and engineering classrooms that often reward students more for rote learning than for conceptual understanding.[2] There is clearly a need for more emphasis on conceptual understanding in the chemical engineering curriculum. But developing high-quality instructional materials is time-consuming and requires expertise.[3] Even with access to instructional materials, it is also useful to be able to deliver them in class in ways that all students can participate and that both students and the instructor get formative feedback.

The AIChE Concept Warehouse (CW) is a community-developed, web-based tool to decrease instructional barriers and to help faculty implement concept-based active learning in class.[4,5] The CW provides three distinct but complementary functions: (a) a content repository, (b) an audience response system and learning management system to deliver content, and (c) learning analytics that provide learning data to instructors and researchers. Instructor and student interfaces are available free at <http://cw.edudiv.org>. After obtaining a CW account, instructors can navigate through the Instructor Interface to find content, deliver it in class through the Student Interface, and use reported aggregate and individual answers and scores to guide instruction. A video describing the CW is available at <https://youtu.be/Nf5w0kG3asY>.

I next briefly describe the three major functions of the CW.

CONTENT REPOSITORY

Educators have access to content through the Instructor Interface, which is organized by tabs. There are three content tabs available: Conceptests, Concept Inventories, and Instructional Tools:

__Milo Koretsky__ is a professor of chemical engineering at Oregon State University. He received his B.S. and M.S. degrees from UC San Diego and his Ph.D. from UC Berkeley, all in chemical engineering. He currently has research activity in areas related to engineering education. His group works on integrating technology into effective educational practices that promote the use of higher-level cognitive and social skills in engineering problem solving and in promoting change towards motivating faculty to use evidence-based instructional practices. A particular focus is on what prevents students from being able to integrate and extend the knowledge developed in specific courses in the core curriculum to the more complex, authentic problems and projects they face in professional practice.

Conceptests: Figure 1 shows two screenshots of the "Conceptests" tab. Conceptests are conceptual questions that ask students to use a core concept or set of concepts to reason through to the correct answer. They help students develop understanding of engineering concepts and help faculty and students identify the level of mastery.

As shown in Figure 1 (a), instructors currently have access to around 3,000 Conceptests available for core chemical engineering classes (see list on left of figure). These can be searched by class, by topic, or using the advanced search tool. Instructors can also write their own Conceptests [Figure 1 (b)], which they can choose to either contribute to the community (for a well-written and general question) or reserve for use only in their own classes (for a question specific to the instructor's delivery). There are several question types to select from including multiple-choice with single answer, multiple-choice with multiple answers, short answer, and ranking exercises.

There are two ways instructors can use this content. Figure 2 shows a screenshot of the Student Interface of a Conceptest on the CW website. This example shows a multiple-choice question with a figure. When assigning a Conceptest, the instructor has the option to choose to have students provide a written explanation and/or answer how confident they are when answering the question (both selected here). Asking students to provide written explanations has been shown to increase student learning.[6-8] To deliver content through the CW, the instructor must set up a class using the Classes tab (see section below). Alternatively, the questions can be downloaded from the CW in PowerPoint or Word for other uses.

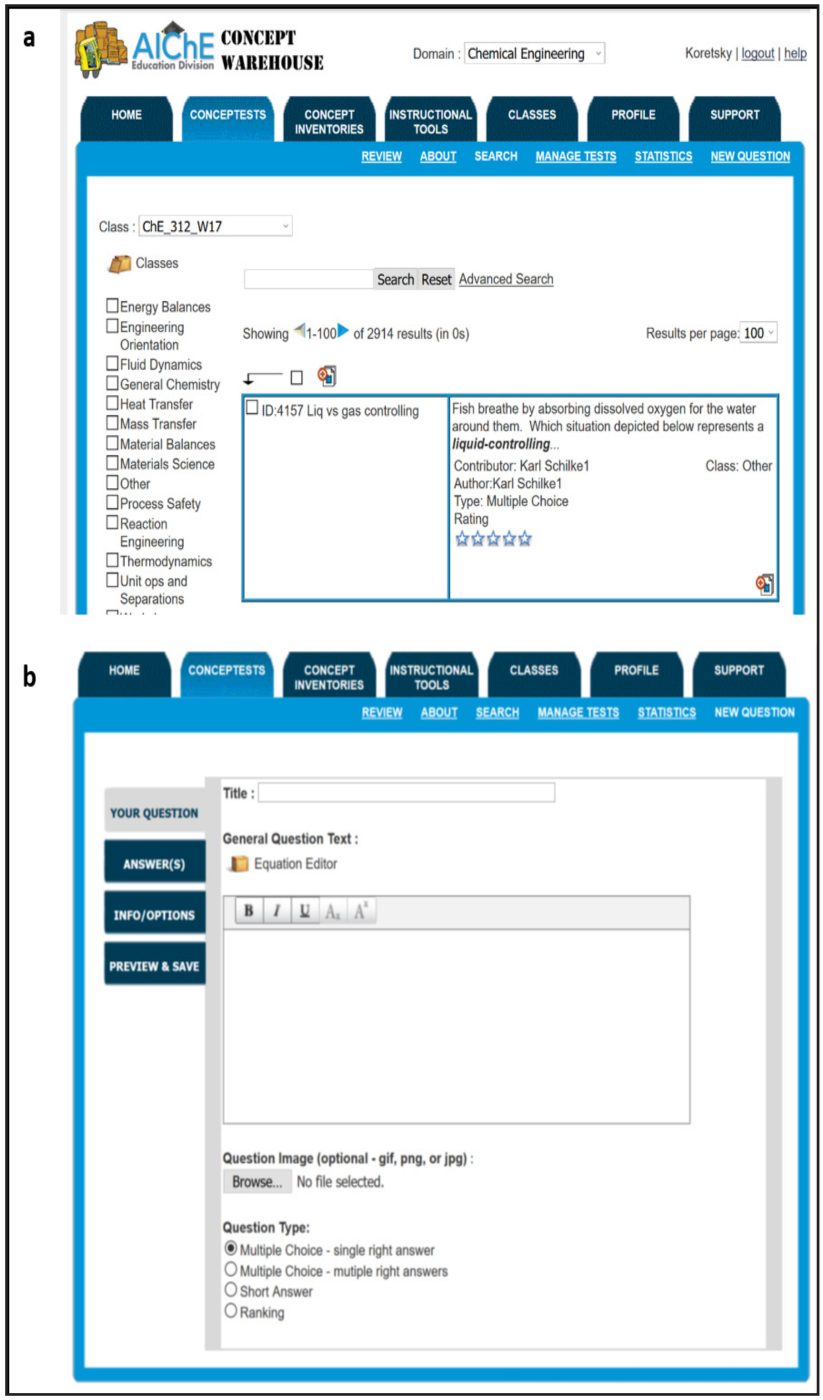

Figure 1. *Instructor Interface: Screenshots of the Conceptests "tab" in the Instructor Interface: (a) the search menu; (b) the new questions tab.*

Concept Inventories: There are 12 concept inventories (CIs) available for summative assessment of students' conceptual understanding. CIs are test instruments meant to help instructors and researchers determine the extent of their students' conceptual understanding about a specific subject.[9,10] The CIs available on the CW have been developed and psychometrically tested according to validity and reliability criteria. These instruments focus on a few core concepts in a subject and several questions (items) are used to test understanding of each concept. CIs can be used in ABET assessment processes or in rigorous education research studies by administering the CI at the start and end of a term to quantify learning gains.

Figure 3 shows a screenshot of the Concept Inventory tab for the Heat and Energy Concept Inventory (HECI).[11] As shown, an instructor can see the list of items in the "Questions" menu (on left) or select the "Answer Key" to get the same list, but with the answer highlighted. In this way, the instructor has the opportunity to work through the test instrument before assigning it. The following CIs

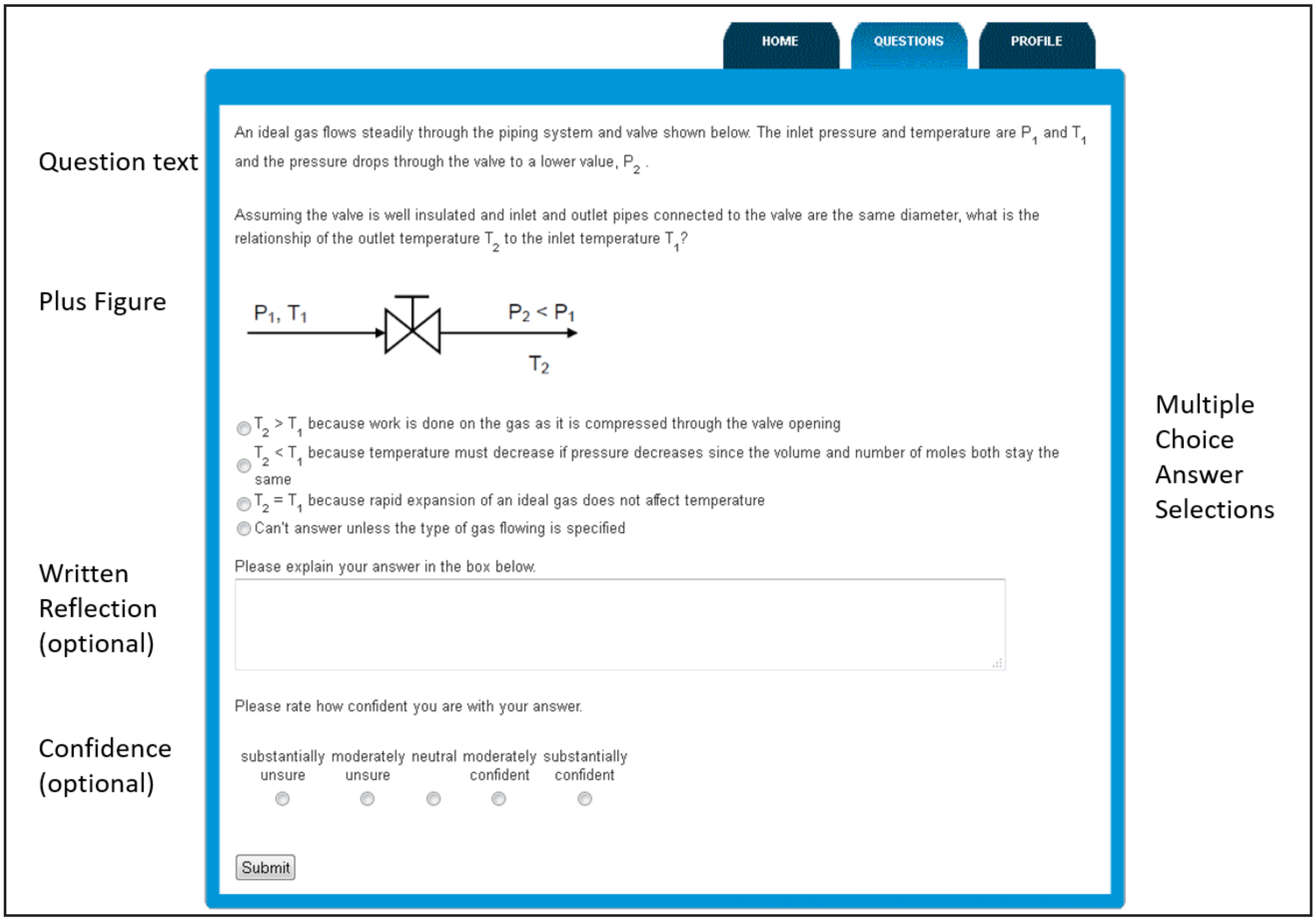

Figure 2*. Student Interface: an example of a Conceptest delivered to students.*

are available.

- *Thermodynamics (35 items)*
- *Heat and Energy (36 items)*[11]
- *three Thermal and Transport Concept Inventories (TTCI)*[12]*. TTCI: Thermodynamics (24 items); TTCI: Fluids (26 items); and TTCI: Heat Transfer (18 items)*
- *Materials (30 items)*[13]
- *Statistics (25 items)*[9]
- *Dynamics (29 items)*[14]
- *four Chemistry CIs (20-31 items)*[15]

Instructional Tools: In addition to Conceptests and CIs, we have recently been adding a set of Instructional Tools to help students develop conceptual understanding. Three of these tools are described next.

Reflection Activities: Quick end-of-class activities (often called minute papers or exit slips), where students are asked to reflect on class materials, have been described as providing one of the best returns on investment of class time and instructor effort.[16] These activities provide a way to help students reflect on content and provide instructors an assessment of where students are struggling. Based on research findings,[17] the CW provides a hybrid reflection activity that allows students to choose amongst a "Most Surprised" prompt, "Muddiest Point" prompt, or both. The Instructor Interface provides a list of student responses, which in a large class can be overwhelming. To facilitate interpretation, the instructor is also provided word clouds to analyze the data, and a table of the most common response themes.

Interactive Virtual Labs: In the Interactive Virtual Laboratories (IVLs) students are guided through a sequence of around 15 "frames" that prompt them to interact with simulations and relate microscopic (molecular) phenomena of a system to macroscopic representations and answer questions.[18] The IVLs target difficult concepts, and each IVL draws upon known student difficulties from the science and engineering education literature. Figure 4 shows the Heat Capacity IVL, which helps students understand why constant pressure heat capacity (c_p) is larger than constant volume heat capacity (c_v). The CW has the following IVLs available: PV Work; Reversibility; Heat Capacity (c_v vs. c_p); Hypothetical Paths/Chemical Reaction;

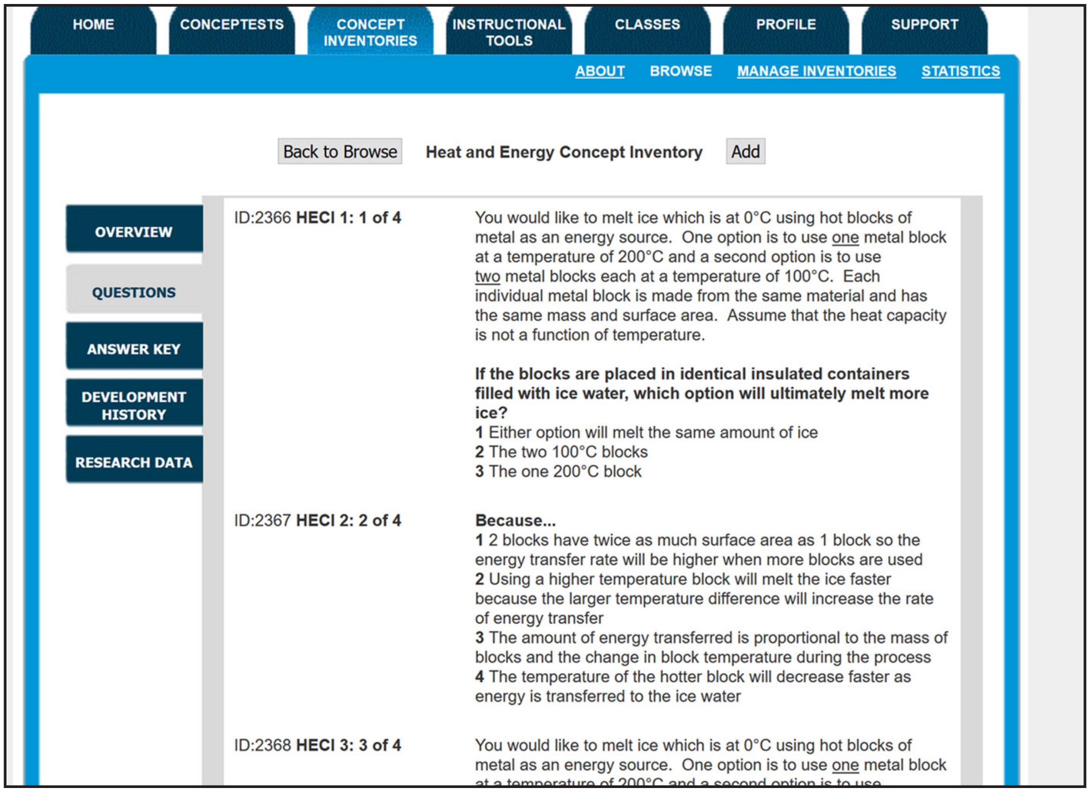

Figure 3. *Instructor Interface: a screenshot of the concept inventory tab.*

Hypothetical Paths/Phase Equilibrium; Reaction Rate and Chemical Equilibrium; and Phase Equilibrium. A video describing the IVLs is available at <https://youtu.be/1t17fh026Pw>.

Inquiry-Based Activities: Inquiry-based activities (IBAs) have been shown to significantly improve student scores on tests of conceptual learning.[19,20] The CW currently has two heat transfer IBAs on topics in which students commonly show misconceptions: rate vs. amount and radiation. As shown in Figure 5, the Rate vs. Amount IBA helps students understand the difference between how fast energy is transferred and the total amount of energy transferred. The recommendations in Figure 5 on effectiveness and the perceived ease of use are based on research data.

SITE FOR INTERACTIVE TEACHING (AUDIENCE RESPONSE SYSTEM)

As an instructor, you can use the site in class or for homework to deliver content and collect responses, as students answer on their devices (cell phones, tablets, laptops). Figure 6 shows screenshots of the mobile student app, which is formatted to optimize use on cell phones. Setting up the CW to use in class is a one-time process (for each class you teach) and requires only a few steps: creating a new class in the "Classes" tab, pasting in the emails of your students, and sending

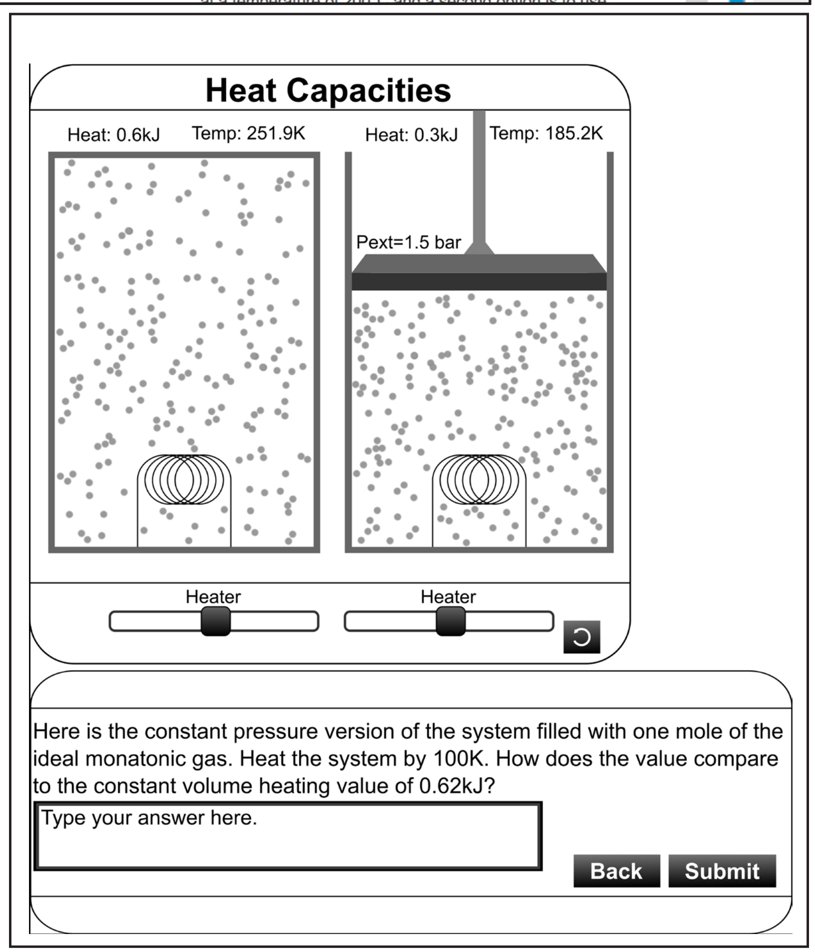

Figure 4. *Heat capacity (c_v vs. c_p) Interactive Virtual Laboratory. The actual IVL image has been rendered with a white background for readability.*

an automated email that provides them a link to the Student Interface. When you find a question, inventory, or tool that you want to use, add it to "Manage Tests," "Manage Inventories," or "Manage Tools"; and then assign it from the menu. You can also link several Conceptests together in "Manage Tests" so that they are delivered sequentially in a single assignment.

ANALYTICS FOR FORMATIVE ASSESSMENT

If you assign activities through the CW, you can take advantage of the analytic and scoring capability on the Instructor Interface. Figure 7 shows screenshots of analytics available including a catalog of student responses throughout the term (left) and multiple-choice and written responses to a specific conceptest (right). When you ask students to provide written explanations or you use the Surprised and Muddy reflections Instructional Tool, clickable word clouds are available to help make sense of student responses more quickly.[21] You can also access a grade sheet that summarizes student performance.

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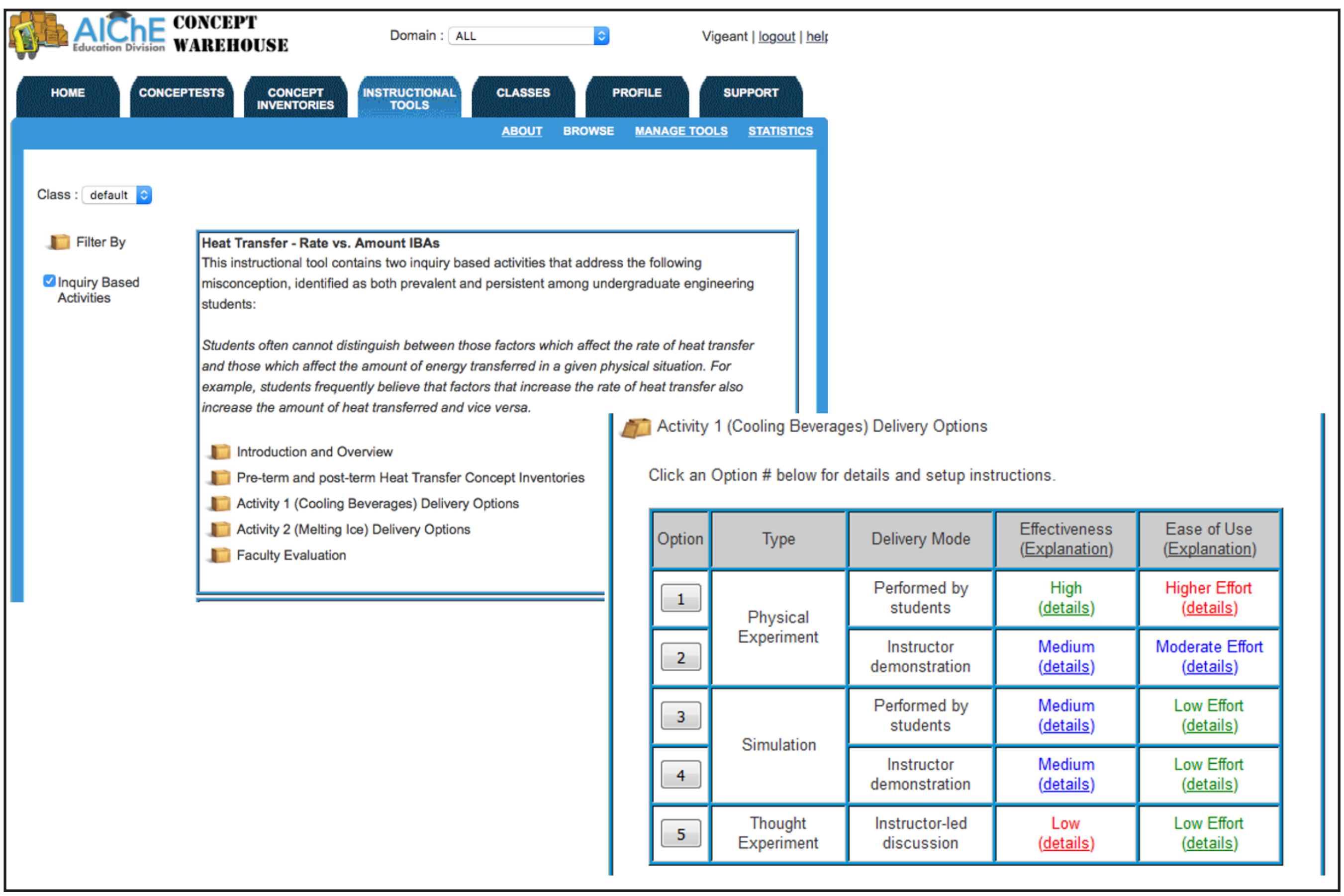

Figure 5. *The Rate vs. Amount Inquiry-Based Activity. There are five delivery options available (bottom right).*

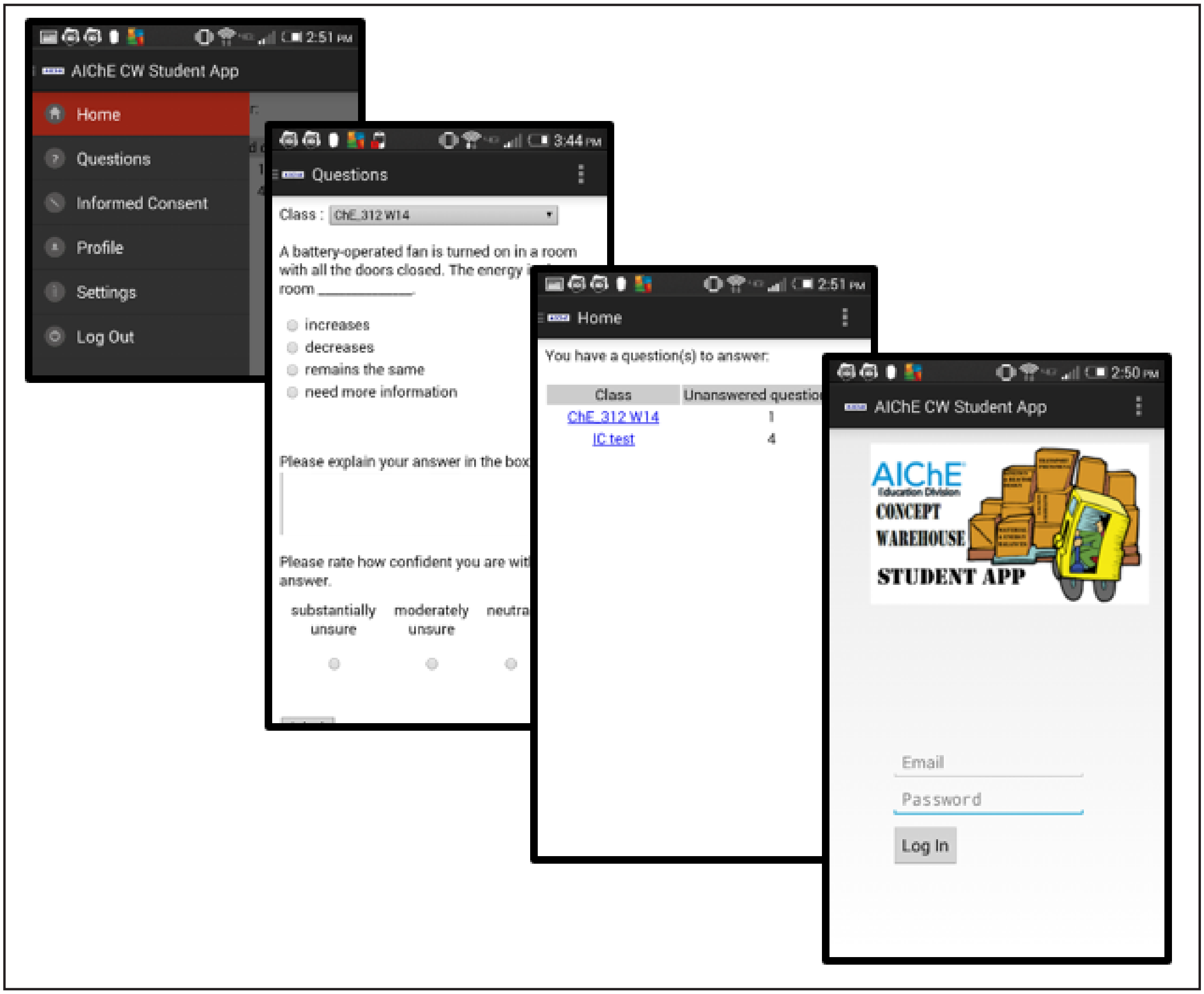

Figure 6. *Screenshots of the Student Interface on mobile student app for interactive use in class.*

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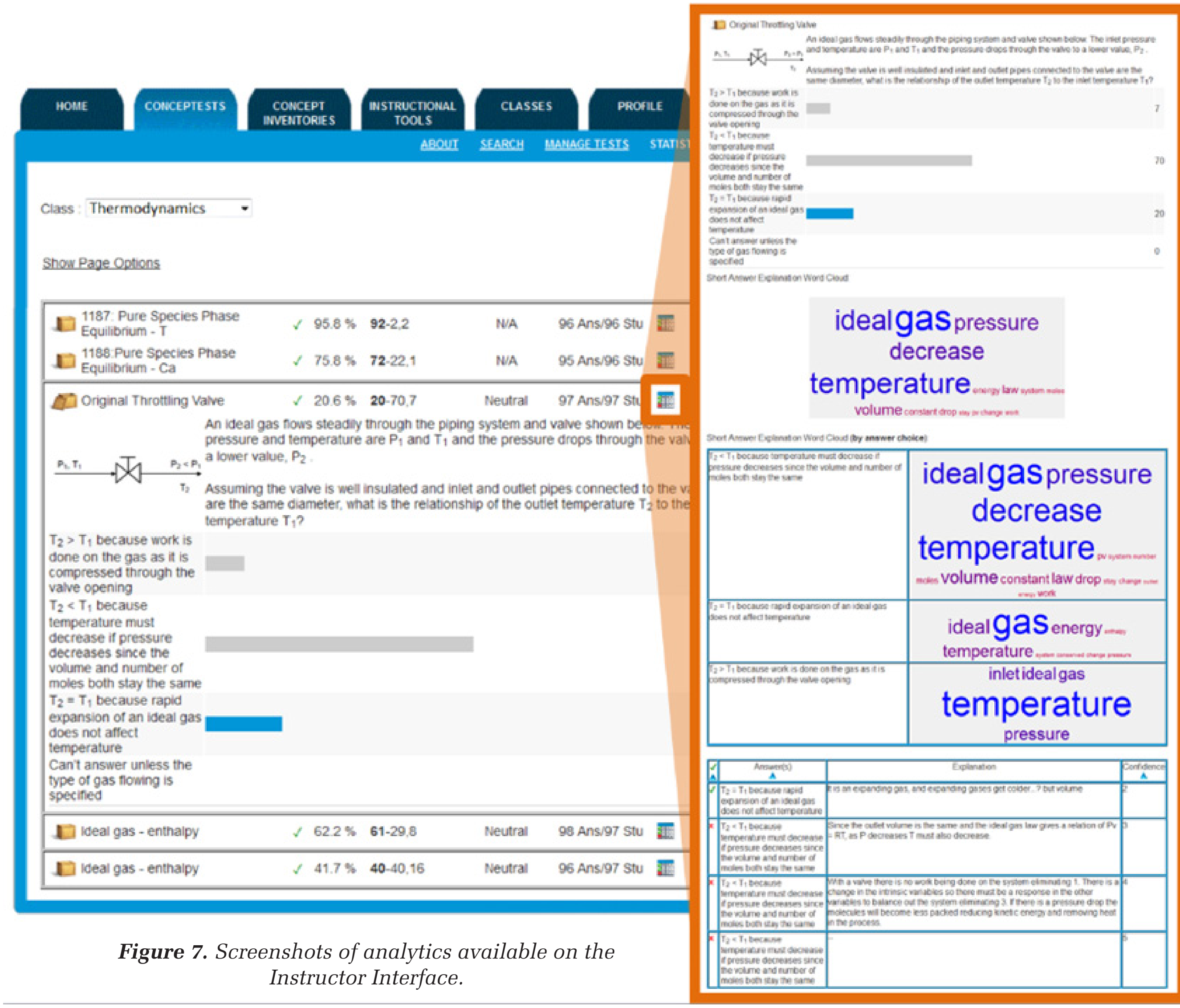

***Figure 7.** Screenshots of analytics available on the Instructor Interface.*

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