AC 2008-976: A WEB-BASED INTERACTIVE SCIENCE AND ENGINEERING LEARNING TOOL THAT PROMOTES CONCEPT-BASED INSTRUCTION

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A Web-based Interactive Science and Engineering Learning Tool that Promotes *Concept-Based* Instruction

Abstract:

The undergraduate engineering classroom of the 21st century has the opportunity to enhance student learning through the effective integration of technology into the classroom. This paper describes the development of a Web-based Interactive Science and Engineering (WISE) Learning Tool that facilitates active learning in the classroom and metacognition and allows assessment of student learning (formative assessment). WISE allows an instructor to pose to the class different types of questions (including: multiple choice answers, multiple choice with short answer follow-up, numerical answers, short answers, and Likert-scale survey). WISE is designed to utilize the College of Engineering's Wireless Laptop Initiative so that every student in a class is simultaneously engaged, creating a learner centered environment based on active learning. It can be used to develop activities that probe for conceptual understanding and deeper level thinking. It allows real-time formative assessment by the instructor. After the students have submitted a response to an activity, the instructor can review a summary of the results with the class. For example, bar graphs are automatically compiled for multiple choice questions. For short answers, the instructor can view the set of responses and select specific answers to share with the class. Depending on the class response, the instructor can choose an appropriate method (e.g. peer instruction, instructor explanation) to reinforce or correct the response. It builds from the current educational methodology of concept inventories to assess students' conceptual understanding. However, as opposed to the model of pre and post assessment, which is often the goal of concept inventories, this learning tool can be used daily to monitor student understanding. WISE also presents the opportunity to contribute meaningfully to the knowledge base in student learning in engineering. The use of the computer to probe student thought processes has been demonstrated as an effective education research tool. Two elements of WISE make it particularly useful. First, students are assured of anonymity in their responses. Second, the automatic recording of student responses allows instant summarization of students understanding and convenient collection of the results for analysis. The initial deployment of WISE in the curriculum is presented.

Introduction:

It has been shown that, with traditional instruction, students are better rewarded by rote learning than by conceptual understanding.¹ In fact, one study has shown that chemistry students demonstrated a 38% success rate on conceptual problems as compared to a 95% rate on numerical problems.² However, it has also been shown that the lack of conceptual understanding severely restricts the student's ability to solve a new problem.³ Alternatively, *concept-based instruction* is based on the premise that the understanding of concepts is central to understanding a subject and extending knowledge to new problems and areas.⁴ By incorporating concept-based instruction, students can transition from problem solving by example, where they seek a one to one correspondence between an example problem they had been shown and the problem they are

given, to a higher level of cognition where they solve problems by applying the fundamental principles covered in the course to any of a variety of entirely new problems.

The undergraduate engineering classroom of the 21st century has the opportunity to enhance student learning through the effective integration of technology into the classroom. In an effort to promote the use of advanced technology to develop a more engaging and innovative learning experience for students, the College of Engineering (COE) at Oregon State University implemented a Wireless Laptop Initiative in 2002 which allowed large-scale implementation of wireless technology in the classroom and required all undergraduate engineering students to own a laptop.⁵ Similar laptop initiatives have been implemented at universities across the country.⁶⁻⁹

In order to promote concept-based instruction, we developed the Web-based Interactive Science and Engineering (WISE) Learning Tool. This technology-enabled learning tool is designed to allow students and instructors to utilize the COE's Wireless Laptop Initiative to incorporate higher levels of interaction during classes. The WISE Learning Tool allows an instructor to pose questions that probe for conceptual understanding and supports a variety of student response types, including: multiple choice answers, multiple choice with short answer follow-up, short answers, numerical answers, ranking exercises, and Likert-scale surveys.

WISE also presents the opportunity to contribute meaningfully to the knowledge base in student learning in engineering. The use of the computer to probe student thought processes has been demonstrated as an effective education research tool.¹⁰ Two elements of WISE make it particularly useful. First, students are assured of anonymity in their responses. Second, the automatic recording of student responses allows instant summarization of students understanding and convenient collection of the results for analysis.

WISE is one of many applications that attempt to engage students through applying technology to provide an active classroom. Classroom Presenter (for tablet PCs),¹¹ Ubiquitous Presenter,¹² DyKnow,¹³ Active Class (for PDAs)¹⁴ and classroom response systems, or "clickers,"¹⁵ all share a similar pedagogical theme with WISE. However, none of these systems provides the same specific features, as discussed below, for engagement in the wireless laptop environment. Additionally, it is attractive to have a system that can be modified readily in its intended development as a research tool.

The objectives of the **WISE** Learning Tool are to:

1. Provide **formative assessment** of student learning, both allowing instructors to make necessary alterations and corrections to their instruction, and guiding students where to direct their learning efforts.
2. Form an integral part of the instructional activities themselves, transforming the classroom into a more **learner-centered** environment.
3. Provide a tool that **education researchers** can use to collect data to understand specific aspects of student learning.

Software Pedagogy and Design:

WISE is designed for use in the context of a learner centered class based on active learning. It is designed to allow real-time formative assessment by the instructor. After the students have submitted a response to an activity, the instructor can review a summary of the results with the class. Depending on the class response, the instructor can choose an appropriate method (e.g. peer instruction, instructor explanation) to reinforce or correct the response. Specifically, the software is designed to achieve the following characteristics:

- Support Active Learning
- Have interactivity
- Provide feedback to instructors and students
- Identify misconceptions
- Have multiple exercise organizations
- Have multiple answer types
- Support anonymity
- Provide uncomplicated instructor exercise development

The WISE Learning Tool consists of an instructor interface and a student interface. The instructor interface consists of four major areas, the exercise library, class activities, the grade book, and statistics. The exercise library is where the exercises are created. Class activities are where the exercises are used directly in class. The grade book and statistics are used for analysis after class. A further discussion of the instructor interface with sample screenshots is provided in Appendix A. The student interface allows students to view and answer exercises assigned by the instructor. It will be illustrated in the implementation section of this paper. The student interface also allows students to view their statistics, instructor willing, and pose virtual hand raise questions.

WISE is web-based for a number of reasons. First, this allows for the software to be centrally managed. A change can be made to the web-server or database server and takes effect immediately. Additionally, students and teachers do not need to download and install the latest version. Second, it is better for security. Very little processing is done on the students computer, so it is difficult for students to modify or trick the program. Third, this setup maximizes compatibility and ease of use for users. The COE requirement does not specify the model of wireless laptop a student should purchase. While not all computers have Windows or Java, they usually have a web-browser. This architecture allows LDAP authentication where students can use their standard COE computer accounts and allows the grade sheets to be automatically populated.

Implementation:

WISE has been used in 9 classes since Fall 2006 (F 06) with 501 students participating. A summary of its use is presented in Table 1. The two classes in which its use is assessed in this paper are described in more detail below.

Table 1. Summary of use of WISE at OSU. F 06 refers to Fall 2006, W 07 to Winter 2007, Sp 07 to Spring 2007, Su 07 to Summer 2007, etc.

Class	Term	Title	Students	Exercises
ChE 311	F 06	Chemical Engineering Thermodynamics I	34	7
ChE 312	W 07	Chemical Engineering Thermodynamics II	46	45
ENGR 221	W 07	The Science, Engineering and Social Impact of Nanotechnology	31	31
ChE 213	Sp 07	Process Analysis	79	28
ChE 212	Su 07	Energy Balances	5	19
ChE 414	F 07	Senior Lab I	50	13
ChE 312	W 08	Chemical Engineering Thermodynamics	66	in progress
CE 102	W 08	Problem Solving and Technology	60	In progress
ENGR 211	W 08	Statics	129	in progress

Pilot Study. The first use of WISE in a classroom setting was a two hour Pilot Study in Chemical Engineering Thermodynamics I (ChE 311) in Fall 2006. In the class period before the use of WISE, students were asked to bring their wireless laptops, and were reminded again by email. Of the population of 50 students, 34 (68%) students participated in the activities using a laptop, while the other 16 (32%) students did the activities on paper. Reasons provided for not having a laptop included, not owning one, forgetting it, and lack of a power outlet. Seven questions were posed to the class covering a range of topics that had already been covered that term, including: thermodynamic properties, the first law and the second law. This activity was “out of context” in the sense that the entire content from the course was integrated in this activity and that it was delivered by a different instructor. Six of the questions were multiple choice with short answer follow-up while one question was a short answer. Of the multiple choice questions, the percentage of problems with correct answers ranged from 0% to 86%.

Full Use in Class. The most extensive use of WISE in a class to date was in Chemical Engineering Thermodynamics II (ChE 312) in Winter 2007, where it was used during the 9 recitation sections and for 1 homework assignment. It was typically used for between 30 and 60 minutes during the 2-hour recitation. Sometimes it was used in the beginning of class, sometimes at the end, and sometimes in shorter blocks dispersed throughout the class. It is believed that by both varying the type of questions that are asked and the part of class that WISE is deployed, it remains “fresh” and students tend to be more engaged. 45 in class questions and 1 homework question were delivered. The 45 questions included: 18 multiple choice mostly with short answer follow-up and 27 descriptive answer questions. Of the latter set, 5 were concept-based and 22 were calculation-based, 1 requiring extensive use of an Excel spreadsheet. Thus, the problems were roughly split evenly between concepts and numerical calculations. The software has been modified so that the calculation-based questions can now be automatically graded according to the numerical answer, within a tolerance.

There were 46 students enrolled in the class. The number responding to WISE activities with their wireless laptop ranged from 39 – 44. While most of the students in class were able to

participate, there was never complete engagement. Again, students who did not have a laptop used pencil and paper. The average percentage of students who answered the multiple choice questions correctly was 62%, and the range was from 20% to 91%. A summary of the results from the multiple choice questions from this class is presented in Appendix C.

Innovations in Teaching and Learning:

One of the 7 problems used in the Pilot Study is discussed next to illustrate how this tool is used in class and to demonstrate the utility of WISE as an assessment tool to identify misconceptions. Figure 1 shows a screen shot of the problem¹. This problem was adapted from the Thermal and Transport Science Concept Inventory developed by Ron Miller and coworkers.¹⁶ The assigned problem had 4 multiple choice options. However, unlike the Concept Inventory tests, no justification is given for each choice. Rather, students are asked to provide their own justification in a short answer text box that accompanies the problem (see Appendix B). We term this activity, a “short answer follow-up”. The use of short answer follow-ups offers students the opportunity to practice reflection on their selection of multiple choice answers. It has been shown that descriptions of one's thinking directed to another individual are likely to alter the course of thinking, providing deeper thought.¹⁷ The students had a specified time limit for the question (5 minutes) and responded using a web browser with their wireless laptop. The answers were “jumbled” in random order for each particular student, so the order of choices varied from one laptop to the next. The correct answer is 1 ($T_2=T_1$). To solve this problem, students needed to understand two concepts. The correct logic could be as follows: first, the steady-state energy balance across the valve shows that the enthalpy of the exit state, 2, equals the enthalpy of the inlet state, 1, i.e., it is an isenthalpic process; second, the enthalpy change of an ideal gas depends on temperature only. Therefore, since the enthalpy does not change, neither does the temperature. A modification of this problem followed as the next multiple choice question, in which high pressure steam flowed through a valve. In that case, students need to understand that in order to overcome the attractive interactions in an isenthalpic expansion of a real gas, the temperature would decrease.

The distribution of answers chosen by the students is also shown in Figure 1. This figure is representative of what the instructor might show the class to facilitate discussion. Surprisingly, not a single student selected the correct answer, $T_2=T_1$. 23 students answered $T_2<T_1$ while 9 students answered $T_2>T_1$. 2 students did not submit answers before they were timed out. Students explained their choice with a short-answer follow-up. Additionally, the instructor is able to select a subset of these responses to use in class discussion. Using the most common answer, $T_2<T_1$, as an example, short answer follow-ups that could be displayed included: “The ideal gas law states a directly proportional relationship between T and P. Therefore, if P decreases, T should” and “According to $Pv=RT$ T must go down as P goes down.” 18 out of 23 written responses clearly and directly alluded to the ideal gas law in the rationale; the concept of an energy balance was missing from all responses. From the answers and the discussion that followed, the most prevalent misconception of this group of students is that they believe that both the (extensive) volume and the number of moles are constant at the inlet and the exit. This misconception is analogous to the amount vs. rate misconceptions discussed by Miller et al.¹⁸ From this perception, students then applied the ideal gas law:

¹This screenshot actually shows how the results are presented; Appendix B shows a screenshot of what is available to students through the student interface

Web-based Interactive Science and Engineering Learning Tool

Grade Sheet

[Exercise Library](#)
[Class Activities](#)
[Grade Book](#)
[View Grade Sheet](#)
[Manage Students](#)
[View Statistics](#)
[Administration](#)
[Help](#)

Logged in as:
 Milo ([logout](#))

Contact point:
[Milo Koretsky](#)

An ideal gas flows steadily through the piping system and valve shown below. The inlet pressure and temperature are P_1 and T_1 and the pressure drops through the valve to a lower value, P_2 .

Assuming the valve is well insulated and inlet and outlet pipes connected to the valve are the same diameter, what is the relationship of the outlet temperature T_2 to the inlet temperature T_1 ?

Please explain your reasoning in the space provided below the answer choices.

- 1 $T_2 = T_1$
- 2 $T_2 < T_1$
- 3 $T_2 > T_1$
- 4 Can't answer until I know what gas is flowing

Source: Ron Miller

	0
	23
	9
	0

Figure 1. Ideal gas valve problem and student responses. The correct answer is 1.

$$\frac{P_1}{T_1} = \frac{n_1 R}{V_1} = \frac{n_2 R}{V_2} = \frac{P_2}{T_2} = \text{constant}$$

This logic resulted in the selection of answer 2.

Multiple choice answers based on common misconceptions are termed “distracters.” Developing effective distracters is challenging, dynamic, and typically labor intensive involving interviews and “think aloud” protocols with students.¹⁹ The power of the short answer follow-up is that the students describe the logic of their choice, themselves, and therefore it allows instructors and researchers a dynamic window into the students’ misconceptions. One possible restatement of the distracter for the problem above could be of the form, “since the gas is an ideal gas and volume and the number of moles stays the same from the inlet to the exit, the temperature decreases with decreasing pressure.” This statement is actually modified from one of the student answers. This rationale is quite different than that which is used in the distracter on version 3.0 of the Thermal and Transport Science Concept Inventory.¹⁶

WISE is best used when the instructor can dynamically respond to the class answers. For example, Figure 2 shows class results for a phase equilibrium problem formulation delivered in ChE 312. The answers were roughly divided evenly between choices D, E, and F. Seeing this result, the instructor divided students into teams of three, one who answered D, one E and one F, and asked to reconcile their answers. The question was the reassigned and 77% of students answered correctly. This form of peer instruction has been demonstrated to be effective.²⁰

Grade Sheet

Consider species i that is part of a mixture that is in vapor-liquid equilibrium. The system pressure is high, but the saturation pressure for pure i at the system temperature is low. Which of the following equations is the best choice to accurately solve for the composition of i :

- A. $y_i P = x_i P_i^{sat}$
- B. $y_i P = x_i \gamma_i P_i^{sat}$
- C. $y_i \hat{\phi}_i P = x_i \gamma_i P_i^{sat}$
- D. $y_i \hat{\phi}_i P = x_i \gamma_i \hat{\phi}_i^{sat} P_i^{sat} \exp \left[\int_{P_i^{sat}}^P \frac{V_i^l}{RT} dP \right]$
- E. $y_i \hat{\phi}_i P = x_i \gamma_i P_i^{sat} \exp \left[\int_{P_i^{sat}}^P \frac{V_i^l}{RT} dP \right]$
- F. $y_i \hat{\phi}_i P = x_i \gamma_i \hat{\phi}_i^{sat} P_i^{sat} \exp \left[\int_{P_i^{sat}}^P \frac{V_i^l}{RT} dP \right]$

1 E		13
2 F		14
3 D		12
4 A		1
5 C		0
6 B		0

Figure 2. High pressure phase equilibrium problem formulation. The correct answer is E.

A primary objective in ChE 312 is to, as much as possible, push students beyond *Application* to *Analysis* and *Synthesis*. In terms of Bloom's Taxonomy of Learning,²¹ a *threshold* of activity from lower to higher level learning lies in the transition from *Application*, where concepts are employed to solve problems in new situations to *Analysis* which includes the breaking down of informational materials into their component parts, and then understanding the individual parts along with the relationships between them. This development is promoted through stressing the connection to conceptual understanding through WISE, and challenging students with creative new exam and homework problems. Most exam problems were developed to probe and promote higher order thinking skills. Student performance (% pass) on higher level skills is shown in Figure 3. The % pass increased from 35% in Exams 1 and 2 to approximately 70% by the final exam, showing an increasing trend. Student performance on lower level questions (blue diamonds) is shown for comparison. While it is not possible to quantitatively establish the extent that the use of WISE contributed to this increasing trend, it can be stated that WISE was an integral part of the course delivery and that students performed better at the end of the course on problems requiring higher level cognition relative to the beginning.

Figure 3. Development of higher level skills in Bloom’s taxonomy that increases students’ ability to identify, formulate and solve engineering problems.

Assessment:

Pilot Study (ChE 311). Student perceptions of the Pilot Study of WISE were measured using a survey. The survey consisted of three Likert-scale questions and two questions focused on the use of their wireless laptops in general. The survey also elicited comments in general. Results from the Likert-scale survey questions are summarized in Table 2. They indicate students agreed that WISE was effective, facilitated conceptual understanding and had the potential to positively impact learning in the classroom. Of the 93 responses, only 6 indicated “somewhat disagree” and none indicated “strongly disagree.”

Table 2. Assessment data from Fall 2006 pilot using a Likert-scale (1=strongly disagree to 5=strongly agree)

Question	1	2	3	4	5	Avg	n
Using WISE in class today improved my understanding of fundamental thermodynamic concepts.	0	0	7	20	4	3.90	31
I think that integrating WISE into my engineering classes would improve my learning in the classroom.	0	4	5	17	5	3.74	31
Using WISE today in class was an effective use of my wireless laptop.	0	2	5	15	9	4.00	31

Additionally written student comments on the experience included:

“This tool seems to be effective at going over topics covered in class and clearing up tricky points. I don’t feel that grades should be determined from this technology due to obvious trouble shooting problems and other considerations but it seems to be an effective teaching tool. Overall through our excercises on the 2nd law of gases and solids, I greatly clarified my knowledge on u, s, and h’s dependence on temperature and pressure in different cases.”

“I like it. It makes the class much more interactive, and helps keep your attention.”

“I think this was great in terms of holding my attention better! I grasped the concepts a little better and I had fun!”

“This was fun. I like how the instructor is able to dismantle misunderstandings that the class seems to have.”

Full Use in Class (ChE 312). Student perceptions of the use of WISE in ChE 312 were also measured using a survey. The survey consisted of nine Likert-scale questions and one question that focused on the type of problem format most preferred. There were also three questions which required written comments. Results from the Likert-scale survey questions are summarized in Table 3, placed in ascending order from highest ranked to lowest ranked. In the highest rated response (4.0), students believed the short answer follow-ups were useful in promoting reflection. They also indicated they were more engaged intellectually and more actively involved through WISE. The lowest rated responses were that WISE improved awareness of misunderstandings (3.1) and that WISE should be used in other classes (3.1). However, for the latter question, it is unclear whether students believe WISE would not be useful in helping them learn or they simply prefer a less interactive environment since it has lower cognitive demands. Unlike the Pilot Study, a few students showed a strong disagreements of the statements. WISE facilitates several different types of questions. Table 4 presents the results for what type of question the students felt was most effective. As indicated in the table, different students liked different types of problems. These results again show a perceived value in the short answer follow-up, and indicate a preference towards conceptual problems.

Table 3. Assessment data from Winter 2007 Thermodynamics class, using a Likert-scale (1=strongly disagree to 5=strongly agree)

Question	1	2	3	4	5	Avg	n
The short answer follow-ups to multiple choice questions helped me to think more about the question and the answer that I chose.	0	2	6	24	11	4.02	43
I have to think more in class sessions that use WISE than those that do not.	2	4	7	15	16	3.89	44
I am more actively involved in class when WISE is used	1	5	10	12	16	3.84	44
When I was asked to solve a numerical problem that required calculations, using WISE made me focus on the problem more than in other classes when I know I do not have to turn it in.	2	4	8	22	8	3.68	44
Using WISE helps me to understand the concepts behind the problems.	0	8	5	27	4	3.61	44
Seeing the class responses to a concept question (bar graph) helps increase my confidence.	2	1	16	20	5	3.57	44
In this course, I am more aware of my misunderstandings than in courses taught by traditional methods.	1	6	13	17	7	3.52	44
WISE should be used in other classes	5	6	14	15	4	3.16	44
The change in awareness of my misunderstandings is due to WISE.	4	8	14	18	0	3.05	44

Table 4. Survey results of most effective question type

The following types of problems were given in WISE. Which one do you think was most effective?	
short answer - concept	15
problems with numerical answers	9
multiple choice with short answer follow-up	17
multiple choice without short answer follow-up	1
Excel spreadsheet calculations	2

In addition to the survey, students were asked to comment on the following three items:

1. Describe any problems specifically based with **technology** that you encountered when WISE was used in class
2. Describe any benefits of using WISE in class
3. Write any additional comments or thoughts

A summary of the student perception based on these comments follows. The technology issues that were mentioned in more than one response included: timed out when trying to submit a timed problem (13 responses), battery life (6 responses), timed out of the server (6 responses), problems with connectivity with the wireless network (5 responses), linking of questions (4 responses), cumbersome to bring a laptop to class (3 responses). Technical problems have a large impact when trying to deploy innovative uses of technology in the classroom and this type of assessment gives an opportunity to improve its effectiveness. Several of these problems have been addressed by improving the software. To limit the effect of students timing out a question, a 15 second buffer has been added, while server issues have been addressed by increasing the time until it logs students out. Finally, on linked questions, students can now go backwards and change the answers they previously submitted. The greatest technical issues that remain are consistent connectivity from the wireless for every student in class, and the limits of the classroom architecture. Ideally a class would have desks with power outlets and have space to house a laptop in addition to taking notes.

The benefits the students describe in using WISE largely reflect what it was designed to accomplish. They state they are actively involved (18 responses), cognitively engaged (14) and understand better (22). They all interact, and they must think in class. As one student put it, “[you] cannot sleep and complete WISE simultaneously.” There were many students who appreciated the immediate feedback and the realization that their understanding was at a similar level to their peers. Other benefits were articulated that were not thought of in its design. For example, one student stated, “I have issues with concentration in class because of my anxiety. When using WISE it is easier for me to stay focused and I get more out of it.”

While research suggests that exclusively lecturing in class limits student learning,²² the main concern students had was the amount of class time WISE took. One student wrote, “I would have appreciated more lecture on the topics we’re discussing in class.” Some students also commented that they felt it was good, but still had some bugs to work out. There was also dissatisfaction about not being able to see the questions posed after the class was over. Finally, one student commented, “this class was tougher than other classes because it [had] more of the conceptual material.”

Conclusion

A Web-based Interactive Science and Engineering (WISE) Learning Tool that facilitates active learning in the classroom and metacognition and allows assessment of student learning (formative assessment) has been developed and implemented in 9 engineering classes. WISE allows an instructor to pose to the class different types of questions (including: multiple choice answers, multiple choice with short answer follow-up, numerical answers, short answers, and Likert-scale survey). The pilot application and the integrated deployment in a junior level class has been described and assessed. WISE has been demonstrated as a useful tool to identify student misconceptions and to promote active learning as demonstrated by peer instructions. Student surveys show that students perceive that they are more engaged, think more and gain better conceptual understanding in classes that use WISE. On the other hand, there is a concern that less material is covered than in a traditional lecture-based class. Some of the technical challenges have been addressed within the software; however, other challenges require more systemic

infrastructure modifications such as classroom architecture design and wireless connectivity issues.

Acknowledgements

The authors acknowledge financial support from a LL Stewart Faculty Scholar Award and a Teaching and Learning Grant from the Center for Teaching and Learning and to Paul Montagne and Steve Cleveland for technical discussions on software development and for their support in implementation. The authors also greatly appreciate the use of the questions in the concept inventories developed by Ron Miller and coworkers. The authors appreciate Niki Schulz's thoughtful feedback on the paper.

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Appendix A. Instructor Interface in WISE

The instructor's exercise library enables the creation of a wide variety of exercises. Instructors can create both graded and un-graded multiple choice exercises with and without short answer follow-up questions. Associated answers and distracters can be jumbled or not. Instructors can also create Likert scale surveys, short answer exercises, and numerical exercises with a correct answer and a tolerance or just directly enter a range for the correct answer. No matter the kind of exercise, exercises may be created with a variety of content. They may have plain text or custom html. Pictures, hyperlinks, references, and notes may also be added. It also allows for the creation and linkage of topics, concepts, and learning objectives to exercises to help with organization and analysis. An example of the screens to create the "Boiling Water" exercise is shown in Figures A1 – A3.

The class activities area allows for the assignment and organization of the exercises created above. In class exercises can be scheduled ahead of time for the week and day of use. Then, they may be started and stopped manually or started and stopped automatically via a timer. Homework is assigned only by due date. Groups of homework or in class exercises can also be linked in a sequence. There is also a virtual hand raise feature where questions or comments are accessed in real time. The screen for Week 1, Wed is shown in Figure A4.

The grade book is where results are tabulated and students are managed while the statistics area displays statistics for the instructor. This latter area also includes an analysis to help with ABET reports. It lists the number of exercises corresponding to each learning objective and the point percentage by total and by exercise type, including exercises manually graded. One such screen is shown in Figure A5.

WISE Learning Tool Home - Microsoft Internet Explorer provided by OSU College of Engineering

https://secure.engr.oregonstate.edu/che/WISE/WISE.php?goto=CreateExercise

WISE Learning Tool Home

WISE Learning Tool

Oregon State UNIVERSITY

[Exercise Library](#)

[Create Exercise](#)

[View Exercise](#)

[Topics/Concepts](#)

[Class Activities](#)

[Grade Book](#)

[Statistics](#)

[Administration](#)

[Help](#)

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Web-based Interactive Science and Engineering Learning Tool

Create Exercise - Details

*Title

*Exercise Type

*Skill Area

Concept

Topic

Course Objectives

(*) Indicates Required Field

Figure A1. Create exercise menu (Screen 1)

Figure A2. Create exercise menu (Screen 2)

Figure A3. Create exercise menu (Screen 3)

WISE Learning Tool Home - Mozilla Firefox

File Edit View History Bookmarks Tools Help

https://secure.engr.orst.edu/wise/wise.php?goto=InClassExercises

Getting Started Latest Headlines

WISE Learning Tool

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[Exercise Library](#)
[Class Activities](#)
[In Class Exercises](#)
[Homework](#)
[Virtual Hand Raise \(0\)](#)
[Grade Book](#)
[Statistics](#)
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In Class Exercises (Week 1 - Wednesday)

Select New Week Week 1

Select New Day Wednesday

[Add existing](#) [Create new](#)

	CONCEPT	TOPIC	TITLE	LINKED	STATUS
☐	First Law	5.5 Joule-Thomson Expansion and Liquefaction	Valve Tout	No	completed
☐	Phase relationships	6.2 Pure Species Phase Equilibrium	Boiling Water	No	completed
☐	Phase relationships	6.2 Pure Species Phase Equilibrium	Solid-vapor-1	Yes	completed
☐	Phase relationships	6.2 Pure Species Phase Equilibrium	Solid-vapor-2	Yes	completed
☐	Phase relationships	6.2 Pure Species Phase Equilibrium	Solid-vapor-3	Yes	completed
☐	Phase relationships	6.2 Pure Species Phase Equilibrium	Solid-vapor-4	Yes	completed

Assign Re-Assign Results Link To Previous Remove View All

Move Up Move Down

Move To:

Monday	Week 1
Tuesday	Week 2
Wednesday	Week 3
Thursday	Week 4

Figure A4. In class exercises menu; the last four exercises are linked.

WISE Learning Tool

Oregon State UNIVERSITY

[Exercise Library](#)
[Class Activities](#)
[Grade Book](#)
[Statistics](#)
[View Statistics](#)
[Manage Student](#)
[Stat View](#)
[ABET](#)
[Administration](#)
[Help](#)

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Statistics

Organize by: Concept or Topic or Exercise or Multiple Choice (20)

CONCEPT	Avg. % Correct	Range % Correct	# of Exercises
Other	63.49	52.81	3
First Law	65.91	0	1
Phase relationships	58.09	66.54	8
Mixing	59.3	58.14	2
Fugacity-liquid	55.42	44.24	2
Reaction rate vs. equilibrium	80.49	0	1
Chemical Reaction Equilibrium	76.54	1.89	2

Figure A5. Summary statistics of multiple choice exercises

Appendix B. Screenshot of the Valve Problem from the Student Interface

Web-based Interactive Science and Engineering Learning Tool

Conceptualization Exercise

[Virtual Hand Raise](#)

[Exercises](#)

[Conceptualization](#)

[Math Primer](#)

[Real World](#)

[Examples](#)

[Links](#)

[My Statistics](#)

[Homepage](#)

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An ideal gas flows steadily through the piping system and valve shown below. The inlet pressure and temperature are P_1 and T_1 and the pressure drops through the valve to a lower value, P_2 .

Assuming the valve is well insulated and inlet and outlet pipes connected to the valve are the same diameter, what is the relationship of the outlet temperature T_2 to the inlet temperature T_1 ?

- ☐ $T_2 > T_1$
- ☐ $T_2 < T_1$
- ☐ $T_2 = T_1$
- ☐ Can't answer until I know what gas is flowing

Please explain your reasoning in the space provided below.

Submit

Figure B1. Screenshot of the student interface corresponding to the problem in Figure 1.

Appendix C. Summary of results from multiple choice questions in ChE 312

Table C1. Summary of results from ChE 312 multiple choice questions

Question	%	#	Distracters					#	Date and time
	correct	correct	1	2	3	4	5	Students	
1	65.9	29	8	7	0			44	1/10/2007 11:04
2	86.1	37	5	1	0			43	1/10/2007 11:18
3	65.9	29	12	3	0			44	1/10/2007 11:27
4	50.0	22	13	9	0			44	1/10/2007 11:27
5	58.1	25	12	6	0			43	1/10/2007 11:27
6	19.5	8	22	11	0			41	1/10/2007 11:27
7	65.9	29	13	2	0	0		44	1/24/2007 10:06
8	88.4	38	5	0	0			43	1/24/2007 10:34
9	59.0	23	10	3	2	1		39	1/31/2007 11:07
10	60.0	24	8	8	0	0	0	40	1/31/2007 11:19
11	38.1	16	12	9	4	1	0	42	1/31/2007 11:29
12	30.2	13	14	6	5	3	2	43	2/7/2007 10:07
13	90.9	40	2	2	0			44	2/7/2007 10:41
14	32.5	13	14	12	1	0	0	40	2/21/2007 11:02
15	76.7	33	9	1	0	0	0	43	2/21/2007 11:15
16	80.5	33	8	0	0	0		41	3/7/2007 11:42
17	75.6	31	6	4	0	0		41	3/7/2007 11:42
18	77.5	31	8	1	0	0		40	3/7/2007 11:42
Average	61.7%	26.3	10.1	4.7	0.7	0.5	0.4	42.2	