STUDENT ATTITUDES IN THE TRANSITION TO AN ACTIVE-LEARNING TECHNOLOGY

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Education research has provided substantial evidence that active learning strategies have a positive impact on student learning.[1] Using pre/post-test data of more than 6,000 physics students, Hake[2] found that courses that used active-learning methods had learning gains that were twice as large as the gains for classes that used only traditional lectures. Similarly, over a span of 13 years, Poulis, et al.,[3] studied more than 5,000 students in chemical engineering, electrical engineering, industrial engineering, chemistry, and physics classes. They found the pass rate in the classes that used active, concept-based instruction was 25% greater than those classes that used traditional lecture.

Student resistance, however, can deter implementation of these alternative active-learning approaches.[4] Furthermore, the prevalence and impact of student resistance is often understated. Students react to the change from sitting passively in lecture to becoming actively engaged in their own learning. This change challenges their assumptions about what learning involves and the appropriate roles of the student and the instructor,[5] revealing their expectations of what it means to be in a "good class"[6] and what should be "normal operating procedure."[7] It is argued that students know what works to achieve high grades in the traditional lecture environment and resist changes to "the system." One study of seven anatomy and physiology instructors who changed their classes to incorporate active-learning pedagogies found that five encountered significant student resistance.[8] In the context of *Problem-Based Learning*, Woods[9] identifies stages of coping with such changes that are similar to coping with a catastrophic event, including: shock, denial, strong emotion, resistance, acceptance, struggle, better understanding, and, finally, integration. While this model suggests that student resistance can fade with time, there is the danger that initial student resistance will cause an enthusiastic instructor to abandon innovative pedagogies. One goal of this study is to examine how student perceptions change with time as an active-learning technology is integrated into the department learning environment.

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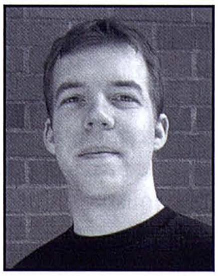

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Active-learning pedagogies have become enabled by technology-based classroom tools. For example, the use of Personal Response Systems, or clickers, has increased substantially.[10,11] Clicker technologies enable students to provide instantaneous feedback to instructor questions via a handheld device. Each clicker unit has a unique signal so that the answer from each individual student can be identified and recorded. Most clickers are limited to multiple-choice questions, however.

This study uses an alternative, technology-based tool, the Web-based Interactive Science and Engineering (WISE) Learning Tool.[12] Its use of computer technology permits a significantly wider range of learning activities than clickers allow. Specific to this study is the ability to ask students to provide short-answer, written explanations following multiple-choice questions. Pedagogically, the short answers provide students opportunities for metacognition through reflection.[13] Chi, et al.,[14] argue that the active process of explaining encourages students to integrate new knowledge with existing knowledge and leads to richer conceptual understanding. In addition, analysis of free-response explanations can provide researchers greater insight into the nature and range of student misconceptions.[15-17] A second goal of this study is to ascertain if students believe that providing written explanations increases the effectiveness of conceptual questions.

RESEARCH QUESTIONS

This study analyzes student responses over time to a survey about their perceptions of the use and effectiveness of WISE. Specifically, the research questions are:

1. *How do student perceptions change with time as a new active-learning technology becomes integrated into the department curriculum and culture?*
2. *Do students perceive that written explanations facilitate deeper reflection about their answers to the multiple-choice concept questions?*
3. *Is there any evidence in their statements of how students conceive conceptual learning?*

METHODS

This study spans five years and encompasses a cumulative total of 237 student participants. All students were enrolled in the second term of a junior-level, undergraduate Chemical Thermodynamics course at Oregon State University. The research was approved by the Institutional Review Board and participants signed informed-consent forms. The course is required for chemical engineers and taken as an elective by a small number of biological and environmental engineers. Therefore, each cohort has had similar programmatic experiences across the two and a half previous years of the curriculum. It is not possible to characterize the equivalence of each cohort in detail, however, and results of this study should be interpreted with that in mind.

The Web-based Interactive Science and Engineering (WISE) Learning Tool is used to collect student responses.[12] WISE is enabled through a Wireless Laptop Initiative, which mandates that every student own a laptop computer. In the course studied in this paper, WISE was used once a week in the two-hour recitations that the entire cohort attended. Over the five years of the study, an increasing fraction of the cohort used Internet-capable, smart cell phones instead of laptops. The same instructor taught the course all five years. This instructor has substantial teaching experience, including with active-learning techniques. While this study represented the first experiences in using WISE, the instructor has implemented several other technology-based innovations in the curriculum.

WISE is designed for use in the context of a learner-centered class based on active learning and real-time formative assessment. It 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. 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 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.[18] 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.

Figure 1 shows an example of a typical concept question as it would be displayed simultaneously on the students' laptops or smart phones. Such concept questions are designed to be conceptually challenging but typically require no computation so that students cannot rely solely on equations to obtain the answer. They focus on the most important concepts in a subject. The concept questions that were used were designed towards several possible objectives, including: to elicit or reveal pre-existing thinking in students, to have students apply ideas in new contexts, to ask students to qualitatively predict what will happen, to use examples from everyday life, or to have students relate graphical and mathematical representations. The question shown in Figure 1 asks the students to select a multiple-choice response, to provide a written explanation of their response (termed a "short answer follow-up"), and to rate their confidence. While this general format was the most common used in the course in this study, other question types were also used, including short answer, numerical answer, and ranking exercises.

Figure 2 (next page) shows a photograph of the use of WISE during a class. The logistics of delivery are based on the Peer Instruction pedagogy developed by Eric Mazur.[19] Students are first asked to respond individually to the concept question posed. They then self-select into small groups to discuss the answer. Next, the question is posed again and they respond individually. Finally, the instructor displays the results and can either explain the rationale for the correct answer or can lead a class-wide discussion, if appropriate. An analysis of student responses in WISE based on different delivery methods is reported elsewhere.[20] This type of active-learning pedagogy is often technologically supported with clickers. Clickers, however, are limited to the multiple-choice portion of the question. One goal of this study is to determine if students perceive that the reflective elements of questions like those shown in Figure 1 prompt deeper thinking and evidence-based reasoning.

Student perceptions of WISE were measured in each of the first five years that this technology-based, active-learning tool was used in the thermodynamics course. Year 1 represents the first time WISE was used throughout any course. Over the time of the study, WISE was integrated into other courses

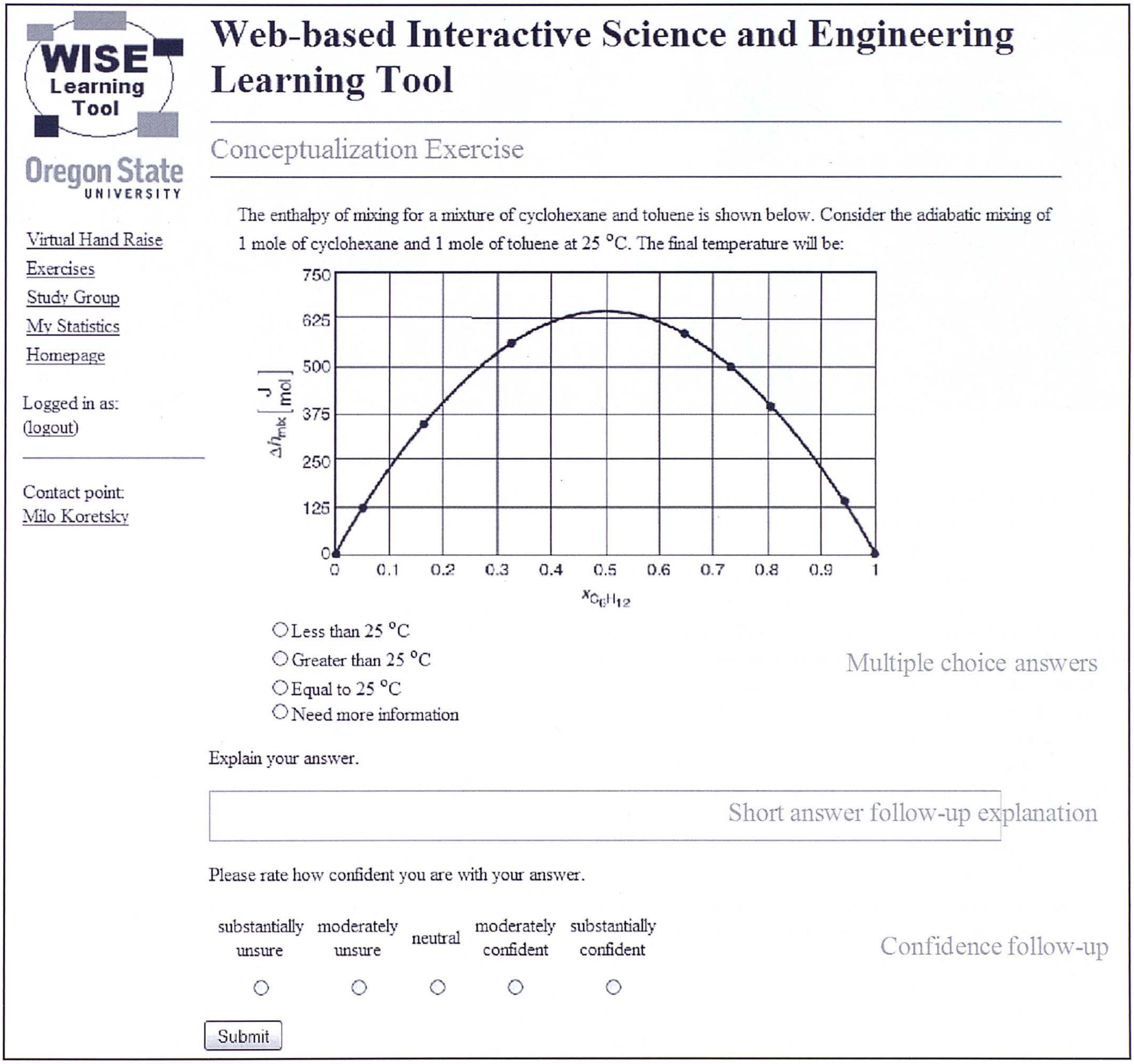


Figure 1. *A sample interactive concept question, as the students see it in the WISE learning system. The "short answer follow-up explanation" prompts students to be reflective in their response to the multiple-choice question.*

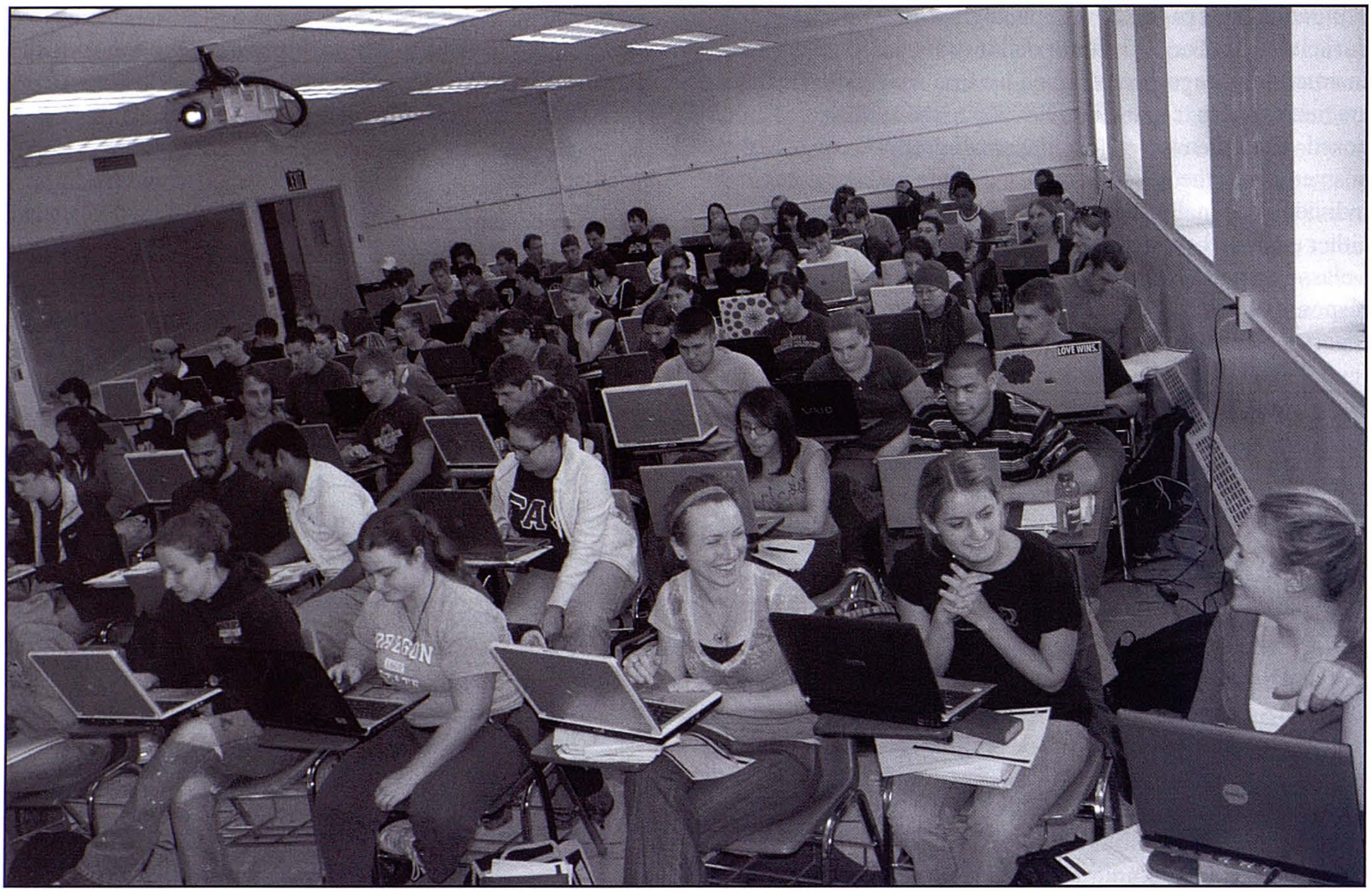


Figure 2. *Students engaged in a learning activity using WISE.*

in the curriculum, including the three required sophomore-level courses that preceded thermodynamics. The department culture also facilitated the transition to using WISE. There is broad collegial and administrative support for this active-learning initiative, some of which is described as follows: faculty in the program were willing to adopt the technology into their courses; the department has historical value of curricular innovation and a focus on student learning; the department head understands the value of and is supportive of curriculum reform; the faculty demonstrate respect for previous curricular innovations by the faculty member who developed WISE (the primary author of this paper); and many of the faculty who integrated WISE also voluntarily participate in an engineering education research seminar led by this faculty member.

The survey instrument consists of eight Likert-scale statements (1=strongly disagree to 5=strongly agree) and three questions that require written comments. The Likert-scale statements are shown in the first column of Table 1. Statements 1 through 6 were adapted from a similar study on clickers.[21] Statement 8 was written specifically to address Research Question 2 in this study. A non-parametric Kruskal-Wallis test[22] was used to compare student responses to each statement by year and to determine if the median rank was statistically different (*i.e.*, not statistically the same). This test does not assume the populations are normally distributed, but does assume that the distribution for each year has the same shape.

Three free-response questions were also asked, as follows:

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, and*
3. *Write any additional comments or thoughts.*

In this study data are reported for Years 1, 2, 4, and 5. In each of these years the course was taught in the same classroom, which had adequate wireless coverage for all of the students' laptops. The class was moved to an alternative room in Year 3 that had insufficient wireless coverage to allow all of the students in the class to simultaneously access WISE on their laptops. This classroom environment presented an additional challenge in delivering the technology-based, active-learning pedagogy. Eventually, the class was divided in half, with one half using WISE and the other half doing a pencil and paper activity, and then the activities were reversed. This delivery was significantly different from the four other years. Consequently, this cohort was excluded from the study.

RESULTS AND DISCUSSION

The average ratings for the eight Likert-scale statements and the number of responses for Years 1, 2, 4, and 5 are shown in Table 1. A five-point scale was used with a rating of 1 indicating the student "strongly disagrees" with the statement, a rating of 3 being neutral, and a rating of 5 indicating the student "strongly agrees." All of the responses in Table 1 indicate that, on average, students viewed all eight statements favorably each year. In Years 4 and 5, six of the eight statements had average ratings greater than 4. The highest-rated responses are in bold. In three of the years, students agreed most strongly with the statement that their written reflections, the "short-answer follow ups," were useful in promoting reflection and encouraging deep thinking. They also indicated they were more engaged intellectually and more actively involved through WISE. The lowest-rated statement was the one that asked if WISE, specifically, was responsible for improved awareness of misunderstandings.

Figure 3a plots the percentage of students who agree with each statement (ratings of 4 or 5) for each year in the study and Figure 3b plots the percentage who disagree (ratings of 1 or 2). For all statements, the proportion of students who agree with the statement is much greater than the proportion of students who disagree. Additionally, for most statements it appears that the percentage of students who agree trends upward with time and the percentage of students who disagree

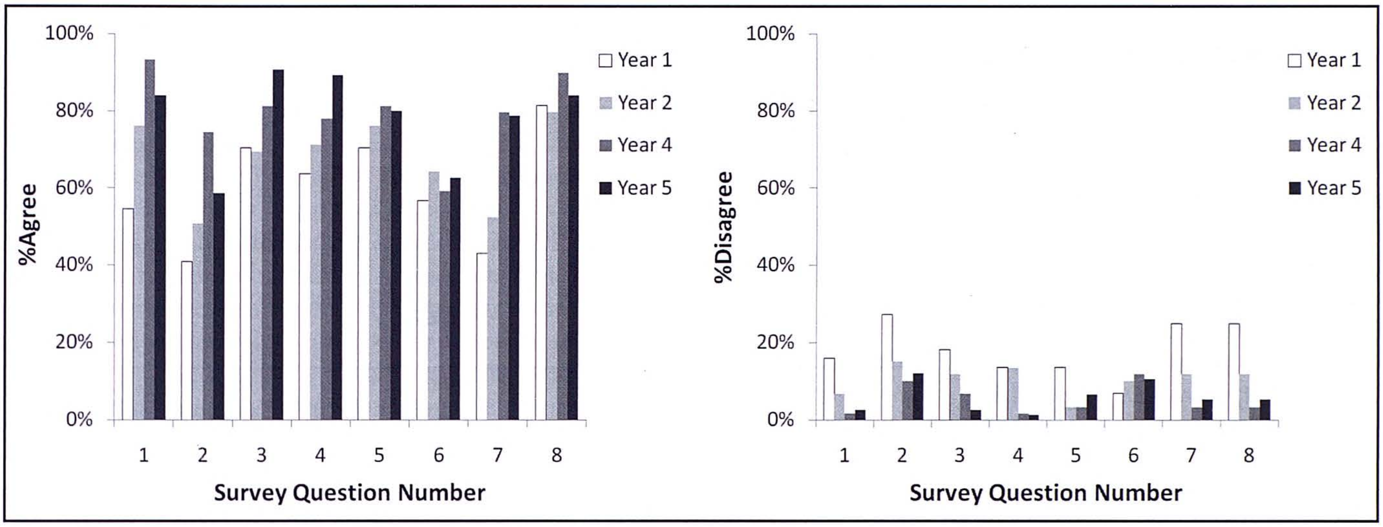


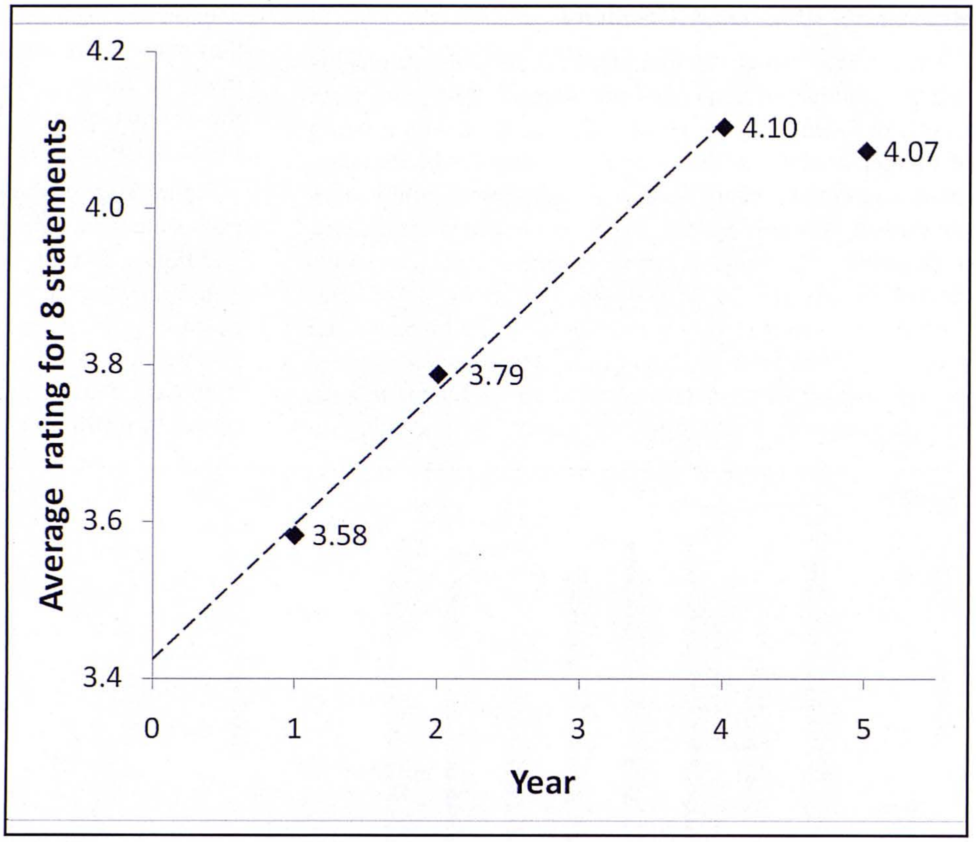
Figure 3. *a) Percentage of students who agree (rating of 4 or 5) with each of eight statements in the student survey for the four years of the study. b) Percentage who disagree (rating of 1 or 2). See Table 1 for the statements.*

TABLE 1
Average scores of student survey at the end of the Chemical Engineering Thermodynamics 2 class, using a Likert-scale (1=strongly disagree to 5=strongly agree).*
In the last column, the p-value for the Kruskal-Wallis test, applied to the "unsteady-state" data in Years 1, 2, and 4.

Statement	Year 1 (N = 44)	Year 2 (N = 59)	Year 4 (N =59)	Year 5 (N =75)	p
1. In this course, I am more aware of my misunderstandings than in courses taught by traditional methods.	3.52	3.95	4.37	4.16	0.0000
2. The change in awareness of my misunderstandings is due to WISE.	3.05	3.37	3.76	3.64	0.0004
3. Using WISE helps me to understand the concepts behind the problems.	3.61	3.69	4.22	4.24	0.0001
4. I am more actively involved in class when WISE is used	3.84	3.88	4.15	**4.36**	0.3371
5. I have to think more in class sessions that use WISE than those that do not.	3.89	4.00	4.19	4.15	0.3899
6. Seeing the class responses to a concept question (bar graph) helps increase my confidence.	3.57	3.78	3.64	3.75	0.4059
7. If WISE was used in other classes, my conceptual understanding in those classes would be better.	3.16	3.49	4.08	4.09	0.0000
8. The short answer follow-ups to multiple-choice questions helped me to think more about the question and the answer.	**4.02**	**4.14**	**4.41**	4.20	0.0307

* The highest-rated responses are in bold.

Figure 4 (right). Aggregate average student rating of all eight statements plotted vs. the year of the study. Year 1 was the first time WISE was used for a course. The line represents a fit to the proposed "unsteady-state" process of student normalization.



trends downward. This change of perception with time is discussed in the next section.

Change in Attitudes With Time

Figure 4 plots the aggregate average rating of all eight statements vs. year of the study. Year 1 represented the first comprehensive use of WISE in a class. The ratings show a proportionate increase in Years 1-4, and then level off in Year 5. We attribute Years 1 through 4 as a transition (unsteady-state) period as this technology-enabled, active-learning tool is integrated into the curriculum at OSU. We believe that Year 5 indicates student attitude at "steady-state" or "saturation" for this course. For convenience, we label it as "steady-state" for the purposes of this paper, but acknowledge this assignment is speculative. The initial 4-year period corresponds to one generation of college students.

Based on this observation, we asked, "For which statements can we state to greater than 95% confidence that the ratings had changed over Years 1 to 4 of the study?" The p-values for such a statistical analysis using the Kruskal-Wallis test are shown in Table 1. Five statements (1, 2, 3, 7, and 8) have p-values less than 0.05. We can infer that there is statistical evidence that student ratings for these statements improved with time. Three statements (4 - 6) have p-values much greater than 0.05. This result indicates that there is not statistical evidence that students are rating these higher with time. Said differently, even though ratings appear to generally trend upward for statements 4 - 6, we cannot state with confidence that this trend is not due to statistical variation from year to year.

The statements that show statistically significant upward trends are distinctly different in character than those that do not. The ones that do not show significant changes represent more direct in-class activity ("more actively involved in class" or "think more in class sessions") and emotional responses ("bar graph helps increase my confidence"). On the other hand, those that show a significant upward trend are more interpretive, specifically about learning ("aware of my misunderstanding," "understand the concepts," or "my conceptual understanding would be better"). These latter types of statements are more likely to be influenced by students' subjective attitudes about the technology-enhanced learning tool. In a similar study on student perception, White, et al.,[23] also found initial reticence of students to admit the extent to which they have learned in the transition to a problem-based learning pedagogy.

The nature of answers to the free-response questions of the survey is consistent with this analysis. In Year 1, there were several statements indicating trepidation about the use of WISE. Several students expressed concern that the class time used for the active-learning exercises would detract from the amount of material covered (*e.g.*, "I felt like if we did not use WISE we would be able to cover much more material in the class."). Additionally, the following response alludes to some general negative discourse among the cohort: "I think you will have recieved (sic) enough info from students on why they didn't like it, I think that the questions asked with reguards (sic) to concepts help us to direct our thinking, but the concepts cannot be written in some book, read and learned without a thought process happening." These types of statements were absent from student comments in the Years 2, 4, and 5, suggesting a shift in the normative expectation from other students.

As WISE has been delivered over time, students' perceptions of its effectiveness improve, and they view it as more beneficial to their learning. There are several factors that could contribute to this change in student attitude, including:

1. *Assimilation of WISE in the department's learning environment*
2. *Improvement of the technology*
3. *Improvement in the instruction*

We believe that the most significant factor in the change in attitude for the cohorts in this study is the assimilation of WISE in the department's learning environment, *i.e.*, with time WISE has simply become part of the normative student expectation about learning. The first year it was used in the junior-level thermodynamics course, there was interaction with seniors (some of whom were retaking the class) who did not use this technology the year before. We speculate that this disparity sets up a dynamic of "why do we have to do it when they didn't?" More importantly, over the next two years, WISE was integrated into the three sophomore-level courses (Material Balances, Energy Balances, and Process Data Analysis). Thus, by Year 4, most students had three previous courses where WISE was used to facilitate active learning. The effect of this assimilation is clear when reading the free-response survey items from Years 4 and 5 where students frequently contextualize their comments for the thermodynamics class based on experiences from past classes (*e.g.*, "No problems in this class but some classes I have had have had problems with logging on or submitting answers"). Such curricular integration makes students less likely to dismiss this pedagogy as a pet project of a maverick instructor. When adapting innovative educational technology and pedagogy, as much as possible, it is useful to have a coordinated approach through a set of courses in the curriculum.

The second factor affecting students' perception of WISE is the technology. Especially with new technologies, even small glitches in performance can be greatly amplified in student perception. Since the software was developed in-house, a "continuous improvement" approach was used where small changes in the software were made in response to student feedback. Perhaps more importantly, the wireless connectivity in the College of Engineering has systematically been improved over the five years of this study. In response to the survey question, "Describe any problems specifically based with technology that you encountered when WISE was used in class," the percentage of students that stated there were no technology-based problems increased in each year of the study (except Year 3 as explained above). In Year 1, 51% of the students reported no problems, 59% in Year 2, 67% in Year 4, and 78% in Year 5. The most common problems cited were network connectivity (27% in Year 1 to 14% in Year 5) and battery life (10% in Year 1 to 5% in Year 5). These problems are generally at the level of the technology infrastructure and not associated specifically with the WISE software application.

Finally, teaching with learner-centered pedagogies requires that the instructor deploys a different set of skills than the traditional didactic lecture. There can be a transition as an instructor adapts. For example, Keeney-Kennicutt, et al.,[24] describe student attitudes about a web-based writing and assessment tool they used in a general chemistry course. Their study shows a similar pattern in student response growing more favorable over time; however, unlike the study reported in this paper, their initial perceptions were overwhelmingly negative (four out of the five items had more students disagree than agree). They attribute the change in student attitudes over the seven semesters in the study primarily to the adjustments they made in instruc-

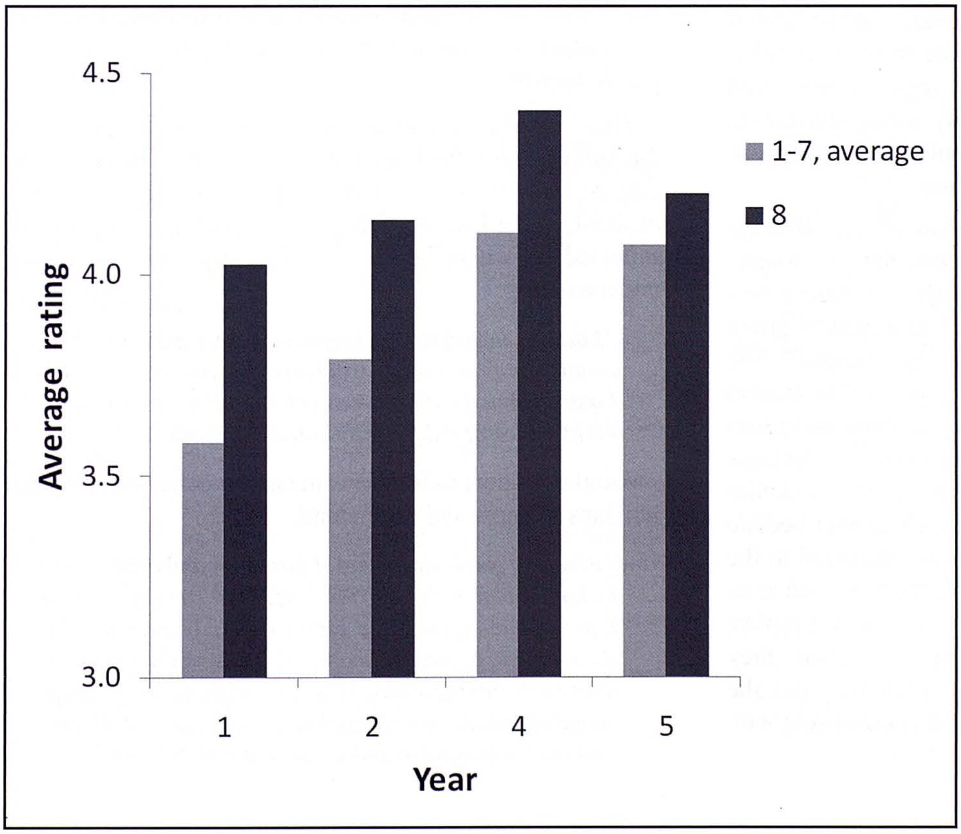


***Figure 5 (left).** Student aggregate average rating for statements 1-7 and average rating for statement 8 vs. year in the study.*

tion and implementation. While aspects of instruction were changed over the five years of this study, we believe that this effect was the least significant of the three discussed above.

It is critical for instructors adapting innovative pedagogies for the first time (and for administrators evaluating those instructors) to recognize that there is a transition period as students adjust to the new expectations. In this context, it is important to be prepared for the possibility of strong initial student "push back." As shown in Figure 3b, the percentage of students in this study who disagree, part of whom initially formed a "vocal minority," decreases dramatically with time from as high as a quarter of the cohort for some statements in Year 1 to just a few percent in Year 5. This type of student resistance within a class can be attenuated by repeatedly explaining to students the purpose of and rationale for the active-learning technique[6] and building rapport in the classroom.[25] Due to the factors cited above, however, it may take several years for students to completely normalize expectations and reach "steady-state."

Perception of Value of Written Reflection in Learning

As Table 1 shows, in Years 1, 2, and 4, the average rating for statement 8, "the short-answer follow-ups to multiple-choice questions helped me to think more about the question and the answer," had the highest value of all the Likert-scale statements. It was also rated very favorably (4.20/5.00) in Year 5. Figure 5 compares the aggregate averages of the other seven statements to the statement 8 rating for each year of the study. Clearly students viewed the reflective written explanations as beneficial to learning. One of the advantages of the laptop-based technology interface of WISE is the ability to develop a more diverse range of question types than available with clicker technology. In their view, simply asking students to reflect on their answer choices to multiple-choice questions affords reflection and encourages thinking.

A recent study of the use of clickers in Introductory Biology studied the effect of displaying an "intermediate bar graph" after students answered a concept question, but before they discussed with their peers as compared to a control group where the intermediate class result was not shown.[26] The authors found this practice negatively impacted the answer choices following peer discussion. They attribute the result to students unthinkingly accepting the consensus of the class in selecting the second multiple-choice answer. In a similar study, we found that when using WISE, such an intermediate display had no effect on student choice as compared to the same type of control group.[20] While other factors need to be considered in comparing the two studies, one could speculate that by having students provide a written reflection, they were prompted to already be "thinking" when they saw the intermediate results. Such an explanation is consistent with the disparate results between studies.

With the increasing use of clickers in the classroom, we suggest that the development of a written free-response capability into Personal Response Systems would be fruitful for clicker manufacturers. Alternatively, instructors could have students write answers with pencil and paper while using these active conceptual questions. This modification may only partially realize the desired reflection, however. Finally, as an alternative to laptops, programs like WISE that integrate written reflection can be enabled by smart phones. Over the five-year study, unsolicited responses from students commenting on their use of smart phones have steadily increased (0 in Years 1 and 2, 2 in Year 3, 12 in Year 4). Of these 14 responses, only one cited a technical issue using the phone (lower than the rate for laptops). To the contrary, most respondents seemed to be boasting about using a smart phone (*e.g.*, "I had no problems. I enjoyed being able to use my iPhone instead of bringing a computer to class"). Reflection plays a critical role in promoting learning. We believe that there is a great opportunity in using smart phone technology to promote reflection in this active-learning pedagogy.

Student Interpretation of Conceptual Change

A primary goal of the active-learning pedagogy enabled by WISE is to transcend beyond asking students to memorize definitions and algorithms and instead to focus on conceptual learning. Posner, et al.,[27] believe that a critical condition for such conceptual change to occur in a student is when his/her prior knowledge comes into cognitive dissonance with new knowledge. The resolution of this conflict can lead to learning if the concept being examined is restructured and the conception is incorporated into an integrated schema, like that of experts.

There are many comments to the free-response portion of the survey that reflect students' own interpretation of conceptual learning based on their experience with the WISE-enabled, active-learning pedagogy. For example, one student reflected on where he/she has difficulty with conceptual understanding:

> *"I usually understand concepts that are intuitive, it's the counter intuitive areas I struggle most with. In this course I quickly found out what was counter intuitive and learned how to think of it differently to make it intuitive."*

Another student indicated a change in his/her view of what it means to know and understand:

> *"From my previous courses, I just learn and apply. I will be honest that, in most of the case, I just know how to do it mathmatically (sic) and get the right answer, but...what does it mean behind the math, I don't think I'm that aware until I got into this class. This class required lots of understanding instead of just problem solving. And I did learn alot (sic) and experienced a different way to learn."*

These comments reflect a very individual interpretation of their experience in alignment with the goals of the curricular innovation. It should also be realized, however, that throughout the term this goal of conceptual learning has been made explicit to students, so their comments should be considered with that in mind.

CONCLUSION

Student attitudes were measured over the first five years that the WISE-based active-learning pedagogy was introduced into a junior-level chemical engineering course. In general, students viewed this learning experience more favorably with time. This study has several ramifications for instructors considering technology-based integration of pedagogy into the classroom. Elements that affect student perceptions include: (1) degree of curricular integration and the department culture, (2) the ability to improve technology as problems arise, and (3) modifying instruction appropriately for this type of pedagogy. In addition, students view the activity of providing written reflections as very helpful to learning. Technology developers and course designers who desire pedagogical integration of conceptual questions might consider ways to prompt such reflection in students, although more study is needed to see if improved student performance does indeed align with the student perceptions seen here.

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