AC 2011-351: INTERDISCIPLINARY COURSE DESIGN OPPORTUNITIES FOR CHEMICAL ENGINEERS:A MATERIAL BALANCES COURSE WITH INTEGRATED CONCEPT-BASED ACTIVE LEARNING PEDAGOGY - COMPARISON OF STUDENT PERCEPTION AND PERFORMANCE WITH THEIR ATTITUDES AND APPROACHES TO LEARNING

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A Material Balances course with integrated concept-based active learning pedagogy - comparison of student perception and performance with their attitudes and approaches to learning

Abstract

It is well established that students have a diverse array of learning styles and take different approaches to learning. For example, approaches to learning have been classified as "surface", "deep", and "achievement". Research has shown that there are several advantages to promoting and fostering a deep approach to learning. One method for encouraging a deep approach to learning is to utilize formative assessments that focus on conceptual understanding rather than recall or rote calculations. To that end, a Web-based Interactive Science and Engineering (WISE) Learning Tool that promotes concept-based learning has been incorporated into a multi-disciplinary Material Balances and Stoichiometry course. In an effort to examine the efficacy of WISE in the context of student epistemologies and approaches to learning, students also completed an attitudinal survey focused on beliefs about chemistry (CLASS-Chem) and a learning approaches survey (R-SPQ-2F). Understanding students' beliefs about conceptual learning and their approaches to learning is necessary to properly interpret student feedback and make appropriate adjustments to new teaching methods like WISE. A comparison of the two survey instruments is presented, along with an analysis of the extent to which students' performance on conceptual exercises and perception of WISE as a useful learning tool correlate with their attitudes and approaches to learning. The results presented here serve as a baseline for a longitudinal study seeking to determine whether active, concept-based approaches can change students' approaches to learning over time.

Introduction

Beginning with the pioneering work of Marton and Saljo[1, 2], a large body of research has emerged regarding student approaches to learning, the concept that the way students approach a task is influenced by their view of knowledge (epistemology), previous experiences, perception of the task, attitudes, motivation, context, and learning environment.[3, 4] Three different approaches to learning have been identified: a deep approach where students have an intrinsic motivation to learn and seek to maximize meaning; a surface approach where students rely on rote calculations and memorization and are typically motivated by external factors; and an strategic approach where students attempt to maximize grades using the most efficient method, and may take either deep or surface approaches, as appropriate. From a constructivist view, learning is the process of synthesizing new information with prior learning, making connections between fundamental concepts, and constructing a framework to be able to approach problems from different perspectives. Clearly, for effective learning a deep approach is preferred. Research has shown that students who adopt a deep approach are more likely to retain, integrate and transfer information at higher rates and more likely to enjoy learning.[3, 4] As such, a primary aim of teaching should be to promote the value of deep learning and concept-based knowledge structures and to facilitate the adoption of deep approaches to learning using appropriate teaching methods.

Many instructional innovations have been developed with the aim of promoting deep approaches to learning.[5-8] This study uses the Web-based Interactive Science and Engineering (WISE) Learning Tool developed at Oregon State University (OSU).[9] WISE provides the technology to support a student-centered pedagogy that promotes active, concept-based learning in a multidisciplinary engineering curriculum. Briefly, the tool allows an instructor to pose conceptual questions in several formats (e.g., multiple choice, numerical, short answer, and ranking) during class that probe for conceptual understanding. Students answer the questions using wireless laptops and responses are immediately available to the instructor. After an initial deployment of a question, the instructor can proceed in several ways. Class responses can be displayed to the class and students can be asked to discuss the problem with a neighbor or group. Following the small group discussions, the question can be posed again[10]; it has been shown that this type of peer-instruction can increase conceptual understanding.[11] At any point, the instructor can interject with appropriate discussion or address misconceptions discovered when going through the written explanations to multiple choice questions, for example. WISE activities serve as formative assessments that focus on conceptual understanding and provide a rich environment for identifying and addressing misconceptions through immediate feedback. In addition, they are highly interactive and promote a learner-centered environment. These features of the WISE Tool are closely aligned with teaching and assessment methods known to promote deep approaches to learning.[12, 13]

Several survey instruments have been developed to measure student attitudes about and approaches to learning. In the 1970s and 1980s, surveys that were designed for general use in higher education included the Study Process Questionnaire (SPQ)[14] and the Approaches to Study Inventory (ASI).[4] Both surveys have been recently updated to revise wording, reduce items, and incorporate new research on learning. In the 1990s, domain-specific surveys were developed specifically for physics, including the Maryland Physics Expectations Survey (MPEX),[15] the Epistemological Beliefs Assessment for Physical Science (EBAPS),[16] and the Colorado Learning Attitudes about Science Survey (CLASS).[17] MPEX and CLASS have been modified for chemistry in the form of CHEMEX[18] and CLASS-Chem,[19] respectively. This study uses both the revised two-factor Study Process Questionnaire (R-SPQ-2F)[20] and CLASS-Chem.

Research has shown that learning approaches are not static, they are context specific and students may change their approaches to learning over time.[12, 20] One of the primary uses of these survey instruments is to assess changes in students' attitudes or approaches in response to various teaching methods and innovations. For example, the RSPQ-2F has been used to study the effect of memory games,[21] different teaching methodologies,[22] and on-line learning components in calculus[23] and neuroanatomy[24] courses. Kortemeyer[25] found that students' conceptual learning (as measured by course grade and a concept inventory) in a first year physics course was correlated with student responses to the MPEX, but was even more highly correlated with demonstrated expert like behaviors as observed in discussion boards accompanying on-line homework assignments. In both cases, students who displayed more expert-like behavior demonstrated greater conceptual gains over the course of the semester.

Interestingly, researchers in various fields commonly find declines in students' beliefs and learning approaches as they progress through the curriculum. Using CLASS, Adams et al.[17] found nearly universal deterioration in beliefs about physics and physics knowledge during a first semester physics course. Barbera et al.[19] found similar results using the CLASS-Chem survey in first year general chemistry courses. Kember et al.[26] summarize several studies using the SPQ and found that average deep approach scores declined over three years for students enrolled in a range of courses at a polytechnic campus in Hong Kong and in an accounting degree program. On the other hand, they report that innovative instruction can lead to improvements in student beliefs. A project based design (graphic, industrial, interior photographic and fashion) curriculum, and a business curriculum promoting self reflection both resulted in statistically significant increases in deep approach scores as measured by the SPQ. Although conventional lecture-based educational practices tend to reinforce more naive beliefs, innovative instruction can develop more expert-like beliefs, which in turn can promote learning.

Over the last four years, the WISE Learning Tool has become an increasingly integral component of the Chemical, Biological and Environmental Engineering (CBEE) curriculum at OSU, and has been integrated into the three courses in the 2nd year sequence. At this point, we are interested in investigating the extent to which the use of WISE in the curriculum influences students' attitudes and approaches to learning over time. The objective of this study is to evaluate a chemistry specific attitudinal survey (CLASS-Chem) and a more general learning approaches survey (R-SPQ-2F) as means to characterize the students' beliefs and learning approaches. Using these surveys, we aim to establish a baseline with respect to student attitudes and approaches that can be used in a longitudinal study centered on the effectiveness of WISE for promoting deeper, concept-based learning.

Research Questions

The following research questions are addressed in this study. As measured on a cohort of chemical, biological, and environmental engineers at the start of a sophomore level material balances class:

1. Are student responses to a content specific attitudinal survey (CLASS-Chem) consistent with responses to a general approaches to learning survey (R-SPQ-2F)? Is each survey consistent within itself?

2. How does student performance on in-class interactive conceptual questions (WISE) relate to student exam performance. Is student performance related to their reported attitudes and approaches to learning?
3. How do students' perceptions of the effectiveness of the interactive pedagogy correlate to their reported attitudes and approaches to learning?

Methods and Measures

Participants: Participants in this study included 150 (out of 175 enrolled) students a sophomore-level course titled "Material Balances and Stoichiometry" at OSU. These students agreed to participate and signed an informed consent form approved by the Institutional Review Board. Demographics of the participants are shown in Table 1. The course is a requirement of three degree programs (chemical engineering, bioengineering and environmental engineering) and is the first of a three-course sequence that includes "Energy Balances" and "Process Analysis". Being the first department-specific requirement in the curriculum, the course also serves as the entry point for transfer students.

Table 1. Demographics of participating students

	Percentage
Major	
Chemical Engineering	57%
Bioengineering	20%
Environmental Engineering	17%
Other	6%
Gender	
Male	65%
Female	35%

Course Structure and use of WISE: The course met twice a week, for 2 hrs at a time. Class periods blended aspects of traditional lecturing with instructor and student worked example problems. In addition, the WISE Learning Tool was used in class once a week for approximately 20-30 minutes. Typically, two or three conceptual questions would be used in a single WISE session. A screenshot of an example question is shown in Figure 1. Students were asked to answer questions individually, and often required to provide written explanations to justify their choices. Once all students had answered, class results were displayed to the class as shown in Figure 2. Students' written explanations were also available to the instructor and could be used to guide discussion. Often, after seeing the results, students were asked to talk about the problem in small groups and then complete the exercise again. In all cases, a class-wide discussion followed. On average, students answered 96% of the WISE exercises administered during the term with 65% of students answering every WISE question. The final course grade was based on participation in WISE activities (5% plus the opportunity for 5% extra credit based on correct answers), nine weekly homework assignments (30%), and three exams (65%).

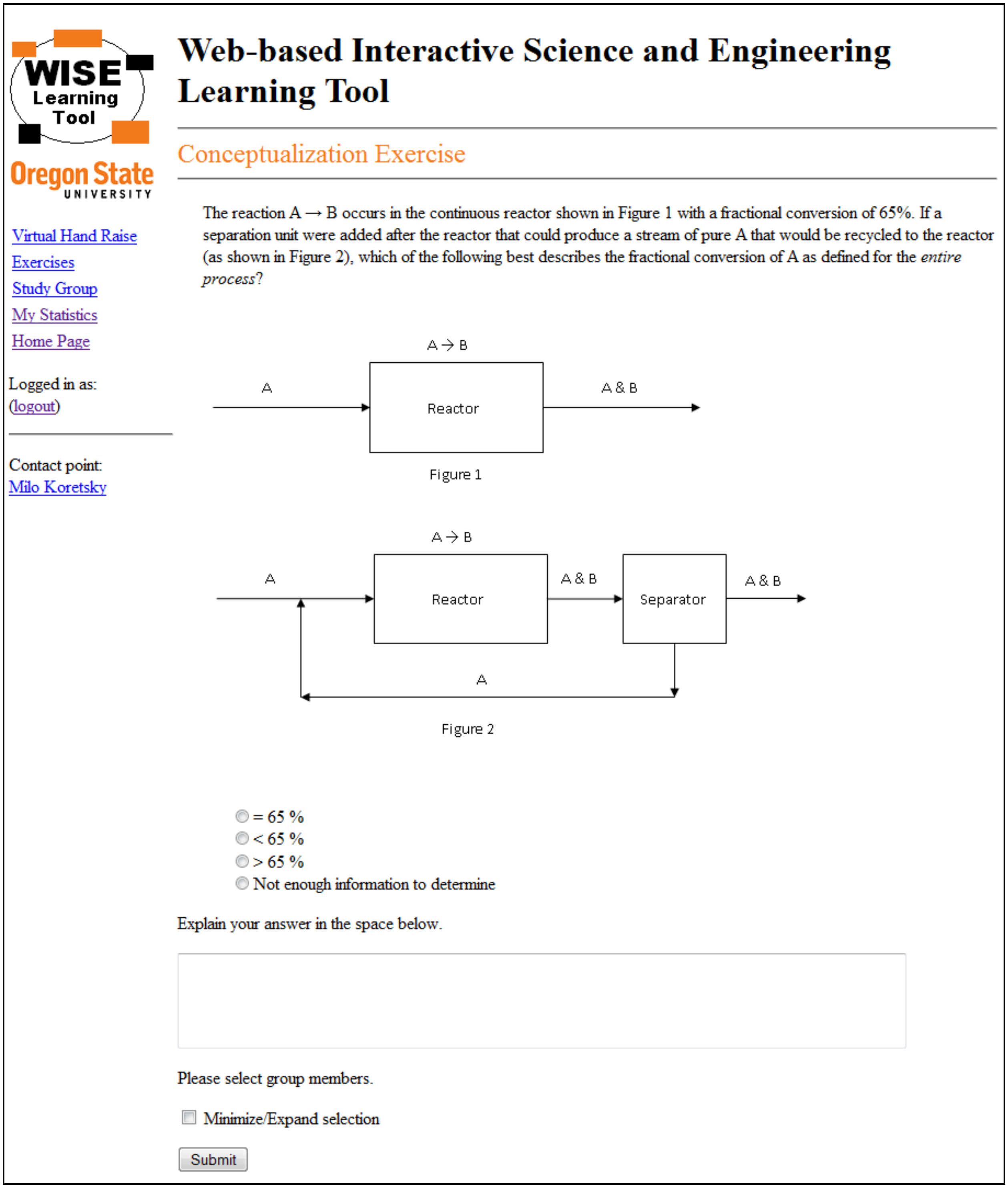

Figure 1. Screenshot of a typical WISE conceptual exercise.

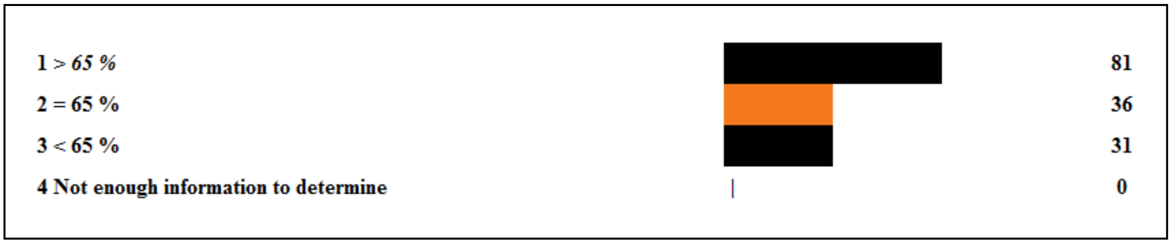

Figure 2. Sample results from WISE question shown in Figure 1.

Student Performance: Student performance on WISE conceptual exercises was measured using the fraction of correct responses to first attempts at WISE exercises. Only questions that an individual student attempted were included in this calculation. The average exam score for each student was used as a metric of overall course performance. Exams contributed 65% of the overall grade and were thought to be the best metric of student learning as homework scores were more likely to be influenced by group work, which was encouraged.

Student Perception: A survey instrument used by Koretsky and Brooks[9] about student perceptions of the WISE Learning Tool was administered on the last day of class. 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. Details of the survey are discussed in the context of the results.

Student Approaches to Learning: Student approaches to learning were assessed at the beginning of the course using the revised two-factor Study Process Questionnaire (R-SPQ-2F).[20] The R-SPQ-2F, a shortened version of the SPQ, is a 20 item questionnaire designed to quickly assess an individual's tendency toward surface or deep approaches to learning. The 20 questions are broken down into four subcategories designed to address strategy and motive. As a result, each individual is given a surface approach (SA) score and a deep approach (DA) score with sub-scores for surface strategy (SS), surface motive (SM), deep strategy (DS) and deep motive (DM). The SA score is calculated by summing the results of 10 Likert-scale questions (1 = "this item is never or only rarely true of me"; 5 = "this item is always or almost always true of me") addressing a tendency towards surface approaches (e.g., "I only study seriously what's given out in class or in the course outlines"). Likewise, the DA score is calculated by summing the results from 10 questions addressing deep approaches (e.g., "I find that I have to do enough work on a topic so that I can form my own conclusions before I am satisfied"). Individuals with higher DA scores (out of a maximum score of 50) identify with deep approaches to learning while individuals with high SA scores identify with surface approaches. In this study, the questionnaire and the scoring were as described in the original.[20]

As outlined by the developers, the R-SPQ-2F is appropriate for investigating the relationship between learning approaches and various aspects of a curriculum, with the aim of making improvements based on the insights gained.[20] The authors are careful to point out, however, that the R-SPQ-2F results are "a function of both individual characteristics and the teaching context" and it is inappropriate to classify someone as a deep or surface learner independent of the context.[20] Furthermore, although the R-SPQ-2F has been widely used in many fields, Immekus and Imbrie[27] have suggested that R-SPQ-2F results may not be able to be interpreted as outlined by Biggs for Western university students and suggest that additional research is necessary to validate the survey.

Student Attitudes about Learning: Student attitudes about learning were assessed at the beginning of the course using the Colorado Learning Attitudes about Science Survey for Chemistry (CLASS-Chem).[19] As opposed to the R-SPQ-2F which focuses on general learning approaches, the purpose of this instrument is to assess students' beliefs about science (specifically, chemistry). CLASS-Chem was selected for this work because, of the attitudinal surveys presented above, it was most closely aligned with the subject matter of the Material Balances and Stoichiometry course and the background of the enrolled students. In addition, CLASS-Chem questions are written to be about chemistry in general, as opposed to a specific course. However, this survey was not developed explicitly for chemical, biological, or environmental engineering and the results of this study should be interpreted with that in mind.

Briefly, the CLASS-Chem survey consists of 50 Likert-style questions (1 = strongly disagree; 5 = strongly agree) designed to assess students' beliefs about (1) learning chemistry; (2) the content of chemistry knowledge; (3) the structure of chemistry knowledge; and (4) the connection between chemistry and the real world. Student answers on each question are scored on the basis of their comparison with survey results using experts in the field (faculty) and an "overall % favorable" score is determined based on the percentage of the questions where the student agrees with the experts. For example, if a student answered "agree" or "strongly agree" on a question where the expert consensus was also "agree" or "strongly agree", that question would be scored as "favorable". Summing all the favorable results and dividing by the total number of questions yields the overall % favorable score. "Overall % neutral" and "overall % unfavorable" scores were calculated in a similar fashion. Additional details of the scoring procedure can be found in Barbera et al.[19] In addition to the "overall % favorable" score, the authors broke the questions down into several subcategories that group questions targeting specific topics like personal interest and problem solving. Of particular interest in this study are the three subcategories addressing conceptual connections, conceptual learning, and the atomic-molecular perspective of chemistry. For the purposes of this work, we created a "conceptual % favorable" score using only the 17 questions in these three subcategories as an additional measure of student attitudes. The three authors completed the survey and aligned with the experts' view on all 45 items for which there is an expert consensus (134 out of 135 matches). This result additionally validates that this instrument is valid for this introductory chemical, biological, and environmental engineering course.

Results and Discussion

Survey Consistency: Summary statistics of the R-SPQ-2F and CLASS-Chem results are shown in Table 2. Participation on both surveys was high, with 95.3% of the consenting students completing the R-SPQ-2F and 98.7% completing CLASS-Chem. Results from both surveys were generally normally distributed. For example, the DA scores from the R-SPQ-2F study are shown in Figure 3.

Table 2. Summary statistics for the R-SPQ-2F and CLASS-Chem Surveys

	Mean	Standard Deviation	95% Confidence Interval
R-SPQ-2F (*n* = 143)			
Deep Approach (DA)	32.4	5.6	31.5 – 33.3
Surface Approach (SA)	26.1	5.7	25.1 – 27.0
CLASS-Chem (*n* = 148)			
Overall % favorable	62.4	18.6	59.4 – 65.4
Conceptual % favorable	60.6	23.0	56.9 – 64.3

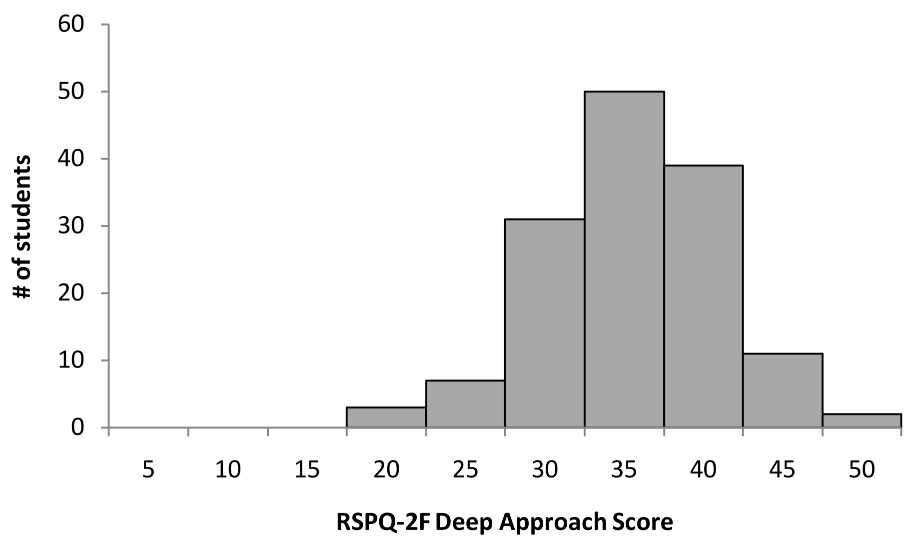

Figure 3. Distribution of R-SPQ-2F deep approach scores

On average, the class was characterized by higher DA scores than SA scores on the R-SPQ-2F, suggesting a greater tendency toward deep approaches to learning. An average DA score of 32.4 out of 50 suggest that students "frequently" engage in behaviors indicative of a deep approach. On the other hand, an average SA score of 26.1 indicates that students engaged in behaviors indicative of a surface approach "about half of the time". As shown in Figure 4, SA scores are negatively correlated with DA scores ($R = -0.24$; $p = 0.0038$), as was hypothesized and shown in the original testing of the survey.[20] However, the weak relationship indicates that additional factors may influence students' answers on the DA and SA questions. Due to the self-reporting nature of the questionnaire, it is conceivable that students may be more honest on some questions than others, anticipating the responses they think the instructor is looking for despite statements at the beginning of the survey to prevent such behavior.

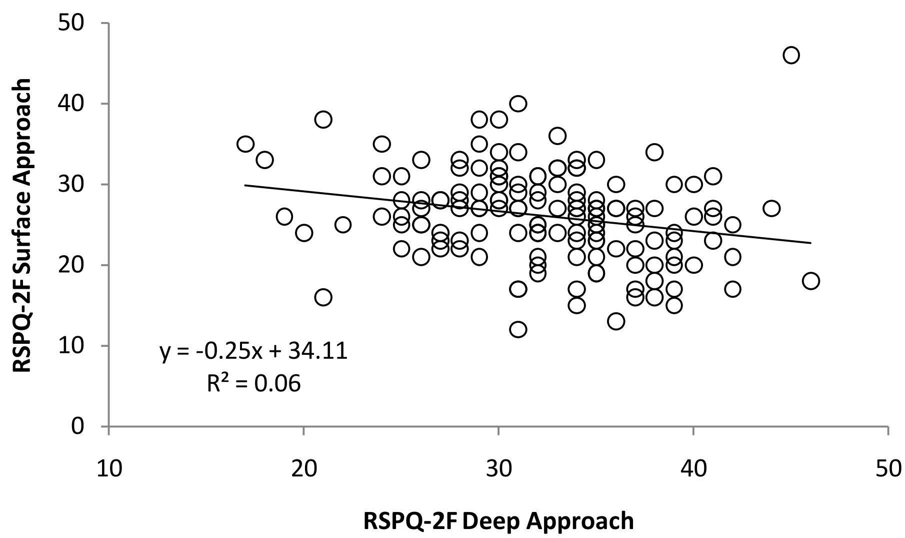

Figure 4. Correlation of R-SPQ-2F surface approach and deep approach scores

Examining the CLASS-Chem results, students in the course report expert-like beliefs on 62.4% of the questions across all categories ranging from personal interest and real world connection to conceptual learning and aspects of problem solving. Average results on the conceptual questions were quite similar with an average conceptual % favorable score of 60.2%. Figure 5 clearly shows that overall % favorable scores are highly correlated with conceptual % favorable scores for individual students ($R = 0.91$, $p < 0.0001$). Therefore, both the overall % favorable scores and the conceptual % favorable scores can be used as an indication of more expert-like views about conceptual knowledge and learning. Because the focus of the WISE Learning Tool is concept-based instruction, we will report only conceptual % favorable scores for the remainder of the paper. Analyses were performed with the overall % favorable scores and the results were essentially the same.

Although the two instruments are designed to assess different characteristics of individual students (i.e., beliefs and attitudes vs. actions/approaches), we hypothesized that there might be correlations between the two surveys. For example, students reporting more expert-like beliefs with respect to conceptual knowledge and learning might also report deeper approaches to learning. Correlations between the two surveys, presented in Figure 6, indicate that the two surveys are indeed consistent. CLASS-Chem conceptual % favorable scores were positively correlated with DA scores ($R = 0.21$, $p = 0.012$), but even more strongly correlated (negatively) with SA scores ($R = -0.43$, $p < 0.0001$). As expected, students with higher DA scores reported more expert-like beliefs and students with higher SA scores shared fewer expert traits as measured by the CLASS-Chem instrument.

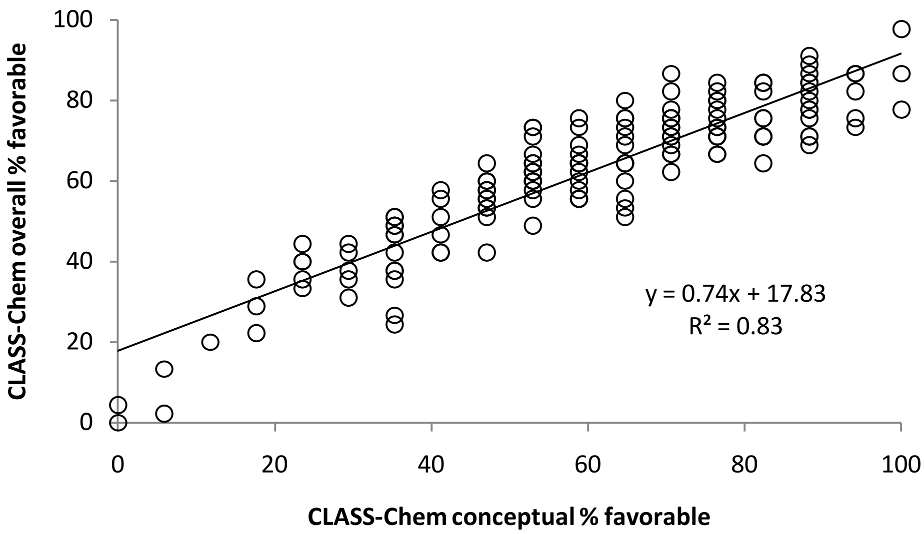

Figure 5. Correlation of CLASS-Chem overall % favorable and conceptual % favorable scores.

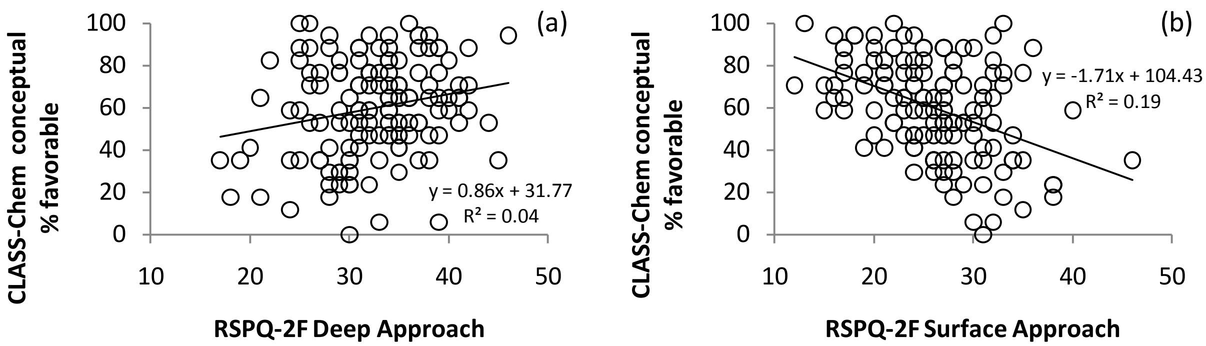

Figure 6. Correlation of CLASS-Chem conceptual % favorable and R-SPQ-2F deep approach scores (a) and surface approach scores (b).

Influence of Attitudes and Learning Approaches on Student Performance: Student performance on WISE conceptual exercises, as measured by the fraction of correct first attempts, is not correlated with DA scores from the R-SPQ-2F ($R = -0.09$, $p = 0.30$). However, as shown in Figure 7, WISE performance is negatively correlated with SA scores ($R = -0.20$, $p = 0.014$). As was hypothesized at the outset of this study, the negative correlation between WISE performance and SA scores indicates that students who identify with surface approaches to learning do not perform as well on WISE conceptual exercises. Although it is difficult to make the corollary statement that students who take deeper approaches to learning perform better (as measured by the R-SPQ-2F), we can see that a surface approach is detrimental. The fact that SA scores are much more strongly correlated with CLASS-Chem results, along with the lack of correlation between WISE performance and DA scores, suggests that SA scores are a better metric of surface approaches than DA scores are of deep approaches for this group of students.

Because WISE exercises focus on concepts rather than memorization or rote calculations, they aim to make students think more deeply about the subject matter. As such, the results presented in Figure 7 are consistent with the hypothesis that students who adopt surface approaches are not as well equipped to answer these types of questions and efforts are necessary to encourage those students to adopt a deeper approach. WISE questions and the way they are administered in class (e.g., question, view class responses, peer-instruction, re-question, discuss) are designed to encourage a deep understanding of key concepts. In previous research, it has been demonstrated that peer-instruction within the WISE framework improves student conceptual understanding.[11] However, it remains to be seen if students positively change their approach to learning over time after having participated in such activities. In fact, as described above, declines in student attitudes and approaches to learning with time in physics and chemistry courses have been shown to be common. It is also possible that meaningful changes occur over time-periods longer than a single course. These remaining questions are the subject of an ongoing longitudinal study following this same cohort of students as they progress through the 2nd and 3rd years of the CBEE curriculum where several classes incorporate the use of WISE. To this end, the results presented here provide a baseline measurement of student approaches to learning.

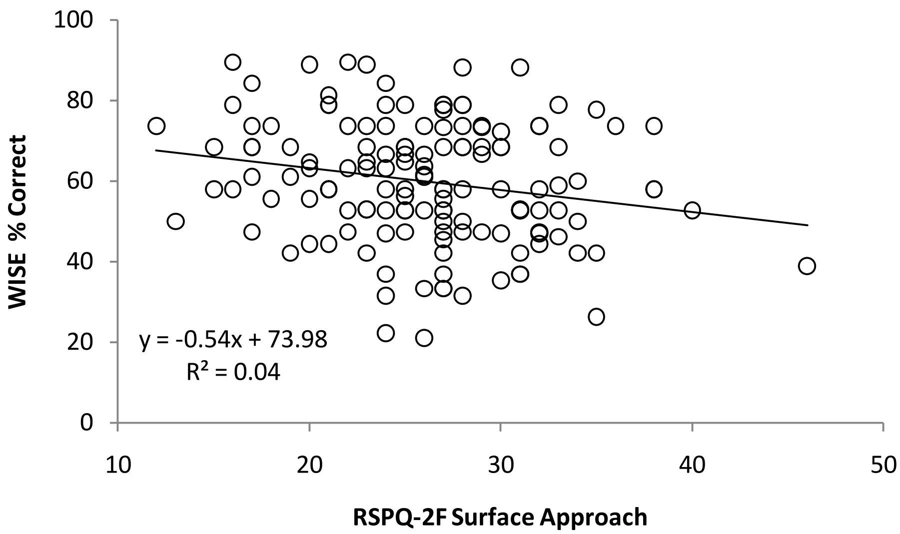

Figure 7. Correlation of student performance on WISE conceptual exercises and R-SPQ-2F surface approach scores.

In relation to attitudes about conceptual learning, WISE performance was positively correlated with CLASS-Chem conceptual % favorable scores ($R = 0.27$, $p = 0.0009$) as shown in Figure 8. In other words, students with beliefs about chemistry more characteristic of an expert performed better on WISE conceptual activities. Barbera et al.[19] state that students with more expert beliefs are likely to view knowledge as “a coherent framework of concepts” and adopt “systematic, concept-based strategies” for problem solving. On the other hand, novices tend to view knowledge as "isolated pieces of information" and rely on "pattern matching to memorized, arcane recipes" when problem solving. On this basis, the positive correlation between WISE performance and conceptual % favorable scores provides evidence that students' attitudes about learning (in particular, their views of knowledge and approaches to problem solving) provide them with attributes that positively influence their ability to make deeper conceptual connections as measured by correct answers on WISE exercises. Furthermore, as with the R-SPQ-2F results presented above, the CLASS-Chem results provide a baseline for the ongoing longitudinal investigation of how student attitudes toward learning change with time.

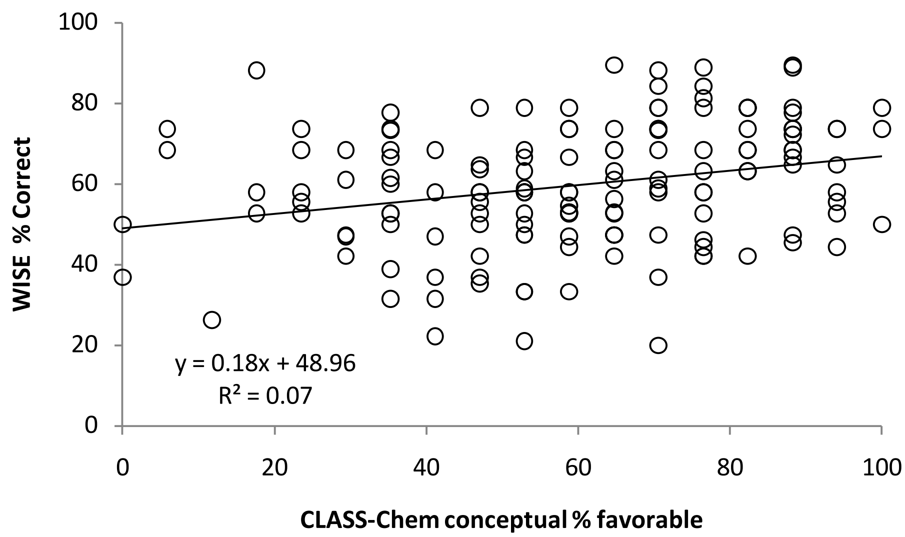

Figure 8. Correlation of student performance on WISE conceptual exercises and CLASS-Chem conceptual % favorable scores.

Despite the fact that the correlations are relatively weak, the findings presented in Figure 7 and Figure 8 paint a consistent picture where student beliefs about conceptual learning and self-reported approaches to learning do influence their performance on conceptual exercises. The correlation between WISE performance and CLASS-Chem conceptual % favorable scores are on the same order as the correlation between WISE performance and SA scores, indicating that both attitudes and approaches play a role in student performance. These findings are important with respect to continued validation of the WISE Learning Tool as a useful innovation. One goal of WISE is to promote an understanding of the value of conceptual learning and deep thinking. As such, it is important recognize that students' views of knowledge are related to their development of knowledge. To that end, the results of the R-SPQ-2F and CLASS-Chem serve to contextualize student learning with their present views of knowledge and learning and provide a baseline for assessing changes with time.

Overall course performance was also examined for relationships with attitudes toward learning and learning approaches. As described above, the average exam score for each student was used as the primary measure of course performance. As with WISE performance, average exam scores were not correlated with DA scores (R = 0.036, p = 0.67), but were negatively correlated with SA scores (R = −0.20, p = 0.017), and positively correlated with CLASS % favorable scores (R = 0.31, p = 0.0001). Correlations were on the same order as those between WISE performance and approaches/attitudes as measured by the two surveys. In general, students adopting a more surface approach to learning performed worse on exams and students with attitudes more characteristic of experts performed better. The weak correlations between assessment results and survey results indicate that factors other than student attitudes about and approaches to learning also influence performance.

Related to the results presented above, the extent to which performance on WISE questions was an indicator of course performance was investigated (Figure 9). Average exam scores were positively correlated with WISE performance (R = 0.50, p < 0.0001). Although this correlation is still relatively weak, it was one of the strongest correlations observed in this work. The exams consisted of approximately 10% conceptual short answer and multiple choice questions and the remainder traditional “work-out” material balance problems. The relative strength of the correlation between exam performance and performance on WISE activities suggests that the two types of assessments are consistent and address similar material. Furthermore, an analysis of student performance on only the conceptual portions of the exams yielded essentially the same results. However, the intent of conceptual WISE exercises is more than simply preparing students to correctly answer conceptual questions. These types of activities are designed to promote deep learning and facilitate the transfer of that knowledge to different situations and more complex problems. The correlation of overall exam performance with WISE performance suggests that students who demonstrate a deeper conceptual understanding (as measured by a greater percentage of correct answers on WISE activities) perform better on more involved assessments that include new, unseen problems that require well-developed problem solving strategies (exams). Generally, higher achieving students perform better on both assessments, which is not surprising.

Relationship of Attitudes and Learning Approaches to Student Perceptions of WISE: A summary of responses to the nine Likert-scale questions on the WISE opinion survey administered at the end of the course is shown in Table 3. With favorable average responses to nearly all of the questions, the opinion survey results show that students generally value WISE as a useful learning tool. Students agreed or strongly agreed that WISE helped them understand concepts (65%), kept them actively involved in class (64%) and made them think more than traditional methods (55%). Furthermore, specific mechanisms of administering the activities and providing feedback were viewed favorably. For example, the simple procedure of posing a question for students to answer individually and subsequently showing the class responses in bar graph format resulted in increased student confidence (74% agreed/strongly agreed). In addition, having students write written explanations of their choices to multiple choice questions made them think more about the answer (73% agreed/strongly agreed). Having the answers to the explanations allowed the instructor to immediately address misconceptions during the discussion period that followed. This is an advantage of the WISE platform when compared to clickers. Having the laptop and the ability to provide written justifications of their choice encourages students to think more deeply about their responses and allows the instructor an additional tool for identifying and addressing misconceptions. Tellingly, a majority of students (58%) indicated that WISE should be used in other classes. On average, students agreed that they were more aware of their misunderstandings in this class; yet, it did not appear that they believed this difference was attributable to WISE. With the exception of question 2, less than 20% of the class disagreed or strongly disagreed with the statements in the survey.

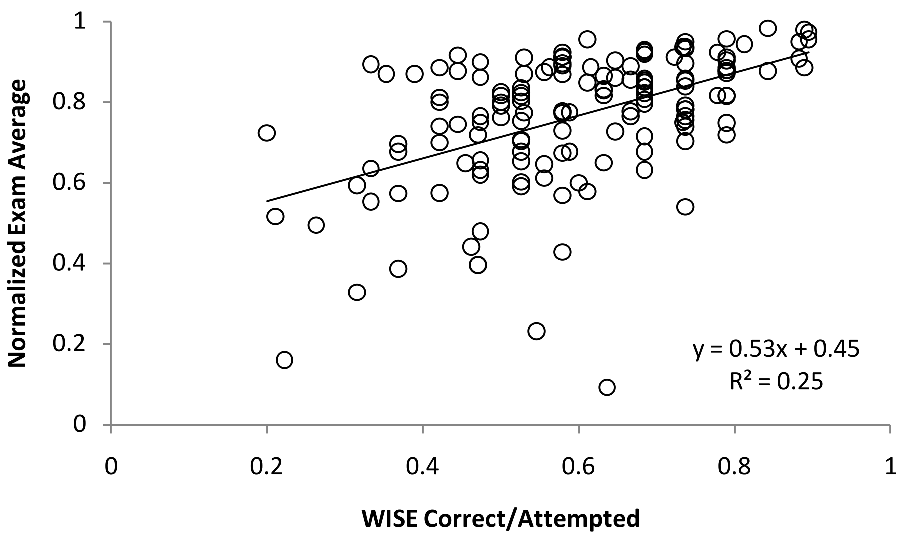

Figure 9. Correlation of average exam scores and WISE performance.

In general, there were no statistical correlations between students' opinions of WISE and the R-SPQ-2F and CLASS-Chem results. One exception, however was question 3 (Using WISE helps me understand the concepts behind the problems). Responses to this question correlated with both DA scores (R = 0.23, p = 0.0059) and SA scores (R = −0.20, p = 0.020). In many respects, this question is the most important for this study focused on deep vs. surface learning approaches in that it most directly addresses conceptual learning. Students who adopt a deeper approach to learning as measured by higher DA scores were more likely to agree that WISE helped them understand concepts, while students with higher SA scores were less likely to feel that way. These results are consistent with the premise that WISE reinforces the understanding of what conceptual knowledge is. A deep learner likely sees the value of conceptual learning where a surface learner may not, and those values may manifest themselves in survey responses. Despite the weakness of these correlations, they fit logically with the presumed relationship between student attitudes and learning approaches and student perceptions of a concept-based instructional tool like WISE. It is interesting that the responses to question 3 were more highly correlated with the DA scores, when such relationships were not significant elsewhere in this work. Also somewhat surprisingly, based on the results presented above, there were no correlations of WISE opinion survey results with CLASS-Chem results.

Table 3. WISE opinion survey results using a Likert-scale
(1 = strongly disagree to 5 = strongly agree)

Question	**1**	**2**	**3**	**4**	**5**	**Avg**	***n***
1 In this course, I am more aware of my misunderstandings than in courses taught by traditional methods.	4	14	50	53	25	3.55	146
2 The change in awareness of my misunderstandings is due to WISE.	20	27	49	41	9	2.95	
3 Using WISE helps me to understand the concepts behind the problems.	8	12	31	71	24	3.62	
4 I am more actively involved in class when WISE is used.	7	16	30	51	42	3.72	
5 I have to think more in class sessions that use WISE that those that do not.	14	12	39	53	28	3.47	
6 Seeing the class responses to a concept question (bar graph) helps increase my confidence.	1	7	30	68	40	3.95	
7 WISE should be used in other classes.	14	10	38	50	34	3.55	
8 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.	10	19	33	61	23	3.47	
9 The short answer follow-ups to multiple choice questions helped me to think more about the question and the answer that I chose.	5	11	23	71	36	3.84	

Anytime an innovative strategy is implemented in the classroom, there is inevitably some resistance to change. As such, there should always be an integrated effort to understand student perceptions by providing multiple opportunities for students to give feedback to the instructor on his/her teaching methods. Although it is important to listen to students, it is also important to respond in appropriate ways. For example, an appropriate response to a large number of complaints about the value of an innovation designed to promote the value of conceptual understanding from students characterized by surface approaches may be substantially different than the response to the same number of complaints from students who associate themselves with a deep approach to learning or expert-like attitudes. Through analysis of responses to the WISE opinion survey it is possible to examine whether or not students' perceptions are influenced by their epistemologies. In the context of the present study, we believe that by further understanding the nature of the student feedback, we will be better positioned to make the appropriate changes to the WISE platform and its integration into the CBEE curriculum.

Conclusions

A Web-based Interactive Science and Engineering (WISE) learning tool developed at Oregon State University to promote active, concept-based pedagogy has been successfully integrated into a sophomore level Material Balances and Stoichiometry course serving chemical, biological and environmental engineering students. As a means of better understand students' epistemologies and approaches to learning in the context of this innovative teaching tool, study participants completed two surveys: an attitudinal survey specific to chemistry (CLASS-Chem) and a learning approaches survey (R-SPQ-2F). Results from the two studies were found to be internally consistent; surface approach scores were negatively correlated with deep approach scores in the R-SPQ-2F and conceptual % favorable scores were positively correlated with overall % favorable scores in the CLASS-Chem. Furthermore, the two surveys were consistent with one another; deep approach scores were positively correlated with % favorable scores (conceptual and overall) and surface approach scores were negatively correlated with % favorable scores.

R-SPQ-2F surface approach scores were negatively correlated with student performance on WISE conceptual exercises and exams while CLASS-Chem conceptual % favorable scores were positively correlated with both measures of performance. In general, correlations with CLASS-Chem results were stronger than correlations with R-SPQ-2F surface approach scores. No statistical correlations were observed between student performance and deep approach scores. In addition, student average exam scores were found to be positively correlated with performance on WISE conceptual exercises. Finally, student opinions of the ability of WISE to improve conceptual understanding were also related to R-SPQ-2F deep approach and surface approach scores. On the basis of the observed correlations, it appears that students' performance and perception is influenced by their attitudes about and approaches to learning. Surface approaches to learning are associated with poorer performance while expert-like views of conceptual knowledge and learning are associated with higher scores on assessments. In addition to demonstrating that the WISE Learning Tool does work in the realm of promoting deep, conceptual understanding of the subject matter, the survey results provide baseline data from which to study the temporal trends in student attitudes and learning approaches in response to curricular innovations.

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