AC 2010-361: A CASE STUDY OF A THERMODYNAMICS COURSE: INFORMING ONLINE COURSE DESIGN

Simin Hall, College of Engineering at Virginia Tech

Dr. Simin Hall is a Research Assistant Professor in the Department of Mechanical Engineering at Virginia Tech and Polytechnic Institute. Her applied research in education is focused on cognitive processes and motivational factors in problem solving in computationally intensive courses such as engineering using online technology. Prior to joining ME at Virginia Tech, she completed a collaborative research project between the Department of Engineering Education at Virginia Tech, College of Engineering at Texas A&M, and Department of Sociology at University of Arizona. The project involved a national survey to assess contributing factors in adopting engineering education innovations by engineering departments across US.

Catherine Amelink, Virginia Tech

Dr. Catherine Amelink is currently serving as the Research Coordinator for the Institute for Distance and Distributed Learning at Virginia Tech. Previously she served has worked on assessment initiatives with the Division of Student Affairs and the Center for Excellence in Undergraduate Education at Virginia Tech and as the Assessment Coordinator for undergraduate education at University of Maryland University College. She is a graduate of the Ph.D. program in Educational Leadership and Policy Studies at Virginia Tech. Her research interests include work-life spillover among faculty and issues confronting underrepresented groups in the STEM fields. Catherine has served as the Coordinator of Special Projects for the Office of the Provost at Virginia Tech focusing on faculty work-life issues, diversity efforts, excellence in undergraduate education, and coordinating university planning activities and served as a doctoral intern with the State Council of Higher Education.

Sam Conn, Virginia Tech

Prior to joining Virginia Tech's Institute for Distance and Distributed Learning as Director, Sam served as Assistant Professor and Chair of the Department of Computer Information Systems at Regis University in Denver, Colorado from 1999 to 2008. In this position he led the university's move to online education in graduate and undergraduate programs. Sam also served as co-director of the online joint-degree program with the National University of Ireland in Galway, Director of the Center for Database Research, and Co-Director for the National Security Agency Center of Academic Excellence. Sam has worked in higher education since 1999 after completing a 23 year career in the field of information systems and technology. Sam maintains a publishing track in Information Systems and eLearning research.

A Case Study of a Thermodynamics Course: Informing Online Course Design

Abstract

Empirical data is needed to measure the effectiveness of problem based online offerings of abstract engineering courses such as thermodynamics courses. Problem solving is central to engineers' work; therefore, it should be central to their education. The hypermedia learning environments offer particular advantages to learners who are inherently self-directed learners[1]. However, the current population taking these courses consists of traditional undergraduates who typically require and expect more structure and instruction[2]. Many students, particularly those with low motivation and achievement, are unwilling to do mindful work, such as executing higher level cognitive processes. Learners in the collaborative problem solving process receive feedback and comments from peers, and from the teacher on the steps of planning, implementing, and executing problem solving processes rather than only receiving feedback from the teacher on their performance. Therefore, peer pressure, as a motivating factor, may push students to perform higher level cognitive functions. In addition, social constructivism[3] suggests that the exchange of critical feedback among peers as well as from the instructor can encourage students to modify their work. Research is needed that will provide insights for engineering departments in design, implementation, and evaluation of online engineering undergraduate courses, especially those that are designed to teach and improve the problem solving skills among students.

The study enhances the scholarship of online teaching and extends the state of knowledge in Human Performance Technology by contributing to the theories of computer-assisted instruction, distance education, and web-based learning applications in abstract engineering subjects. A mixed-method investigation was employed to carry out a case study of one undergraduate Mechanical Engineering course in fall 2009. The data consisted of survey results, field notes, and class observations that focused on examining how students approach problem solving, the role of instructor in facilitating problem solving, the role of peers and students' use of technology as it relates to accomplishing course work in order to better understand how to design an online version of the same course. This study reports the baseline data collected from the control group learning problem solving in thermodynamics in the traditional learning environment and discusses how the data will be used to design the online asynchronous problem-based version of the same thermodynamics course using computational and communication technologies.

1. Introduction

There are numerous reasons for online design and delivery of undergraduate engineering courses. With the limitations on facility and growth of the student enrollment, online teaching presents a viable option for institutions to ensure access to their courses. Research indicates that hypermedia learning environments offers particular advantages to adult learners who are inherently self-directed learners[1]. Web-based delivery allows for flexible learning environments and increases the accessibility of our engineering courses, allowing students who are traditionally unable to attend or uncomfortable attending a standard classroom environment for various reasons. Students lives are becoming much more "asynchronous" for multiple reasons including the need to work, military service, dependent children, etc. In addition, engineering students often participate in “co-op” work/study situation; therefore, it makes sense to make courses available to these students.

However, there are disadvantages associated with online learning few of which are: (a) in the computer-mediated learning social presence consisting of vocal tones and/or facial expression may be reduced, therefore, the instructors have to rely on students to communicate his/her challenge in learning the material, (b) online learning requires students to exhibit higher level of self-regulated behavior than the students in a traditional classroom setting, and (c) current populations taking these online courses consist of traditional undergraduates who typically require and expect more structure and instruction[2].

Social cognitive theories posit that it is possible to design the educational experience so that learning occurs and is enhanced as a result. Designing a course so that student learning takes place requires examining student epistemic beliefs, how feedback is utilized during learning, as well as student perceptions of teaching and learning. For instance, students who require and expect more instruction do so in part because of their epistemic beliefs regarding the nature of knowledge and knowing. Research has shown that epistemic beliefs affect how students approach learning tasks[4], monitor comprehension[5], and plan for solving problems and carry out those plans[6]. In addition, Hofer and Pintrich[7] hypothesized that epistemic beliefs affect achievement mediated through self-regulated learning. Schunk[8] defined self-regulated learning as “learning that results from students’ self-generated thoughts and behaviors that are systematically oriented toward the attainment of their learning goals” (p. 125). In addition, Bandura[9] showed that self-efficacy beliefs impact performance because these beliefs represent people’s perception of their capabilities to perform a task at designated levels. These researchers have provided empirical data on causal or correlational relationships between self-efficacy and epistemic beliefs and self-regulated behaviors and performance in subjects such as mathematics[5, 10].

During problem solving, students assess the difficulty of the task while disambiguating the important from irrelevant information. According to Jonassen[11], problem solvers consider the veracity of diverse ideas and multiple perspectives, plan and monitor their steps, and regulate their progress based on feedback from different sources such as peers, teacher, or instructional materials. Reardon[12] argued that thermodynamics is not a linear subject; rather it has a triangular structure, consisting of principle, processes, and properties. Reardon developed a seven step systematic problem-solving methodology in thermodynamics to help students with conceptual understanding and transfer of knowledge to clarify and organize the scientific concepts involved (Figure 1). Therefore, successful problem solving behavior is linked to self-regulated behavior. Pintrich and Schunk[13] have shown that successful self-regulated learners possess higher levels of motivation (personal influences), apply more effective learning strategies (behavioral influences) and respond more appropriately to situational demands (environmental influences).

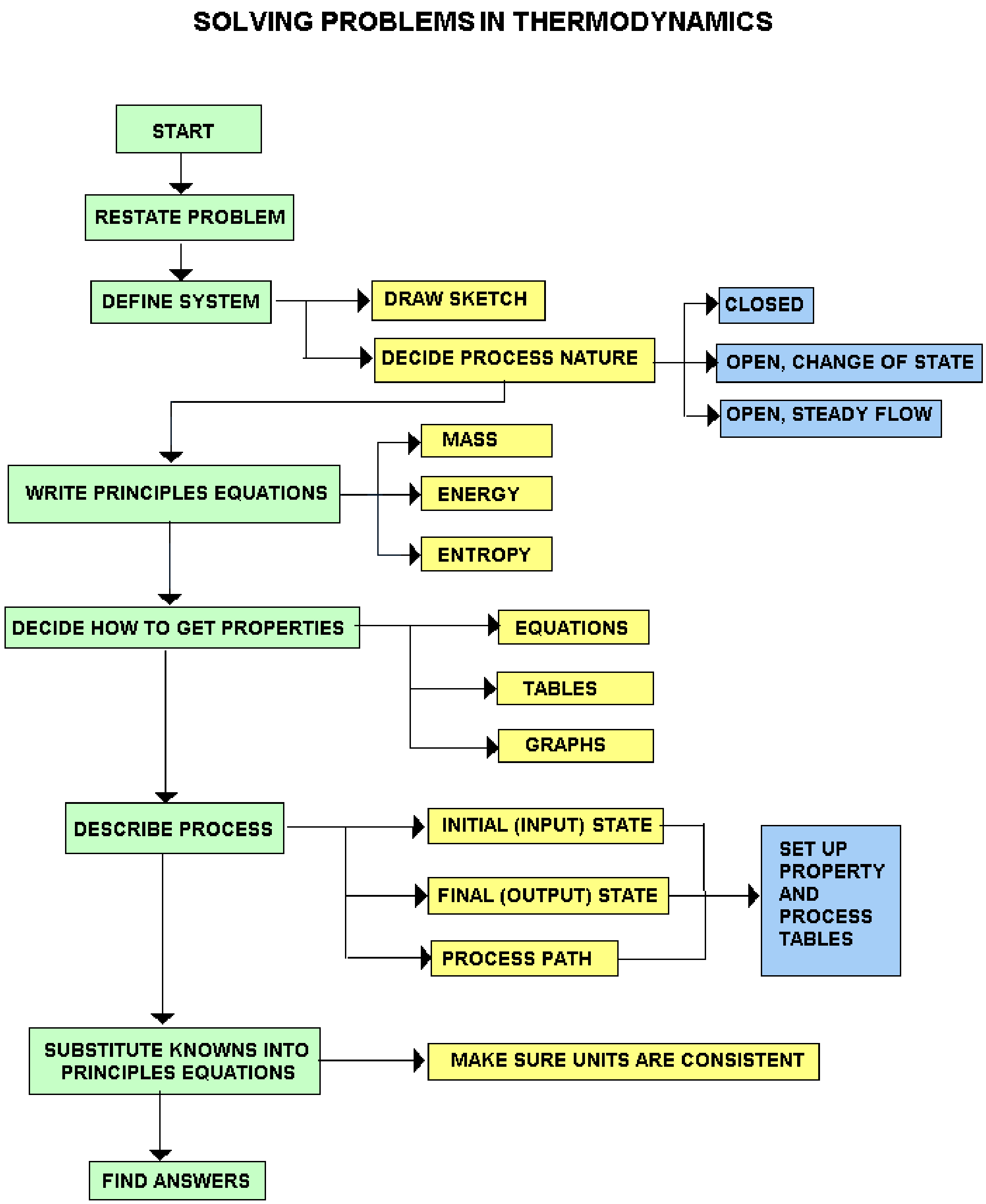

Figure 1. Problem Solving Methodology Diagram (With Permission from Reardon, 2001[12]).

Students' perceptions of various aspects of teaching and learning in a course play an important role in their engagement and performance. Research shows that the effective employment of web-based teaching and multi-media instructional materials could transfer superficial, passive, and mostly memorization learning to deep, engaging, and reflective environment. One indelible aspect of web learning is the opportunity for learners to collaborate during problem solving and actively be involved in their learning. However, Ravert and Evans[2] showed that expecting students at earlier stages of development to learn from courses based on principles of negotiation, shared construction, and peer-to-peer learning could be problematic. Therefore, if tools employed in teaching and learning or instructional design run contrary to students' epistemic beliefs, it would lead to frustration and distress. Students may require greater scaffolding with aspects of online teaching mostly those who see the instructor as the possessor of knowledge. Therefore, the instructional design and strategy selection should address these issues during the course design phase.

We used the aforementioned factors and theories as the framework to design the first undergraduate online-based thermodynamics course on our campus. In the present case study we used several assessment methods to provide baseline data to design an online-based thermodynamics course that promotes self-regulated learning and enhance students' performance in a course that requires intense problem solving skills. Collecting the baseline data associated with this study allowed us to gauge how much structure and guidance to include in the online courseware given the population who will be taking the thermodynamics courses. Specifically, we wanted to know: a) what are students' self-efficacy beliefs about problem solving and epistemic beliefs about instruction, b) how do students use technology to collaborate with peers to accomplish coursework, c) what is the current learning environment within a Thermodynamics course as designed by the instructor, and d) once these three factors have been assessed how can the information be used to design the instruction in the online course to promote self-regulated learning behavior.

2. Research Method

A. Methodology

We employed a mixed-method research design[14] for this case study. The data consisted of survey results and class observations.

The case study involved one fall 2009 section of ME 3134 Thermodynamics, an undergraduate engineering course offered in the Department of Mechanical Engineering at Virginia Tech. Thermodynamics is an abstract course and in the field of engineering education is considered a difficult course for acquiring mastery of concepts, principles, and procedures. In this first course in thermodynamics students are introduced to problem solving and have to actively integrate their prior knowledge in differential equations and statics with new materials to solve engineering problems in thermodynamics.

B. Population and Data Collection

Following approval by the Institutional Review Board at our institution, two main methods were used to collect data, an online survey and field notes taken during classroom observations.

The online survey was administered to the 45 students enrolled in the course. During the first week of class students enrolled in the course received an email explaining the aims and purposes of the study and were asked to complete the survey by following a link included in the email. The instrument measured a) students' self-reported confidence as it relates to problem-solving,

b) students' perceptions of instruction, and c) students' use of technology as it relates to accomplishing course work. The survey solicited demographic data and information about students' rating their frequency of participation in class discussions as well. The five questions related to self-efficacy asked participants how confident they were solving different equations and their confidence as it relates to stating what is known or what is to be determined after reading an engineering problem. Response options were on a five-point Likert scale ranging from 1 'no confidence' to 5 'a great deal of confidence.' Twelve questions related to perceptions of instruction. For example, items asked respondents whether they thought good instructors often bring up questions that have more than one correct answer and whether instructors should present various ideas on an issue. Questions also asked students whether they like it when an instructor asks questions that have more than one answer or brings up questions that the instructor does not know the answer to. Participants could choose from a five-point Liker scale ranging from 1 'strongly disagree' to 5 'strongly agree'. Three items on the survey asked participants how they used technology to collaborate with peers to accomplish course work. Questions asked whether they met in-person, whether they used text messaging or email to accomplish course work, or if they completed work individually. Participants could choose from a five-point Likert scale ranging from 1 'strongly disagree' to 5 'strongly Agree'.

Observations of students and instructor during class also served as a method of assessment. Three main questions served as the basis for the observations: a) How does the instructor facilitate problem-solving? b) What examples of student-centered pedagogy does the instructor use as it relates to teaching problem-solving skills? c) How do the students approach problem-solving when presented with a problem set in class?

For data analysis, descriptive analyses were conducted using the survey data. A priori knowledge was achieved utilizing empirical quantitative data collected through survey of the students. Posterior knowledge was established utilizing qualitative data via classroom observations and field notes recorded on weekly visits to the class. Findings from the data collected were synchronized with the review of literature to reach conclusions regarding research questions of the study and provide the framework for the design of online teaching of the thermodynamics course.

Of the 45 students enrolled in the course, 35 (29 men, 6 women) students completed the survey. Mean scores were computed for each item on the survey. Factor analysis was used to develop three scales for the three constructs measured by the survey. Chronbach alpha scores were used to ensure reliability for the three scales. The mean age for the 35 students were 20.5 (SD=.92).

C. Results from Survey:

C.1. Self-Efficacy

The mean of self-efficacy in problem solving was 4.23 (SD=.54) for all 35 students with a reliability coefficient of 0.82. Therefore, they were confident about their general problem solving skills in engineering courses, revealing a high degree of self-efficacy. The mean and standard deviation for each item that comprised the scale is shown in Table 1.

Table 1: Self-Efficacy Subscale

	Mean	Std. Deviation
1. How confident are you with solving engineering problems?	4.09	.658
2. How confident are you with stating what is known after reading an engineering problem?	4.49	.742
3. How confident are you with stating what is to be determined after reading an engineering problem?	4.51	.658
4. How confident are you with listing all simplifying assumptions to solve an engineering problem?	3.83	.785
5. How confident are you with drawing a diagram to solve a problem?	4.23	.690

C.2. Perception of Instruction

Items used for the "Perception of Instruction" sub-scale were created by Ravert and Evans[2]. Ravert and Evans[2] used this scale to obtain students' responses about knowledge, instruction and instructors with undergraduates taking course in pedagogy and instructional strategies. We wanted to know students' perceptions about knowledge, instructor and instruction as it relates to problem solving in an engineering course. Item responses to the 12 item sub-scale had a reliability coefficient of 0.67 in this pilot test with 35 students. The mean of the subscale on all the 12 items was 3.16 (SD=.44). This indicates that on average students were uncertain about the knowledge, instruction, and instructor. The mean and standard deviation for each item comprising the scale is shown in Table 2.

Table 2: Perceptions of Instruction as it Relates to Problem Solving

	Mean	Std. Deviation
1. A good college instructor often brings up questions that have more than one correct answer.	3.43	.884
2. College instructors should present various ideas on an issue.	4.11	.583
3. It 's not necessary for the instructor to answer all of my questions I post in class; fellow students can often do it instead.	3.00	1.213
4. I like it when an instructor brings up a question that he or she doesn't know the answer to.	2.91	.981

	Mean	Std. Deviation
5. In a course I would learn as much from fellow students as I would from the instructor.	3.26	1.010
6. I usually like it when my instructor answers a question with "it depends" and follows this by a discussion of the topic.	3.31	1.105
7. In the class, I would want the instructor to answer the questions I ask instead of other students answering my questions.	3.46	.817
8. Working with students on solving problems should be an important part of a class.	4.20	.677
9. If I heard an instructor say "we don't know the answer to that" I would worry about taking a class from him/her.	2.63	1.003
10. An instructor who says "nobody really knows the answer to that" is probably a bad instructor.	2.11	.900
11. There is one right answer for most questions and a good instructor knows it.	2.91	.981
12. A good instructor gives facts and leaves theories out of discussion.	2.54	.950

Items 9 through 12 in Table 2 represent students' beliefs in knowledge being isolated facts. High scores on these four items would indicate low perception of knowledge or tendency to absolute, factual, or unambiguous knowledge. Given the low means on these four items, our results indicate that on average students were inclined toward knowledge that is evolving. Students with this belief system are more likely to engage in transfer of knowledge.

Items included on the survey that measure students' perceptions of instruction as it relates to where knowledge should come from (i.e., instructor or peers) reveal that students were uncertain about the role of peers but show a preference for the instructor passing knowledge directly to individual students. Students answering 4 and 5 on item three in Table 2 indicated that they agreed or strongly agreed that i.e. "It 's not necessary for the instructor to answer all of my questions I post in class; fellow students can often do it instead." The mean on this item was 3.00 (SD=1.21) indicating that students were uncertain about peers answering their questions instead of the instructor. The mean score of 3.26 on item 5 in Table 2 indicates similar results, revealing that students are uncertain about what they can learn through collaboration with their peers. However, the mean score of 4.26 for item 8 reveals that students see collaboration with peers as an important part of class. In terms of the role of the instructor, the mean score for item 7 indicates that students show a preference for instruction coming from the instructor rather than the peers. Students also show that they have clear ideas about how ideas should be presented, with a preference towards multiple ideas being presented on a particular issue (Item 2, M=4.11).

C.3. Role of Technology and Peers

We also asked student about using peers, communication and computational technology as it relates to accomplishing course work in the thermodynamics course. Item means for technology related items are presented in Table 3. Students' survey responses for the use of technology for doing homework, class projects, and studying indicated they prefer to complete their work on their own. In spite of prevalent use of technology for day to day communication, these students showed similar preference for interacting with peers for completing class work using communication technology as meeting them face-to-face.

Table 3: Technology

	Mean	Std. Deviation
13. I usually use text messaging or email to do homework, work on projects, and/or review class material with classmates.	3.17	1.32
14. I usually meet classmates face-to-face to do homework, work on projects, and/or review class materials.	2.83	1.27
15. I usually complete homework, class projects, and/or study on my own.	3.46	.95

D. Summary of the Observations

Observations of students during class also served as a method of assessment. The observation data summarized here were obtained with the first author visiting the class once a week and recorded the interaction between the instructor and the students and between students themselves. Three main questions served as the basis for the observations: a) How does the instructor facilitate problem-solving? b) What examples of student-centered pedagogy does the instructor use as it relates to teaching problem-solving skills? c) How do the students approach problem-solving when presented with a problem set in class?

To answer the first question, we recorded the instructor's lecturing and questioning practices. For example, the number of times the instructor lectured, gave instruction, asked an open ended question, asked a closed-ended question, required a response, called for an activity, or introduced a simulation, or Web-based application requiring a response were recorded. We also recorded whether the instructor turned students' questions back to students and tried to engage them in problem solving processes. Lastly, we recorded "What do students come to class with?"

The class met twice a week and the first half of the term, the attendants were high, more than 35 students were present often. The instructor assigned homework but did not collect them. The instructor would post the online quiz and sometimes would release it after students asked questions (the first 30 minutes of the class) or in the last 15 minutes of the class. Usually, each class would start with students in the front row asking questions about homework. The instructor would use these occasions to revisit the concepts. However, seldom homework questions would create peer interactions. The interactions were between the instructor and the individual students who had homework questions.

The instructor would bring problems to some of the classes and would pass it after his lecturing and asked students to gather in groups to solve them. It was not clear however, if the instructor would require the groups to post the answer later on the forum in the “Scholar,” the course management system, that the instructor used to post quizzes, notes, and course materials.

Overall, the instructor attempted to improve collaboration during problem solving, however, with emphasis on homework problems which usually are not ill-structured problems, students tried to solve them individually. Students indicated during class that they sometimes used each other to check answers.

3. Implications for Learning

Our results showed that students’ perception of their confidence in problem solving needs to be nurtured through practical application. The mean of self-efficacy in problem solving was 4.23; however, students’ self-efficacy may be lacking in certain areas as they did not contribute to forums and had difficulty verbalizing their difficulties in relation to comprehension of course material during class. This could be due to their epistemic beliefs about the role of instructor and instruction or the environment within a typical thermodynamics course. The learning environment we observed operated in accordance with this belief system. Students typically received feedback on their completed work, or on tests. This is feedback on performance but not on the process of comprehension, evaluation, and execution. While the instructor provided feedback on the process of comprehension through homework and introduced some ill-structured problems, the completion of these problems were not emphasized or graded. Research has shown that feedback about reasons for an error does not provide any direction to correct the error nor motivates students to explore new alternatives for finding solutions[15].

Previous research[12] and our observations indicated that in thermodynamics students tend to be overwhelmed by the number of equations, constants, and parameters. They want an example for every possible kind of problem, so that they can know how to get the answers to homework and exam problems. Schommer et al’s[5] research indicated that better performance was negatively correlated with belief in simple knowledge (knowledge is isolated facts or unchanging). They showed that beliefs in simple knowledge resulted in cursory learning. Mara and Palmer’s[16] study showed that students who exhibited signs of responsibility and commitment could operate within a contextual relativistic framework. These individuals could learn in multiple ways and from multiple sources and made thoughtful judgments from incomplete data or ambiguous situations, which according to Jonassen[11] are necessary skills for solving complex problems. Based on the data collected from this study, the web based course will adopt a problem based approach with examples in each of the principles, processes, and properties areas of thermodynamics as well as problems that integrated all these areas to enhance the skill of transfer. Furthermore, our study revealed that students were inclined toward knowledge that is evolving. Students with this belief system are more likely to engage in transfer of knowledge. In terms of designing course materials for online delivery the results from our study showed that case studies or project based problem sets that do not have a clear right or wrong answer would benefit student development as students who have these epistemic beliefs engage in active meaning making. Case studies and problem sets that require higher order thinking skills can encourage development in terms of personal responsibility and commitment towards learning among students with these epistemic beliefs. In thermodynamics, it is naïve for students to assume that memorizing lists of definitions constitute a strategy for understanding. Based on our findings, the online course design and delivery requires students' active participation in learning the concepts and solving the problems through providing and receiving feedback from peers and the teacher, therefore, students must show greater responsibility in evaluating peers' feedback and their own understanding. This is designed to move students away from expecting that the teacher would have all the answers.

Our findings reveal that students who enroll in Thermodynamics at our institution may have high epistemic beliefs but that they may be lacking in certain areas when it comes to problem-solving. We will employ a few strategies to provide scaffolding and challenge learners in areas that they revealed they had low-epistemic beliefs in the web-based version of this course. For example, we will use worked out examples to model monitoring steps of problem solving using question prompts. Question prompts include procedural prompts, elaboration prompts, justification prompts and reflection prompts for different cognitive and metacognitive purposes. Ge and Land[17] recommended the following examples of questions prompts. Procedural prompts are designed to help learners complete specific tasks in problem solving, i.e. an example of this ..., or another reason that is good...; elaboration prompts are designed to prompt learners to articulate thoughts and elicit explanations, i.e. what is a new example of...?, or why is it important?, or how does .....affect...?; justification prompts are designed to help students to articulate the steps they had taken and the decisions they had made, i.e. can you explain why you selected that solution?, or why did you decide to focus on that goal?; and reflection prompts elicit explanatory responses and high level thinking elaboration and is intended to facilitate knowledge building of students, i.e. to do a good job on this problem, we need to ..., .

In terms of collaboration, findings from the study reveal that students were hesitant to collaborate and were more likely to use peers when required by the instructor. Given these findings, the collaborative assignments for the web-based course will start with worked out examples and move students to case studies with explicit emphasis on students providing self-explanations on steps of solutions and writing the logic for the methodology devised by Reardon (Figure 1). In addition, we will employ features of web-based feedback technology to improve the application of students' self-efficacy through monitoring, modeling, and learning from errors. The collaborative assignments[18] are designed to maximize integration and active processing of the new information in the long term memory through the feedback sources. This technology makes the continuous reciprocal interaction between three personal, environmental, and behavioral influences possible[19]. The web-based feedback technology enables students to interact with the teacher and each other by providing and receiving feedback[19] and also to learn by monitoring their errors[15]. One way this will be done is a wiki that will be used to enable students to interact with the teacher and each other by providing and receiving feedback. This system transforms the concept of technology to an environment for social interaction[18] and also provides a medium for recording reflection from peers, instructor, and students themselves[20]. The main concept behind the web-based feedback system (WBF) that will be used in the online course is that the teacher posts the homework assignments, individual or class projects on the system and each student within each group prepares homework and uploads it to the WBF. Each student is then asked to make follow up revisions to the original work until the final solution is derived.

The instruction via web-based feedback system facilitates explicit practice of skills of monitoring, reflection, and integration[18]. These skills are modeled with examples. Students learn through these models the steps of problem solving[21]. In completing the assignments, a student may plan the steps to the solution, the procedures to be shown in the solution, and finally execute the plan. In reviewing peer homework, student must read, compare, or question ideas, suggest modification, or even reflect how well students work is compared with others. These cognitive processes involve monitoring the adequacy of steps adopted. However, if student receives a message that a step is not adequate, then the student must regulate the cognitive function and employ other alternatives.

Furthermore, our new online design of the course allows a portion of the grade for participation in group problem solving. Students' participation grade for weekly problem solving activity will consist of three components of relevance, engagement, and clarity. We would provide students with rubrics that combine the three components of relevance, engagement, and clarity with the seven steps of problem solving. To improve students' perception of source of instruction and instructor, we employ a peer-assessment procedure in integrating problem solving rubrics with learning the thermodynamics concepts. Liu, Lin & Yuan[22] showed that peer assessment is more strongly related to teacher assessment than self-assessment. In addition Pintrich and Schunk[13] have shown that peer assessment enable students to become more involved in class activities. The instructor would be guiding these assessment activities through posting questions that challenge students to search for multiple ways to demonstrate their problem solving planning. These exercises move students in their justification for knowledge to a constructivist stance. In addition, the teacher would keep an active personal page with a design problem that requires regular attending similar to students' pages. The teacher would model steps of questioning and researching the materials on an ill-structure problem in order to move students from the certainty of knowledge to the design solutions that would evolve as the materials become more sophisticated in the course and some of the design constraints can be removed.

4. Summary

We hypothesize that instruction using a problem based learning format and the interactive technology will result in a dynamic learning environment and meaningful interaction and collaboration among students and with the teacher. We expect through problem based design and delivery of instruction through the online course that the students' problem solving skills will more quickly advance in comparison with conventionally in-class taught students.

In the traditional teaching of thermodynamics course, we found that instructors use lecture and example problems to facilitate students' learning of the subject. In the redesign of the course for online teaching, our emphasis is primarily focused on introducing students to the rigor of problem solving by motivating them to exhibit more self-regulated learning behavior to improve their contextual learning, review, and meaningful collaboration during problem solving exercises. Therefore, the instructor provides a short lecture on the subject and then uses problems as a starting point for acquisition of knowledge in an interactive collaborative environment.

Research[3] indicates that the exchange of critical feedback among peers would encourage students to modify their works according to peers and teacher feedback. The redesign of the course is structured to help the learners in the collaborative problem solving process to receive feedback and comments from peers, and from the teacher on the steps of planning, implementing, and executing problem solving processes rather than only receiving feedback from the teacher on their performance. The scaffolding provided consists of question prompts, modeling giving quality feedback, assigning students to groups to facilitate collaboration, explicit use of technologies that enable students to interact with teacher, teaching assistant, and peers effectively.

Acknowledgment: The authors would like to acknowledge the Institute of Distance & Distributed Learning at Virginia Tech for funding and support for this research.

Bibliography

1. Knowles, M. (1990). The Adult Learner: A Neglected Species, 4th edition. Houston: Gulf Publishing.
2. Ravert, R. D., Evans, M. A. (2007). College student preferences for absolute knowledge and perspective in instruction: implications for traditional and online learning environments, The Quarterly Review of Distance Education, 8(4), pp 321-328.
3. Rogoff, B. (1991). Social interaction as apprenticeship in thinkin: guidance and participation in spatial planning, in Perspectives on socially shared cognition, L. B. Resnick, J.M. Levine, and S.D. Teasley, Eds. Washington, DC: APA, pp. 349-383.
4. Schoenfeld , A. (1983). “Beyond the purely cognitive: Belief systems, social cognitions, and metacognitions as driving forces in intellectual performance,” Cognitive Science: A Multidisciplinary Journal, (7:4) pp 329-363.
5. Schommer, M., Crouse, A., Rhodes, N. (1992). “Epistemological beliefs and mathematical text comprehension: Believing it is simple does not make it so,” Journal of Educational Psychology, 82, pp. 435-443.
6. Schommer, M. (1990). Effects of beliefs about the nature of knowledge on comprehension. Journal of Educational Psychology, 82, 498-504.
7. Hofer, B. K., Pintrich, P. R. (1997). “The development of epistemological theories: beliefs about knowledge and knowing and their relation to learning,” Review of Educational Research, (67: 1) pp 88-140.
8. Schunk, D. H. (2001). Social cognitive theory and self-regulated learning. In B. J. Zimmerman & D. H. Schunk (Eds.), Self-regulated learning and academic achievement: Theoretical perspectives (Vol. 2, pp. 125-152). Mahwah, NJ: Lawrence Erlbaum Associates.
9. Bandura, A. (1986). Social Foundations of thought and action: A social cognitive theory. Englewood Cliffs, NJ: Prentice Hall.
10. Pajares, F., Miller, M. D. (1994). “Role of self-efficacy and self-concept beliefs in mathematical problem solving: a path analysis,” Journal of educational psychology, (86: 2) pp 193-203.
11. Jonassen, D.H. (2000). “Toward a design theory of problem solving*,” Educational Technology, Research and* Development. 48(4); pp 63-85.
12. Reardon, F. (2001). Developing Problem-Solving Skills in thermodynamics Courses, Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition.
13. Pintrich, P. R., & Schunk, D. H. (2002). Motivation in education: Theory, research, and applications (2nd ed.). Englewood Cliffs, NJ: Prentice Hall.
14. Creswell J.W. & Plano Clark, V.L. (2007). Designing and Conducting Mixed Methods Research, Sage Publication.

15. McKendree, J. (1990). Effective feedback content for tutoring complex skills. Human-Computer Interaction, 5, 81-413
16. Marra, R.M. & Palmer, B. (2004). Encouraging intellectual growth: senior college student profiles, Journal of Adult Development, 11 (2), pp 111-122.
17. Xun, G. & Land, S. M. (2004). A conceptual framework for scaffolding ill-structured problem-solving processes using question prompts and peer interactions, ETR&D, 52 (2), pp 5-22.
18. Clark, R. C., & Mayer, R. E. (2003). E-learning and the science of instruction, San Francisco, CA: Pfeiffer.
19. Wang, S. L., & Lin, S. L. (2007). The application of social cognitive theory to web-based learning through NetPorts. British Journal of Educational Technology, 38, 4, 600-612.
20. Liu, E. Z., Lin, S. S., Chiu, C., & Yuan, S. (2001). Web-Based Peer Review: The learner as both adapter and reviewer. Institute of Electrical and Electronics Engineers, 44(3), 246-251.
21. Schunk, D. H. (1987). Peer-models and children's behavioral change. Review of Educational Research, 57, 149-174.
22. Liu, E. Z., Lin, S. S., & Yuan, S. (2002). To propose a reviewer dispatching algorithm for networked peer assessment system. Proceedings of the International Conference on Computers in Education (ICCE).