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

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Abstract— This paper reports on a case study involving the collection and analysis of qualitative and quantitative data to propose online course design of an undergraduate thermodynamics course. The data includes students' self-efficacy as it relates to problem-solving and students' epistemic beliefs as they relate to interacting with peers, instructors, and instruction. Thermodynamics is an abstract engineering course with intense problem solving. The case study methodology provides baseline data for construction of an online thermodynamics course informed by audience characteristics, learning traits, preferences for instruction and modes of interaction, tendencies toward absolute knowledge, dualistic and non-relativistic profiles, and lack of collaborative skills. This investigation is significant and of interest to educators faced with the challenge of teaching thermodynamics online to a student population with low to moderate levels of epistemic belief and/or low self-regulation and self-efficacy. The study serves as a baseline for follow-on research and establishment of a line of inquiry to refine a methodology for elevating levels of students' epistemic belief in collaborative learning environment for engineering courses (online or face-to-face).

***Index Terms*— online course design, thermodynamics, epistemic beliefs, self-efficacy, collaboration, self-regulation.**

I. INTRODUCTION

The online offering of engineering courses are intended to increase access to engineering education and meet the needs of students who participate in "co-op" work/study situations in addition to those who need to work or are in military service and also transfer students. However, there are issues that engineering faculty view as impediment to the design and delivery of most undergraduate engineering courses including the intense problem solving aspects of these courses in addition to physical understanding of the concepts and mathematical formulations. Many faculty rely heavily on lecture format to help students to process difficult and abstract engineering principles in addition to familiarizing students with engineering mindset that require seeking multiple solutions because of conflicting constraints.

In a recent study of seven four-year colleges in the U.S., it was found that approximately 50 percent of all self-declared engineering majors dropped out during their first year because of the high degree of dislike towards the instructional experience specifically the lecture format [1]. Recently published results [2] showed that there is an increased need within engineering education to be more aware of the student learning process and effective ways of teaching them. We combined the results of these studies with the recent data from the employment projection for 2006-2016 period that indicate engineering will be among the fastest growing occupations [3] and the recent study at Virginia Tech about Trends in Distance Learning [4] to formulate the present study. The study involved the collection of data from a traditional offering of an undergraduate thermodynamics course to design and deliver its online version. This course is an important course in ME curricula, we wanted to insure the high quality in design and delivery. The web based offering would help some of our students with their schedule.

Thermodynamics is considered a difficult course for acquiring mastery of concepts, principles, and procedures. Previous research [5] indicates that many thermodynamics students feel overwhelmed by the number of choices for equations, constants, and parameters. They want an example for each specific kind of problem that they might encounter on homework or exams. Part of this desire is driven by students' epistemic beliefs that learning involves memorization and absorbing isolated facts. This approach is contrary to applying robust problem solving skills. As a result, students do not do well when solving thermodynamics problems that require integrating previous knowledge with new principles, processes, and properties.

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, other studies [6] 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.

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 elevate levels of students' epistemic belief in collaborative learning environment for engineering courses and promote self-regulated learning behavior.

II. RESEARCH METHODS

In this study the researchers applied a mixed-method research approach to conduct a case study involving students (N=45) enrolled in one traditionally taught (i.e., face-to-face) fall 2009 section of an undergraduate Thermodynamics course offered in the Department of Mechanical Engineering at Virginia Tech. Appropriate techniques for qualitative investigation also can include case study [7]. The data consisted of survey results, field notes, and class observations that focused on examining how students approach problem solving, the role of peers and students' use of technology as it relates to accomplishing course work, and the pedagogical approaches used to engage this student population.

A priori knowledge was achieved utilizing empirical quantitative data collected through approved Institutional Review Board surveys administered to students enrolled in the course. The first survey consisted of multiple choice items and the final survey focused on open-ended questions. We also conducted a focus group interview and elicited students' open-ended responses to the same questions outlined earlier. In the interview, students were also asked to describe where they got their confidence in relation to problem solving.

To collect quantitative data for the case study, during the first week of class the students enrolled in the course received an email explaining the aims and purposes of the study and were asked to complete a survey by following a secure 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 regarding how students' rated their frequency of participation in class discussions.

The self-efficacy, epistemic beliefs, and use of technology survey items are in Tables 1, 2, and 3 in the result section. Response options for all three instruments were on a five-point Likert scale; for Table 1 they ranged from 1 'no confidence' to 5 'a great deal of confidence,' for Tables 2 and 3 they ranged from 'strongly disagree' to 5 'strongly agree'.

Observations of students during class also served as a method of assessment. Over the term, the researchers observed the course once each week and interactions between the instructor and the students and between students were recorded in field notes. We evaluated interactions between the faculty member and students by recording related occurrences of faculty and student questions and student responses. A matrix was constructed to record the number of times the instructor engaged in lecturing, and asked open-ended and closed-ended questions. Student behavior including the number of students who responded or tried to respond to the faculty member or peers was also recorded. The number or percent of students who were engaged in the class as well as the number or percent that were inattentive was also recorded using the matrix. Three main questions served as the basis for the observations and recording of qualitative data: 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?

In this paper, we present the quantitative results from the survey data. The graphical presentation of a few items on the survey and subsequent discussion are intended to illuminate our approach to using epistemic data to design this thermodynamics online course which intended to elevate levels of students' epistemic belief and promote self-regulated learning behavior in collaborative learning environment. The qualitative data consist of class observations. In reporting the quantitative and qualitative results we used a *Concurrent Triangulation* method[8]. This technique reconciles and brings together numeric (quantitative) and text (qualitative) data. It is grounded in the views of participants and is intended to integrate the two forms of data to best understand research problems.

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. Cronbach alpha scores are reported as a measure of reliability for each construct. Reliability is a measure of internal consistency between survey items. One common measure of test reliability is coefficient alpha by [9]. The closer the Cronbach alpha is to one, the less error between true and observed scores. The mean age for the 35 students was 20.5 (SD=.92).

III. RESULTS

A. *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 I.
SELF-EFFICACY SUBSCALE (FIVE-POINT LIKERT SCALE, 1 IS THE MINIMUM & 5 IS THE MAXIMUM SCORE)

Items, Mean and Standard Deviation		
Item	***Mean***	***SD***
How confident are you with solving engineering problems?	4.09	.658

Items, Mean and Standard Deviation		
Item	***Mean***	***SD***
How confident are you with stating what is known after reading an engineering problem?	4.49	.742
How confident are you with stating what is to be determined after reading an engineering problem?	4.51	.658
How confident are you with listing all simplifying assumptions to solve an engineering problem?	3.83	.785
How confident are you with drawing a diagram to solve a problem?	4.23	.690

B. Perceptions of Instruction

Items used for the "Perceptions of Instruction" sub-scale were created by using a previously designed instrument [6]. 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). The Response options for this instrument were on a five-point Likert scale ranging from 1 'strongly disagree' to 5 'strongly agree'.

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 II.
PERCEPTIONS OF INSTRUCTION (FIVE-POINT LIKERT SCALE, 1 IS THE MINIMUM & 5 IS THE MAXIMUM SCORE)

Items, Mean and Standard Deviation		
Item	***Mean***	***SD***
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
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

These results are further illustrated by looking at the level of agreement on certain key items among student respondents. Survey item number 4 is an indicator of a learner's relationship to absolute knowledge where faculty are considered the exhaustive sole source of knowledge. Analysis of these responses indicates a majority of the population disagrees or is uncertain s/he is comfortable with faculty who explore or provide information in a non-authoritative manner. In this case, the response indicates the learner population generally binds to absolute knowledge and are not ready to rely on experiential or constructed knowledge (refer to Figure 1). Low confidence levels are associated with learner populations who are not prepared to formalize experiential knowledge and constructed knowledge as a basis for decision making, problem solving, or achievement of findings and conclusions.

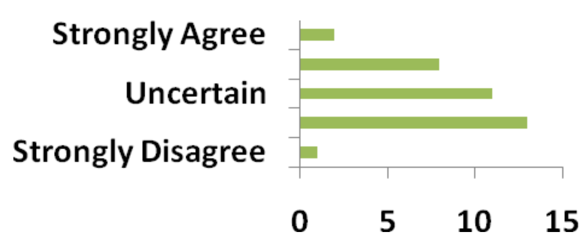

Figure 1. Number of students indicating agreement with Question 4, "I like it when an instructor brings up a question that he or she doesn't know the answer to."

The intent of question 6 offers an opportunity to evaluate the level of complex, contextual information processing (refer to Figure 2). Disagreement or strong disagreement with this statement indicates that a learner acknowledges the existence of contextual information and the role of external or mitigating factors in cognitive evaluation. In the alternative, belief that a source's credibility is lacking if conditions are applied to reasoning indicates a strong tendency toward dualistic, binary thought. Students who agree or strongly agree with this statement expect to hear responses or answers "in context" to certain situational conditions or constraints. Transition from dualistic, binary thinking to mid-range evaluation using a cognitive progression scheme is indicated when respondents express an appreciation for context dependent responses.

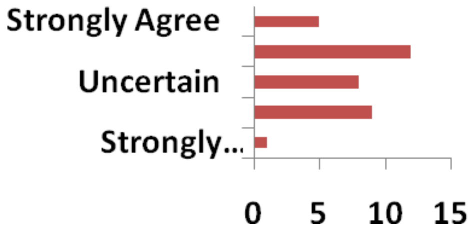

Figure 2. Number of Students Indicating Level of Agreement with Question 6,"I usually like it when my instructor answers a question with "it depends" and follows this statement with a discussion of the topic."

Survey item number 7 assesses the level of dependence of the faculty as sole source of knowledge (refer to Figure 3). Populations who predominantly agree or strongly agree do not find sources of available knowledge aside from the faculty as credible or reliable. Higher order cognitive belief involves collaboration, construction, and evaluation of knowledge with one's peers. Populations generally responding in the affirmative to this item would be found to have tendencies away from absolute knowledge.

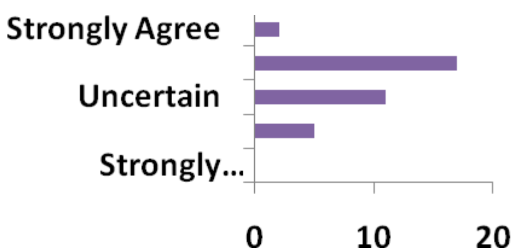

Figure 3. Number of Students Indicating Agreement with Question 7: In the class, I would want the instructor to answer the questions I ask instead of other students answering my questions.

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.

Question 11 is related to epistemic belief and serves as an indicator of positioning relative to cognitive progression's Scheme (Figure 4). Respondents who agree or strongly agree with the statement illustrate a tendency toward dualism and binary thinking. Dualism indicates a predisposition toward belief that one correct answer and one incorrect answer to problems exists. Students exhibiting this tendency search for a right answer and a wrong answer and involve limited or no context in their evaluation. Operating from a non-contextual viewpoint limits cognitive responses to binary answers where absolutes overshadow any opportunity for flexible thinking. From an epistemological framework, agreement or strong agreement with this statement reflects beliefs inconsistent with interpretivism and an ability to juxtapose contextual information with facts to derive solutions to or explanations of phenomena. Strong agreement with this statement would characterize a learner strictly as operating with dualistic tendencies.

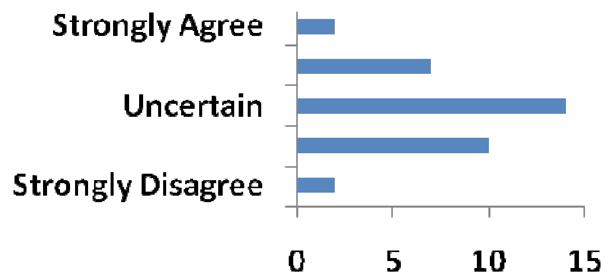

Figure 4. Number of Students Indicating Agreement with Question 11: There is one right answer for most questions and a good instructor knows it

In total, 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.

C. 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 III.
TECHNOLOGY (FIVE-POINT LIKERT SCALE, 1 IS THE MINIMUM & 5 IS THE MAXIMUM SCORE)

Items, Mean and Standard Deviation		
Item	***Mean***	***SD***
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 Class 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?" Did students come with questions about homework or lecture? Were there other evidences of their engagement with thermodynamics outside the class?

The class met twice a week and for the first half of the term the attendance was high with more than 35 students. 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, homework questions would seldom 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 out after lecturing and ask 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 consulted each other for answers.

VI. 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 trouble 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 was 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 [5] 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. Other research [10] 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. Other studies [11] showed that students who exhibit 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 are necessary skills for solving complex problems [12]. 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 concepts and solving 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 mechanism 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 [13]. 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 [5]. This logic consists of (a) what are the known variables, (b) what to be determined, (c) define and draw the system boundary, (d) place the appropriate information on the system, (e) decide the process nature; closed, open—change of state, open—steady flow, (f) determine what equations govern the system, (g) substitute knowns into principles equations: are the unit consistent?, and (h) find answers: is this answer reasonable?

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 [14] 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 [15]. The web-based feedback technology enables students to interact with the teacher and each other by providing and receiving feedback [15] and also to learn by monitoring their errors [16]. 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 [14] and also provides a medium for recording reflection from peers, instructor, and students themselves [17]. 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 [13]. These skills are modeled with examples. Students learn through these models the steps of problem solving [18]. 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. Others [19] showed that peer assessment is more strongly related to teacher assessment than self-assessment. In addition other research [20] has 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.

V. 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. Previous research in thermodynamics instruction at undergraduate levels indicates students are more likely to develop a "feel" for the subject when material and problems are presented in the context of concrete applications [21]. Haung & Gramoll [22] showed the positive impact of visualization, multimedia, and case studies in teaching and learning thermodynamics. 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 [23] 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.

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