Feedback using Asynchronous Discussion Forums in an Online Introductory Thermodynamics Course

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***Abstract*—The asynchronous (i.e., discussion forums) technology was employed for instruction and explication of formative feedback and self-explanation in the first online offering of our introductory thermodynamics course. The goal of the formative feedback was to promote problem solving skills. Exercises were designed to challenge students to search for multiple ways to demonstrate their conceptual understanding of very fundamental physical notions. In the case study presented in this paper, we provide observational data from students, instructors' reflections, the types of questions used in the guided activities, and the role of formative feedback in problem-solving courses. The instructors' reflections illuminated the importance of well-prepared forum questions and motivation for participation (reward) would result in more instances of interaction among students. The discussion focuses on ways to improve forum questions, instructor' feedback, and the frequency of the feedback to improve students' metacognitive strategies in learning and the application of the course material. The observational data are also examined to note if there were any differences in forum contributions online versus students' contributions in a face-to-face class. The study is significant and of interest to faculty and administrators who are considering approaches to increase conceptual understanding in abstract engineering courses as well as access to engineering education via online teaching.**

***Index Terms*— Online teaching, asynchronous technology, synchronous technology, feedback, collaboration, thermodynamics, constructivism, undergraduate, engineering fundamentals.**

I. Introduction

ME2124 (Introduction to Thermal-Fluid Engineering in the Department of Mechanical Engineering) is a required course for students majoring in mechanical engineering and serves as a crucial prerequisite for several very challenging and demanding required technical classes. In response to the needs of engineering students who transfer to the institution or participate in "co-op" work/study situations in addition to those who need to work or are in military service, we designed and offered it online. To meet the rigor of the educational requirements of the ME Department as well as increase access to our undergraduate courses, we examined appropriate online course teaching strategies. Influencing factors and criteria in online course construction generally involve instructional design, educational theory, technological infrastructure, and/or applied research from the scholarship of teaching and learning [1].

ME2124 covers Thermodynamics (approx 1/2), Fluids (approx 1/3) and Heat Transfer (approx 1/4). The topics covered include Thermodynamic properties of substances, equations of state for ideal gases and incompressible substances, system and control volume conservation laws (mass and energy), work and heat transfer, fluid properties, surface stresses (pressure and shear), Bernoulli's equation, introduction to dimensional analysis and Reynolds number, qualitative characteristics of laminar and turbulent flow, viscous losses through pipes, the three modes of heat transfer, steady conduction through composite planar systems, steady convection and surface energy balances, lumped capacitance modeling of transient systems, and introduction to radiation. The course is a 2 credit course meeting twice weekly for 50 minutes (during the traditional academic year). The course is a prerequisite for ME 3124 (Engineering Thermodynamics), ME3404 (Fluid Dynamics) and ME 3304 (Heat and Mass Transfer).

Students are formally introduced to problem solving in engineering and therefore, must actively integrate their prior knowledge with new materials to solve engineering problems in thermodynamics, fluid mechanics, and heat transfer. In the online design of ME 2124, we specifically explored online learning features that could promote successful problem solving. This paper presents our findings and reflection in teaching ME 2124 in regard to feedback that can best promote problem solving. In the next section, the role of discussion forums and feedback in problem solving are discussed. The observational data section includes examples of forum questions and students' responses. The discussion section outlines ways to improve forum questions, instructor' feedback, and the frequency of the feedback to improve students' engagement in learning and the application of the course material. The discussion section includes our reflections on ways to improve formative feedback to guide students in identifying their misconceptions, adopting appropriate task strategies, and correcting procedural errors. The observational data are also examined in terms of differences in forum contributions online versus students' contributions in a face-to-face class. The summary section provides concluding remarks and recommendations for improving the use of feedback in these courses.

II. DISCUSSION FORUMS AND FEEDBACK

One indelible aspect of web learning is the opportunity for learners to provide and receive feedback. Social constructivism [2] suggests that the exchange of critical feedback among peers as well as from the instructor can encourage students to modify their work. Learners engaged in a 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 instructor on their performance. Social constructivist learning theory suggests that feedback is an important consideration because it requires transfer of knowledge and therefore represents students' gain in problem solving. In particular, feedback from peers may push students to perform higher level cognitive functions [3]. In a recent comprehensive review of the kinds of feedback that can best promote successful problem solving, Shute [4] identifies guidelines and features of formative feedback. Our approach adhered to some of the guidelines presented. For example, feedback "elaborate on problems rather than simply verifying correctness," and present "specific and clear" feedback messages in "manageable units" (p.177).

We used the principles presented by Swan [1] in the course design to enhance collaboration and feedback through active engagement with materials and collaboration with peers and instructors. Our previous research [5] showed that synchronous and asynchronous technologies used in course delivery could facilitating teamwork and feedback and impact students' collaboration during problem solving positively. In the online ME2124 we used CentraTM for synchronous lecture sessions and discussion forums for asynchronous instances. Feedback provided through these electronic mediums have been shown to improve students' metacognitive strategies of reflecting, planning, monitoring, and integrating [6] and [7].

During the six weeks of the summer term, we had three synchronous sessions for live lectures and real-time interaction with students each week. Students turned in three sets of homework each week. There was an asynchronous discussion forum for each set of homework. In addition to two instructors, a graduate student monitored these forums to provide timely response to students. In addition, there were conceptual question forums for each lecture. In this paper, we mainly discuss the latter forums.

Our objective was to challenge students to search for multiple ways to demonstrate their conceptual understanding of very fundamental physical notions. According to Jonassen [8], 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. Understanding and having a "feel" for the physical phenomenon would impact problem solving positively [9].The intention for these exercises was to move students from a passive, faculty dependent stance to an active and constructivist stance [2] in addition to helping them to make thoughtful judgments from incomplete data or ambiguous situations [10]. We provided a feedback rubric to help with students' discussion forums postings. The three elements of the rubrics were relevance, engagement, and clarity of students' feedback in regard to problems and topics. However, we generally provided task- level feedback which was specific, timely, and guided their learning.

III. METHODOLOGY

This case study follows a qualitative research approach [11]. The qualitative data includes students' responses to the discussion forums and instructors' reflection. Appropriate Institutional Review Board permission was obtained prior to reporting the data in this paper; however, we have used pseudo names in reporting the students' responses to keep students' identity anonymous.

A. Observational data

Students' data were observed through our online course management system (Scholar). There were a total of 17 discussion forums. The questions in the conceptual forums included the following categories:

1. Providing definitions
2. Applying concepts to solve homework
3. Processing concepts by applying them to other physical cases and problem sets provided by the instructor
4. Making decisions in the context of solving problems with incomplete data

This section presents examples of forum questions in each of the four categories, students' responses, and the feedback we provided. We have included responses from various students to show the variability in students' understanding and instances of constructivist learning. Therefore, student 1 in category 1 is not the same student as in other categories. The summaries of observations for each category are instructors' reflections.

B. Discussion forum questions: Category 1

Questions in the category of providing definitions were intended to help students with "applying concepts to solve homework" and "processing concepts by applying them to other physical cases and problem sets provided by the instructor" and examples included:

a. Define Specific Heat

b. The specific heat at constant volume can be measured by holding volume constant on a sample of a substance. Why would the specific heat be different if the pressure on the sample is held constant instead of volume?

c. If a known amount of energy is added to a sample of substance with exceptionally high specific heat, will the temperature rise of the sample be relatively small or relatively large (compared to a substance with moderate specific heat)? Justify your answer.

Student 1 response:
a.) Specific heat is the amount of heat per unit mass required to raise the temperature of a substance by one degree Celsius or Kelvin.

b.) I'm having trouble fully understanding this one, so hopefully one of you can help me out.

c.) We can use the equation to describe heat transfer situations, Q = mc(T2-T1). We see that the temperature rise and the specific heat are inversely proportional. Therefore, a higher specific heat would result in less of a temperature change.

Student 2 response:
a) specific heat is how much energy it takes to raise a substance one degree K per unit mass. How much energy it takes to change the temperature of a substance.

b) This could be because, if the substance is not an ideal gas, it won't necessarily follow pv= RT so temperature could be related to pressure and volume differently.

c) A substance with a larger specific heat will change temperature less than a substance with a lower specific heat because the larger specific heat substance requires more energy to go up a degree. This makes sense because a higher specific heat would correspond to a larger value for KJ in the units KJ/Kg*K and thus more energy capacity.

Instructor' feedback was:
Good, it appears everyone has a pretty good idea of the general concept of specific heat. The second question about specific heat at a constant pressure is a bit more subtle. The specific heat at constant volume is easily imagined experimentally. Add a small amount of energy via heat transfer to a fixed mass of substance while holding the volume constant and measure the resulting rise in temperature. The ratio of the energy added to the temperature rise (and dividing by the mass of the sample) is the specific heat at constant volume. If however you run the same experiment but now let the pressure stay constant on the sample, its volume will change (just imagine one of your constant pressure piston-cylinder problems). Consequently work transfer will occur (that didn't occur with the constant volume experiment). Therefore for the same energy added (Q), now with work transfer the temperature change will be different and so is the specific heat. So specific heat at constant pressure is different than at constant volume (due to work exchange).

Summary of observations for category 1: Many students have a tendency to devote as little time as possible to the forums, if permitted. This is easily accomplished by them for this Category by simply pulling a definition directly from the text in the book or repeating an equation. Although much of what they are repeating is correct, it is unclear whether they grasp the concept and can apply it in other contexts. It may have been more effective to give feedback to the students through additional questions and pulling in their common experiences, for example with specific heats of various materials as well as to emphasize the role of mass (quantity of the substance). In hindsight, continuing to probe the students with additional questions (sometime rhetorical) during the forum would likely be more effective. However, this must be done judiciously and the asynchronous character of the forums may hinder the effectiveness of this tactic. Timely responses and interaction through the forums is necessary.

C. Discussion forum questions: Category 2

Questions in the category of "applying concepts to solve homework" were intended to help students with practicing with the definitions in the context of problems and thus internalizing the concepts. Examples included:

1. Use your own words to define quasi-equilibrium process. Discuss the differences between equilibrium and quasi-equilibrium in thermodynamics. Can you think of any of homework problems so far that these assumptions had to be made? You may use examples or reference text if necessary.

2. What is the difference between energy and power?

3. What is the difference between gage pressure and absolute pressure?

Student 1 response:
1. A quasi-equilibrium process is a process in which the system remains very close to equilibrium every step of the way. Every moment in time during the process can be considered at equilibrium.

At equilibrium the system is completely balanced and unchanging, where as in quasi-equilibrium the system is changing but is considered to be at equilibrium.

An example of a quasi-equilibrium process would be problem 2.68 from this week's homework, but problem 2.64 would not be considered a quasi-equilibrium process.

2. Energy is independent of time, whereas power is a measure of the energy per unit time.

3. Gage pressure is the amount of pressure above absolute pressure. In other words, gage pressure equals the difference between a given pressure and the absolute pressure (gage pressure is always equal to or higher than absolute pressure or the pressure would be considered vacuum pressure).

Student 2 response:

A quasi-equilibrium process is a process in which the changes are occurring slowly enough that the state of all of the properties of the all of the molecules is essentially the same all the time. Actual equilibrium means that nothing is changing at all, quasi means that it is slow enough to be treated like actual equilibrium

Energy what enables work to be done, power is how fast a certain amount of work can be done (work/time).

Gage pressure is the pressure above the surrounding atmospheric pressure (or whatever pressure your comparing to). Absolute pressure is the pressure relative to the zero pressure of a vacuum, like space.

Instructor' feedback was:

Both of you have the idea of quasi-equilibrium down pretty well. And Dorian has the idea of gage pressure down, I think. Most pressure gages (not all) can only measure pressure relative to the pressure in which they are immersed. So a typical dial pressure gage attached to a tank which itself is sitting in a room will measure the pressure of the gas in the tank relative to the pressure in the room. If the pressure in the room is 14.7 psi (absolute) and the gage reads 200 psi (gage), then the absolute pressure of the gas in the tank is 214.7 psi (absolute). If the gage is designed to measure pressures below the surrounding pressure, then we could measure -10 psi (gage) which would be 4.7 psi (absolute) using the previous atmospheric pressure.

Summary of observations for category 2: The intention of these forum questions was to reinforce these very fundamental concepts that will be applied repeatedly in a variety of subsequent homework problems. Although the students responses are generally correct (except with regards to gage and absolute pressure) it is unclear whether they have a strong grasp of these concepts; their replies are brief and textbook. Requiring the students to cite examples would have been appropriate and one or two additional questions in response to their replies (to force the students to apply the concepts to their own common experiences) may also have induced the students to consider the concepts more deeply.

D. *Discussion forum questions: Category 3*

Questions in the category of "processing concepts by applying them to other physical cases and problem sets provided by the instructor" were intended to help students to apply local learning to global concepts. These instances allowed students to reflect on the new concepts and integrate them with the previous knowledge they had just gained in the previous sections. Examples included:

1. Imagine dragging a large rectangular flat plate at constant velocity through a body of stagnant water. The plate is horizontal and has nearly zero projected area in the direction of motion. Nevertheless, it will be necessary to apply a force to keep the plate in motion at constant velocity. Why, and what is the physical origin of the resistance to motion in this case?

2. In the lecture we demonstrated that under certain conditions the fluid velocity profile is linear between a solid stationary surface and a moving surface above the fluid layer. What does this linear profile imply about the velocity gradient within the fluid layer and the viscous shear stress within the layer?

3. In the lecture we spoke about the no slip condition for viscous fluids where the velocity of the fluid must be equal to the velocity of surface on the surface. Of course above the surface the fluid can be in motion. It is sometimes said that a wing on an airplane generates lift because the pressure above the wing is lower than on the underside of the wing (and that this is true because the air above the wing is moving faster than the air below). However, if the no slip condition is true, the velocity of the air is zero relative to the wing surface, both above and below the wing. Can you explain this?

Student 1 response:

1. Because there is no resistance to air resistance, the resistance must be because of the viscosity of the fluid. This is the friction between the fluid and the plate, similar to the friction between the plate and a solid surface.

2. This linear relationship implies that the velocity will increase proportionately with distance from the surface as well as the shear stress.

3. Yes, there is no slip at the surface of the wing, but only at the surface of the wing. The velocity of the air just a little above the wing is effectively free from this rule and therefore can move faster or slower regardless of the relative speed of the wing. It is this air, which is not on the surface of the wing, that creates lift.

Student 2 response:

1. Due to the no-slip condition which all fluids satisfy, the water goes from zero velocity to the velocity of the plate where the plate touches the water and tapers down to zero away from the plate. This increase in energy of the water (particularly kinetic and possible heat) must be a result of the decrease in energy of the plate.

2. Both the velocity gradient and viscous shear stress are continuous functions increasing linearly from zero at the stationary solid surface to the maximum at the moving surface.

3. Though the air has a zero relative velocity, the distance from the wing to the maximum velocity of the air may be very small; the air accelerates very rapidly from the surface of the wing to the maximum velocity. So essentially the vast majority of the air space above and below the wing has fast moving air and is able to create the high and low pressures to generate lift.

Instructor' feedback was:

Everyone so far, is correct in their responses to these three questions, with the exception of the second question. If the velocity profile is linear (which is a very special case, since most profiles are not), but if it is linear the velocity gradient, dV/dy, is a constant throughout the flow, and since the shear stress is proportional to the velocity gradient, remember it is mu (viscosity) times the velocity gradient, the shear stress is also constant throughout the flow.

Summary of observation for category 3: The one student is confusing momentum and force with energy and heat and none of the students are doing any analytical thinking when considering a linear velocity profile. They have not concluded that the stress varies linearly, they are assuming it must. No one raises a question or objects to the hasty assumption that everything varies linearly if the velocity does. Our response is correct but probably not as effective as posing a few simple additional questions to coax the students through the analysis to discover the answer for themselves or to generalize the result to other velocity profiles. Also, there is no exchange of ideas between the forum participants. This requires instructor intervention. Their grasp of the last question is encouraging however.

E. Discussion forum questions: Category 4

Questions in the category of "Making decisions in the context of solving problems with incomplete data" were intended to help students to embrace ambiguity and make thoughtful judgments from incomplete data or unrelated situations. Examples included:

Do we have enough data to solve problem 1.35? If not, what assumptions do we need to make? If so, please list them.

1.35: The barometer shown in Fig. 1.35 contains mercury (ρ=13.59g/cm3). If the local atmospheric pressure is 100 kPa and g=9.81m/s2, determine the height of the mercury column, L, in mmHg and in Hg.

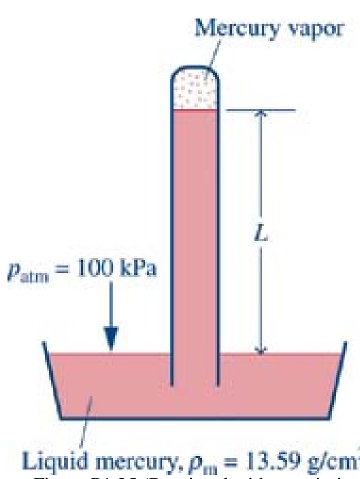

Figure P1.35 (Reprinted with permission of John Wiley & Sons, Inc., Fundamentals of Thermodynamics, 6th edition, Moran & Shapiro, 2008)

Student 1 response:
No. need more info.

In order to solve the problem we would have to assume the volume of the Hg does not change, the Hg vaper in the top of the tube stay constant and the lenght L not at normal atmospheric pressure. The lenght of L not would also need to be known to solve for L final.

Then later he added:

"also the area of the of the Hg that is open to the atmosphere would need to be known"

Student 2 wrote:

I agree with your assumptions, you pretty much summed everything up. I'd like to ask the question of whether these assumptions are reasonable? I would tend to think that since Mercury is a rather dense liquid, the volume would not change significantly. As for the Mercury vapors in the top, I tend to think that barometers would either make adjustments for this change or it is in fact negligible. What does everyone else think?

After this response, the first student wrote:

I think your right about both actually. I just did the reading and since Hg vaper is used the pressure is much less than that of the atmosphere.

Would the area of the exposed Hg to the atmosphere change how much L changes?? I'm not really sure.

Then student 3 wrote:

I believe there is enough information provided in the problem. The pressure of the vapor is small compared to the atmosphere pressure, so the p vapor can be ignored in the equation. The other data needed is provided in the problem statement.

Fourth student responded:

We do not have enough info to solve this without assumptions. Since the height is not given, we must assume that the column is short enough that pressure and gravity can be taken as constant. Also, we must assume that the pressure of mercury vapor is negligible, as the book says.

Another student then responded:

Since the mercury vapor pressure is much less than atmospheric pressure, we can approximate equation 1.12 from the book, giving us the equation patm = ρmgL. This allows us to solve for L using some simple algebraic steps.

Instructor' feedback was:

First, understand that nearly all technical problems require some approximations and assumptions; and we frequently make them implicitly without realizing it. In fact one of our goals in this course is to make you think more explicitly about your assumptions. Let me ask you some additional questions related to your responses.

Like one of your fellow students I would like to ask if some of your listed assumptions are sound or not. One of you thinks we must assume the volume of the Hg remains constant and that the amount of vapor in the top doesn't change. How might the volume of the Hg change, even for a dense liquid? Suppose the fluid were liquid water instead of Hg. Over what period of time might you have to wait to see a significant change in volume of the water (why)? It is also argued that the area of the Hg open to the atmosphere must be known to solve for the height L. Suppose the pan has a diameter that is twice as big (but the depth of the Hg in the pan is otherwise the same). Would you expect the height L to change?

Read a little more in the textbook about the small vapor region at the top of the mercury column. What is the pressure of the vapor in this region, can you find a value for it for mercury at say 20 C?

The assumption that the column must be short (so that gravity and pressure are constant) is an interesting one. How long do you think the column would need to be before the variation of gravity might be important? Go to the internet and find an equation for the variation of g with distance from the earth's surface. From this determine whether the assumption of constant g is reasonable.

Do any of you know anything about surface tension effects between a liquid and a solid surface? I would think we are making some assumption in this analysis about the surface tension between the Hg and the tube.

Summary of observation for category 4: This question could have been better posed, asking for more explanation. That is, not only to list the required assumptions, but to give some qualitative or quantitative justification for them. What we are terming category 4 questions are the most difficult for the students and problematic for the instructor, particularly in an introductory course that introduces fundamental technical concepts. Posing questions which lack complete information or for which require a number of assumptions, while introducing new concepts can be frustrating for the students and even counterproductive. Here we attempt to ease the students into this by asking them to explicitly note the assumptions they must make to obtain a solution. The students obviously struggle and make some unnecessary assumptions. For some of the students their thinking is hasty without serious consideration, our instructor responses are used to force them to think more specifically, or to consider some variation on the problem, and to use other resources.

IV. DISCUSSION AND REFLECTIONS

The forum questions were designed to serve several purposes, (1) to get the students to think more deeply about new concepts that were introduced in the textbook and lecture, (2) in some instances to help them with homework questions, and (3) better prepare them for the quizzes and tests. The primary goal of the forum questions was item (1) i.e. knowledge and understanding of the subject, not the preparation for homework, quizzes and tests. The forum questions were learning related not associated with testing and assessment.

In a face-to-face traditional lecture course, depending upon the instructor's style, very similar questions may be raised for discussion; although in this instructor's experience not as frequently as was the case in the on-line class. More likely the "forum-style" questions would be part of a written homework assignment (textbook's call these "conceptual" questions), to be discussed in class if time permits. The question's we used as forum questions are not different in content from such "conceptual" questions that would be assigned as homework.

In the summer online course, 26% of the total grade was from homework and forums. Our main emphasis in forums was to help students with the steps of problem solving methodology they needed to use in solving homework problems which centered on writing the specific assumptions, constraints, and identifying the correct formulas for the given data before engaging in the mathematical calculations. The feedback rubrics outlined the expectations of their postings and feedback to peers in these forums in terms of relevance, engagement, and clarity.

Due to the time constraints of the summer term (6-weeks), our feedback generally concentrated on task-level feedback. According to Shute [4], a task-level feedback provides more specific and timely feedback as opposed to summary feedback which is intended to modify instruction for the whole class. In addition to forums designed for conceptual questions, students could discuss their homework problems in the forums that were specifically designed for this purpose. In these forums, our feedback was aimed to help struggling students to reduce cognitive loads and supported them in identifying texts that needed to be reviewed or example problems in the text books that addressed their misconceptions. Other times, our feedback provided information to correct inappropriate strategies because of wrong assumptions or offered alternatives for students to identify misconceptions or correct procedural errors.

Since the enrollment was relatively small, our observations are not statistically meaningful, but may be of interest and relevant. We note:

- Only a few students participated in the live (synchronous) class lecture. These few were regular attendees, rarely missing a live (online) lecture. The student receiving the highest score and grade in the course was a regular.
- Those students who regularly logged into the live lecture did avail themselves of the instructor and asked questions during the lecture, although usually only after prompting by the instructor, or when previous forum questions were discussed by the instructor at the beginning of the session.
- It was extremely rare to receive a question via email or otherwise from those students who viewed the lectures asynchronously.

- Participation in the forums was erratic with approximately 2/3 of the students actually responding in any way at all to the forum questions. The instructors believe that the forums have the potential to be a powerful tool to engage the students in much more conceptual questions, but the reward for participation should probably be much higher in order to encourage more consistent and thoughtful participation.

Although the on-line student enrollment was small (35 students enrolled at first, but after the second week it was reduced to 16) compared to the traditional in-classroom offering of ME 2124, the instructors observe that student participation in "forum-type" conceptual questions in the traditional classroom setting are difficult to sustain and are driven by the instructor. Students in a live classroom setting, when dealing with conceptual questions related to technical material, are reluctant to volunteer their ideas, active open discussion is difficult to achieve and maintain except with frequent prompting by the instructor. Students in the on-line course are less inhibited in expressing their ideas or understanding of the material and can inspire other students to respond. The design of well-prepared and thought-provoking forum questions is crucial to the spontaneous interaction between the students, as is motivation for participation (reward). In addition, the on-line version of the course could be used in a larger scale in a traditional offering of the course with addition of the graduate student resource support. In particular, this support would be used to facilitate the forums and run interactive forum groups.

V. SUMMARY

In this paper, we discussed our findings and reflection in online teaching of ME2124, an important pre-requisite to many other ME courses, in regard to guided exercises and feedback to improve problem solving. Our objective was not to compare students' performance in this on-line course with those in traditional offering of the course. Our instructional design was informed by the findings from our Fall 2009 study reported in a 2010 IMECE conference paper [5] which focused on the following variables: students' self-regulation in the online environments, self-efficacy toward problem solving, and epistemic beliefs as they relate to interacting with peers, instructors and instruction. The results in [5] showed that discussion and providing feedback using forums could impact students' engagement and learning positively.

ME 2124 is an important prerequisite course for several higher level, technically challenging courses. This course is also a problem solving course, which in the authors' opinion makes the design of an on-line version of the course more difficult, particularly an on-line course which is asynchronous. As a result the group forums become a very significant requirement of the on-line problem-solving course, in the authors' opinions. It is, to our knowledge, an open research question as to whether asynchronous group forums can function as effectively (for problem-solving engineering courses) as synchronous forums with direct, live instructor-student participation. One consideration will be to provide coaching on the elements and use of the feedback rubric, thus aligning the engagement, relevance, and clarity with the steps of problem solving.

In the authors' experience problem-solving courses usually require much more interaction with the students. Students' attitudes toward on-line courses are not necessarily consistent with this, as asynchronous lectures and asynchronous forums are the main appeal of on-line courses, with relatively little interaction with the instructor. It may be practical to offer a purely asynchronous on-line version of ME 2124 but it will necessarily require much more intensive use of the forums and some strategy to enhance/require regular and consistent interaction between the students and the instructor. A strong incentive (reward) is needed to encourage student participation in the forums, as well as frequent and consistent participation by the instructor, for the forums to succeed and fulfill their purpose. In addition, our feedback could be in the form of posing more frequent questions to coax the students through the analysis to discover the next steps for themselves and therefore, increase the frequency of interaction and collaboration among students. A final concern is the maturity of the students and their commitment to the demands of the course (which are not typical of most students' expectations for an on-line course). Sophomores may not have developed good time-management skills yet, and will not devote the time necessary to succeed in the class and they will be ill-prepared for the subsequent courses which build on the material in ME 2124.

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