AC 2010-2415: SHIFTING GEARS: MOVING AWAY FROM THE CONTROLLED EXPERIMENTAL MODEL WHILE IMPROVING RIGOR IN ENGINEERING EDUCATION RESEARCH

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SHIFTING GEARS: MOVING AWAY FROM THE CONTROLLED EXPERIMENTAL MODEL

Abstract: The authors' recent efforts in educational research have focused on implementation of varied and multiple pedagogies with introduction of a hands-on desktop learning module as the vehicle for introducing pedagogical changes in a fluid mechanics and heat transfer course. It has been difficult to find statistically meaningful results because of small sizes of the classes, a once per year course offering, and in maintaining experimental controls at partner institutions with variant implementations. Along with our problems, there is a poor history regarding random control testing in educational research. This has convinced us to move toward a different class model centered around a project-based approach with design discussions reviewed for critical reasoning by students and faculty within the experimental site institution and industrial representatives outside the institution. We are also shifting away from traditional quantitative definitions of experimental rigor towards the greater utility of field research responsive to the realities of our classroom and the greater opportunity to learn more about how students learn (as well as what they know). In addition, the rubric based approach we have adopted puts the onus of assessment on the expertise of faculty rather than on the expertise of a psychometrician. This paper presents our reasoning, experiences, and results as we take our research from a traditional model towards a design based research model.

Author's note: Since this paper centers on a project-based implementation currently in progress we are able in the present draft to report results on student progress made to date. Final analyses from the semester results will be reported in the ASEE presentation.

Background – What we have done

For the past 12 years we have been developing a pedagogy that combines aspects of *C*ooperative, *H*ands-on, *A*ctive and *P*roblem based *L*earning into a unique classroom environment, which we refer to by the acronym CHAPL. This has been developed in a required second semester junior year course, Fluid Mechanics and Heat Transfer. This course is the second course in our transport series.

CHAPLis a group-centered learning approach in which the instructor and teaching assistants act as preceptors to assist groups in narrowing the discussion focus, probe and guide group thinking when misconceptions are encountered and, on occasion, assist groups in resolving conflicts. One of the pedagogical tools central to this approach is the "Jigsaw" or "Expert" group member idea advanced by Aronson *et al.*(1978)where students are first split into Home Groups and each team member is assigned a set of concepts relevant to the broad field of either fluid mechanics and/or heat transfer. Immediately after this, new "Jigsaw" teams are formed and comprised of students from each Home Group who share responsibility for a concept.

In the initial implementation (Golter, Van Wie et al. 2005) each Jigsaw team was provided access to a dresser sized unit that consists of a small hands-on module, such as an 18 inch long shell & tube heat exchanger with ancillary two and a half gallon hot and cold water reservoirs and five gallon waste containers, thermocouples and temperature display, manometer for pressure readouts across the unit, a Pitot tube for measuring flow rates, and a two foot by three foot white board for students to draw diagrams and develop system models. To allow exploration of their concepts Jigsaw teams were charged with the task of taking two class periods to study concepts embedded within a given module and develop, for their respective Home Groups, a take-home reading assignment and quiz, a quick 5 to 10-minute in-class experimental exercise, and a fill-in-the-blank worksheet with room for derivations of models elicited from the group discussions surrounding an experiment with the piece of equipment being used. All the Jigsaw module activities were edited by the instructor to assure they were rigorous and contained content appropriate for the upcoming group learning activity.

After return to their Home Groups each "Expert" had a class period to guide the rest of their group members through the exercises they developed. The groups were expected to complete the reading assignment and quiz for whichever module they were going to do prior to class each day. The fill-in-the-blank worksheets used in each class were not turned in as homework but in effect substituted for traditional note taking in a lecture course. The students then had a practical, but non-trivial homework module problem involving application of principles surrounding the hands-on modules for any particular week; such as the design of a double pipe heat exchanger for heating syrup at a county fair. The entire process occurred once for the fluid mechanics and once for the heat transfer portion of the class. Other textbook problems were given throughout the semester that were representative of the material being learned or which contributed to an important concept or knowledge base not addressed in the hands-on activities; an example text question asks at what temperature difference do wall temperature effects on viscosity result in a significant, more than 10%, difference in the amount of heat transferred. Roughly half of the module and book problems were group and half individual assignments. Each half of the semester finished with two class periods of group work on an open-ended fluid-flow and heat transfer design project (such as the design of heated water showers at a local river beach), one period for project presentations, and one period for a midterm exam. This approach showed promising results in terms of student engagement and enthusiasm.

After the initial success, we determined that it would be necessary to address the issue of laboratory space if this pedagogy were to be implemented at other institutions. To this end we developed the Desktop Learning Module (DLM), figure 1 (Golter, Van Wie et al. 2006). The DLMs are a system consisting of an approximately one cubic foot base unit and a series of modular cartridges. The base unit contains pumps, flowmeters, thermocouples, water tanks, and digital displays. The cartridges consist of small reproductions of common heat transfer and/or fluid mechanics equipment. The system reaches steady state rapidly so that students can do a set of 3-4 experiments within a ten minute time frame, and obtain results sufficient to reinforce their learning.

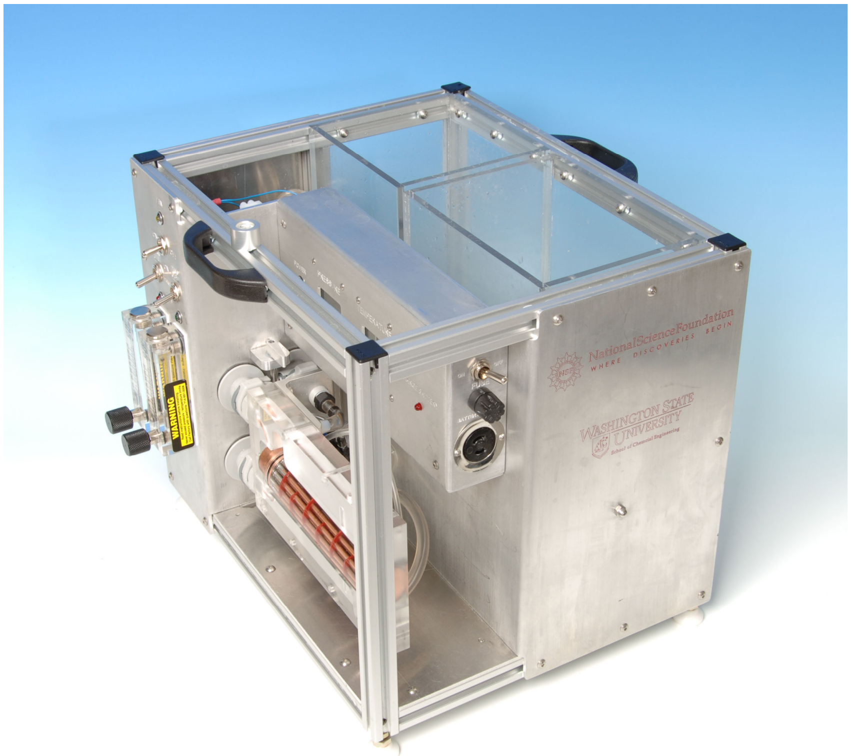

Figure 1: DLM Base Unit with Shell and Tube Heat Exchanger Cartridge

Problems with Control studies and with what we've done

Kennedy(Kennedy 1997) presents a synopsis of the literature relating research to practice in education, specifically K-12. She specifically examines four common hypotheses put forward to explain the gap between research and practice: The research is not sufficiently persuasive or authoritative; The research is not relevant to practice and does not address the issues and concerns of teachers; Ideas from research have not been accessible to teachers and are either difficult to find or understand; The education system itself is either too intractable or too unstable, and therefore unable to engage in systematic change. Further, she notes that the gap between educational research and educational practice has been an ongoing phenomena and complaint of educational researchers since at least 1934. Careful experimental design was a focus of educational research in the 1960's, but such research did not result in broad and rapid adoption of researched innovations. Similarly the 1970's and 80's produced a body of research focused on teacher's concerns and viewpoints, which has had a similarly low immediate impact on educational practice. The article suggests that the educational research lacks the socio-political 'authority' to bring about systematic reform. Regardless of the reason it is clear that research in the field of education has not produced a history of usefulness for educators.

Our particular situation is complicated further in that we have a long time scale, one semester per year, and low numbers, 12-30 students per year. This has made it difficult to conduct true rigorous controlled experiments. Additionally our assessments have been performed on extra-credit assignments where the students receive credit for performing the assessment without any scaling for how well they performed. While this has resulted in very high, usually 100%, participation, there is little external motivation for the students to invest much time in the assignments. Because of the 'tacked-on' nature of our assessments students seem to not give their best effort on concept inventories, rushing to turn them in without thought, nor to design reflections sometimes turning in the very same reflection they submitted earlier in the semester just so they will get credit. The generally low student numbers are also problematic as any meaningful results that may be evident are masked by large standard deviations. In contrast, our qualitative assessments consistently show trends that indicate the environment is consistent with educational best practices. Survey responses show overwhelmingly that in contrast to the traditional lectures students have increased interactions with other students and the instructor, more active learning, immediate feedback from an instructor listening to student discussions, more time on task, high expectations and an appreciation for diverse learning environments.

Student end-of-semester course evaluations through this have usually been slightly low and we see the same comments year after year. Namely: "This course is too much work for only 2 credits."This comment when coupled and contrasted with other feedback that this has been one of the most valuable courses for preparing the students for the 'real world' leaves us disturbed.

Description of new approach

This semester we have shifted the course away from our standard CHAPL design. We reconsidered the learning goals for the course and realized that our real goal is to teach students how to apply the principles of fluid mechanics and heat transfer to 1) design a fluids and heat transfer system to meet some set of requirements and 2) analyze existing designs. In keeping with this, the course will be centered on a single design project with additional learning assessments being made from analysis of existing design cases. This project is proposed by student groups, after which we add "customer requirements" to ensure the project will be complex enough to meet the content requirements of our course. The students submitted a first draft shortly after the midpoint of the semester and will submit a final draft at the end of the semester. The syllabus and grading rubric are attached in the appendix.

We started the class out by doing some reverse engineering of existing designs. This case study analysis gives us an opportunity to provide the students with a framework from which to organize the knowledge they acquire throughout the rest of the semester and some ideas as to what a design should contain. Following this returned to the jigsaw environment and have the student home groups rotate through the equipment stations, giving each student the opportunity to develop relative expertise and encourage interdependence within each design group. This portion of the course will take less time than in previous implementations as we are providing the student groups with the worksheet, reading assignment and quiz that they would have had to develop themselves in prior years. This is in attempt to address the "too much work for 2 credits" feeling while still giving the students a rigorous set of activities to prepare for and use at the various learning stations.

The first set of jigsaw exercises was organized to include a suite of fluid mechanics and heat transfer experiences so that a team will have the fundamental conceptual knowledge to submit a first draft of their design project. The exercises included pressure drop, then heat transfer in a double pipe heat exchanger. Then the same approach was taken for a shell and tube heat exchanger, followed by a flow measurement and Reynolds experiment station. Active learning exercises are also given for pipe optimization and parallel flow situation and homework problems and lectures include material on the energy balance, heat transfer concepts, natural convectionevaporation and radiation. While other heat exchanger designs are forthcoming at this point in the semester the initial set of exercises gives students the basis for understanding pressure drops in almost any geometry, and the general nature of an overall heat transfer coefficient being the sum of a series of resistance. Thus student teams can introduce other heat exchanger types into their projects by including formulas for the varied heat transfer coefficients.

The final portion of the course includes the introduction other heat transfer equipment, and related fluid flow issues, such as an extended area exchanger, a new evaporative cooling unit, packed and fluidized beds and boiling and condenser units. A presentation is also given on heat exchanger optimization. With enhanced understanding and increased ability to model these systems this gives opportunities for the groups to revise their process design and work on areas where their understanding was shown to be weak in their initial project draft. During this time the instructor and students will be actively addressing any misconceptions or weak areas of understanding that arose out of the initial drafts.

During the first phase of the course the students had a small number of textbook homework problems and a write up of the case study analysis to do as individuals. Throughout the course they have a mixture of group and individual problems that relate directly to the equipment they worked with in class, and the data they collected using it. They are also required to submit periodic status reports so that we can monitor each group's progress and intervene if necessary. The students will have a final exam consisting of an assessment of an existing case study design. The course grade is based 60% on the design project, 5% on the case study analysis, 20% on homework, and 15% on the final design analysis. The group portion of each student's grades will be scaled according to peer feedback

We are grading the design projects using a Critical Reasoning rubric *(Appendix,* adapted from one developed by our campus' Center for Teaching and Learning, now the Office of Assessment and Innovation). This rubric can be used to assessstudent ability to critically address a technical design problem. We are asking the students use the same rubric to assess the case studies. This gives them familiarity with the expectations for their own projects and valuable experience in assessment that they can then apply to improve their own work. For the purpose of this rubric we are defining critical thinking as the ability to examine a relatively technical problem or situation, understand what is needed to design a solution, and make appropriate and justifiable simplifications to arrive at a feasible solution. We selected rubric judging criteria such that a score of four (4) is the level of proficiency we would expect from our students at graduation and all other scores are relative to that standard. Table 1 contains the estimated grading criteria for the design related assignments. This provides students with our expectations for their performance at each stage throughout the course. However, because this is the first time to use rating criteria, given ahead of time, as a guideline for establishing grades, we take the liberty to scale the grades. We are finding our initial expectations are overoptimistic as we view our relatively low collective ratings in contrast with the thoughtful and large volume of work submitted by teams (projects) and individual students (case studies); what the instructors deem as quality student-to-students and student team-to-instructor interactions within and outside of class; the feedback acquired through team status reports; the excellent team and individual homework grades; and almost 100%

attendance at an 8:10 am class, in contrast to 30 – 50% attendance rates in the early lecture portion of the course without the rigorous team accountability aspect introduced as a result of our jigsaw exercises

Table 1: Initial targets for converting student rubric score to an amount of credit toward the course grade.

Grade	A	B	C	D
Proposal I (2%)	3.3	1.7	1.2	1.0
Proposal II (8%)	3.5	2.7	2.4	2.0
Initial Project (10%)	3.5	2.7	2.4	2.0
Final Presentation (40%)	3.8	3.0	2.6	2.2
Case Study Analysis I (5%)	2.8	2.2	1.9	1.6
Case Study Analysis Final II (15%)	3.8	3.0	2.6	2.2

Each paper is rated by two individuals, and differences, on the average of the scores from the nine categories, larger than 1 or which cross the proficiency line (score of four) have to be discussed in order to build a consensus score. This is a common convention for validating the assessment in education (ETS 2010) To assure that consistent criteria arebeing used by all raters a test rating isdone, by each individual rater, on a single arbitrary student paper where it israted by each individual and discussed to make sure our rating scales arein agreement. Periodically, raters recalibrate themselves by assessing another common paper. In the end inter-rater reliability isassessed to assure validity of the rating process.

Perhaps the most unique aspect of this implementation is that we will be inviting alums to participate in rating the final design projects. We are asking a group of alums to rate two papers each using our rubric, and to also provide feedback on the rubric itself.

Results to date, prior and anticipated results

Since this paper is concerned with an implementation that is in process at the time of submission, we will report results on student progress to date and anticipated results, which will be summarized at the ASEE conference. To begin with, we anticipate that having the critical thinking rubric tightly integrated with a central aspect of the course (rather than added on at the end and not shared with students), along with the implicit feedback from the professor at each assignment, will result in statistically significant improvements in critical thinking scores over the semester. Secondly we anticipate that there will be, on average, a difference between the ratings by alums that have been in industry for at least a couple of years and the ratings by faculty. Based on the experience of one of the co-authors we anticipate that the alums will rate papers lower than faculty, as they are more used to seeing a higher standard of performance on industrial teams while the instructors will look more at the growth in conceptual understanding of course content.. Finally we anticipate that the changes we are making will address student concerns regarding the amount of work required by the course. This is because assessments are integrated into the course objectives and assignments. Rather than extra design reflections, student teams are assessed on their actual project proposals. They not only appreciate the feedback, but are motivated to improve.

Results from applying the critical reasoningrubric on individual student design reflections in prior years, an example is in figure 2, show very little change over the course of a semester, especially when comparing sophmores at one institution to juniors at Washington State University. Alternately, the score we would expect our students to be capable of by graduation, that is a 4 (to be confirmed by employers). This gap problematic.

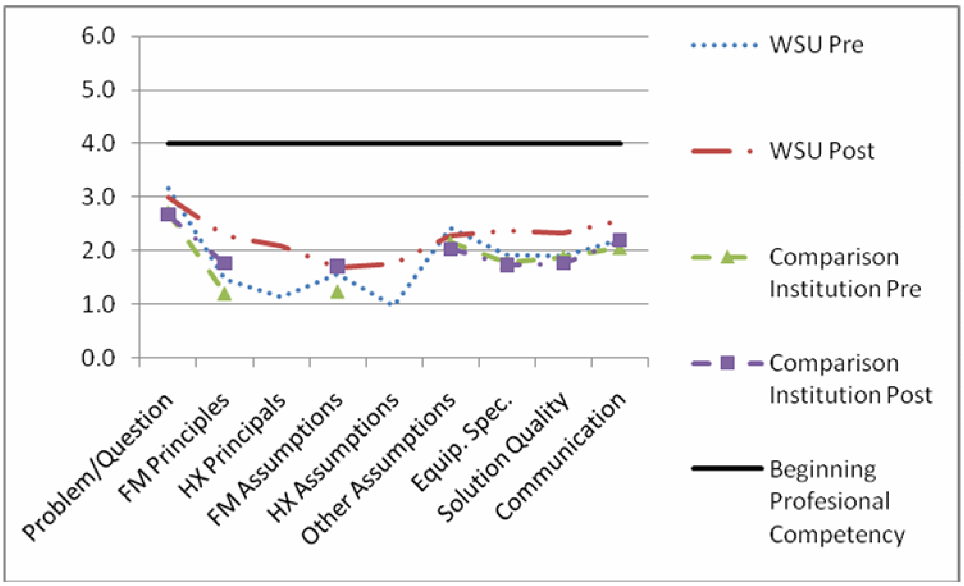

Figure 2: Critical Thinking Rubric results from spring 2009. Comparing the authors' instititution scores (WSU) for second semester juniors tostudent scores in a similarcourse, except given to sophmores and lacking a heat transfer portion, at another institution. While there is a shift in the direction of competency at the authors insitution, it is miniscule in comparison with the gap between the average score, 2.3 at the semester's end, and the target of 4.0 at graduation. Further, an ANOVA analasis of the WSU scores shows that difference is not significant at the 95% confidence level. There is no noticable shift at the comparison institution.

In contrast with previous years, we see evidence of progress in the current intervention. Figures 3 and 4 show the results of Problem Identification portion of all currently completed assignments which used the critical reasoning rubric.

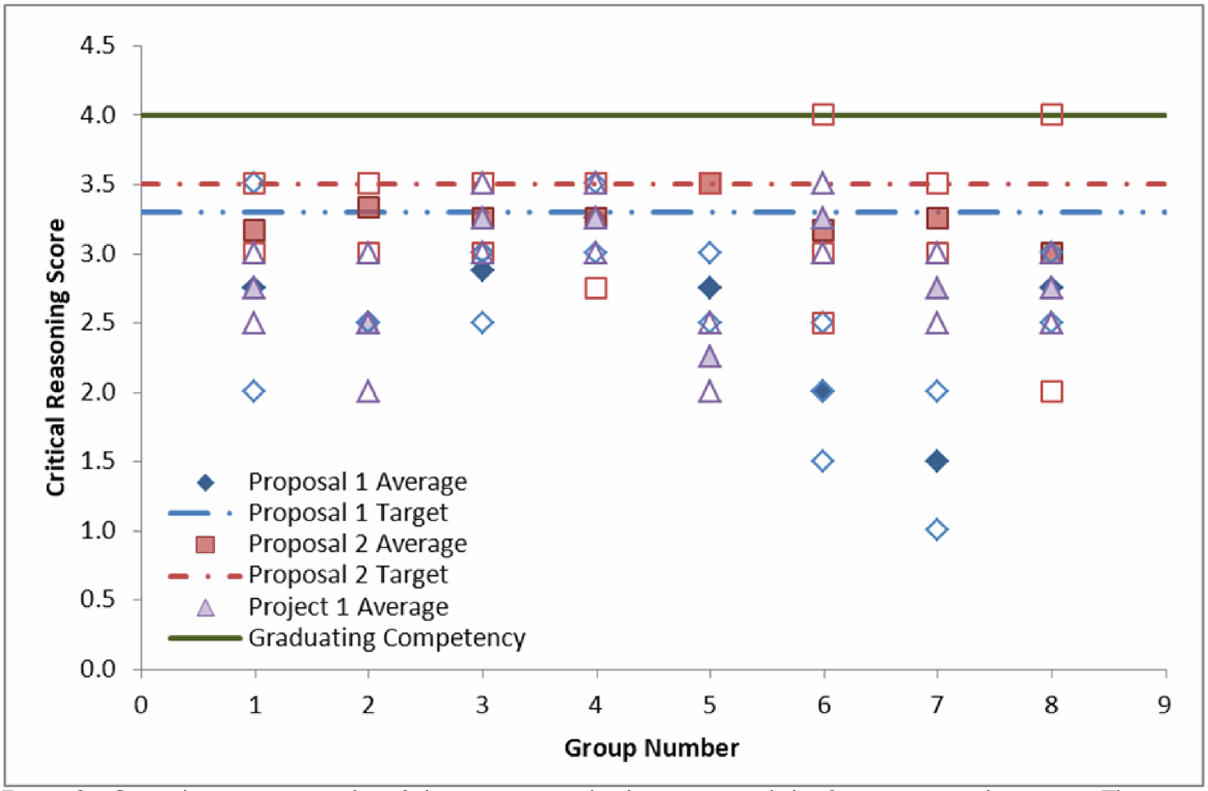

Figure 3: Critical reasoning results of the two proposal submissions and the first project submission. The proposals were only rated on the first aspect of the rubric. That is to say problem identification. To give an indication of the spread of the data, the individual scores are included as the hollow markers. For comparison purposes, only the problem identification portion of the first project submission score is shown.

There are two more assignments yet to submitted. Statistically, all of the significant improvement, Table 2, occurred between the first and second proposal submission. It is less encouraging to note that the first project submission is statistically indistinguishable from the first proposal submission

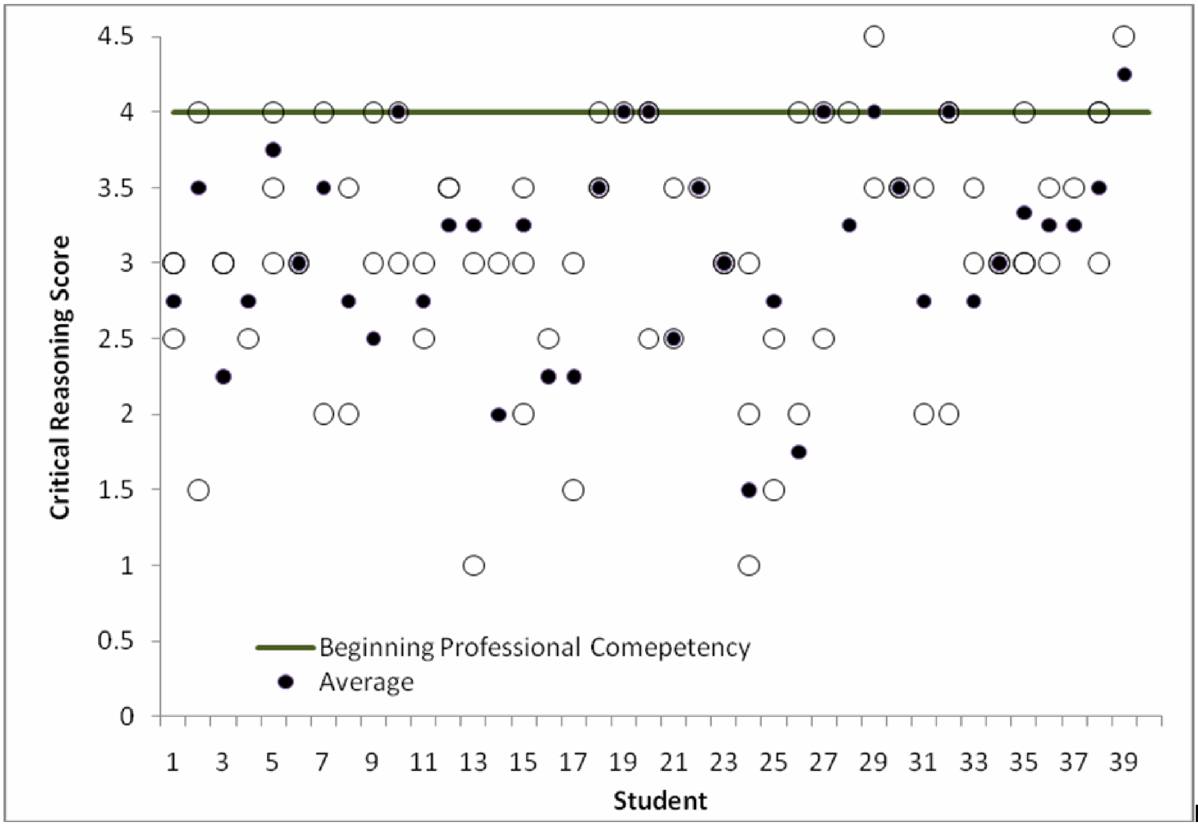

Figure 4: Critical reasoning results of Problem Identification portion of the first Case Study assignment. . To give an indication of the spread of the data, the individual scores are included as the hollow markers.

Visually it is clear,in both figures 4 and 5, that there are some students who did not benefit from the earlier, group assignments.

Table 2: Results of an ANOVA comparing the problem identification portion of the three assignments finished at this point in the semester. A P-value of less than 0.05 indicates that there is a 95% likelihood that the groups being compared are from different underlying distributions.

Groups	*Count*	*Sum*	*Average*	*Variance*
Proposal 1	20	51.0	2.6	0.4
Proposal 2	22	71.3	3.2	0.2
Case Study	79	245.5	3.1	0.6
Project 1	20	51.0	2.6	0.4

ANOVA	*P-value*
Proposal 1 - Proposal 2	2.17E-04
Proposal 1 - Case Study	4.14E-03
Proposal 2 - Case Study	4.59E-01
Project 1 - Proposal 1	1.53E-01
Project 1 - Proposal 2	3.31E-03
Project 1 - Case Study	9.66E-02

Looking more closely at the case study assignment, figure 5, we see that the students performed fairly close to theinitial estimated target of an average score of 2.8. Even the average score of 2.8 is an improvement in the design reflections assessed with the same rubric in prior years. In those years only the project identification section received a score in this range by the final design reflection. Also, if on the improvement seen in the proposal stage is any indication of the improvement that will occur in the case study analysis; we would expect an improvement in the other aspects of the critical reasoning rubric at the end of semester case study in late May.

Further evidence to support that the new project centered approach is serving to improve team and individual student performance is offered by the increased interactions with students. For instance each team has made multiple appointments, usually with multiple instructors, so they can fully understand instructor comments given within our assessment feedback. These interactions take an average of an hour. The students have very specific questions. The discussions are vibrant, and there is a noticeable esprit do corps among group members. This is in stark contrast to previous years when students were given design reflections –in all those cases there was not a single individual or team that made an appointment with an instructor.

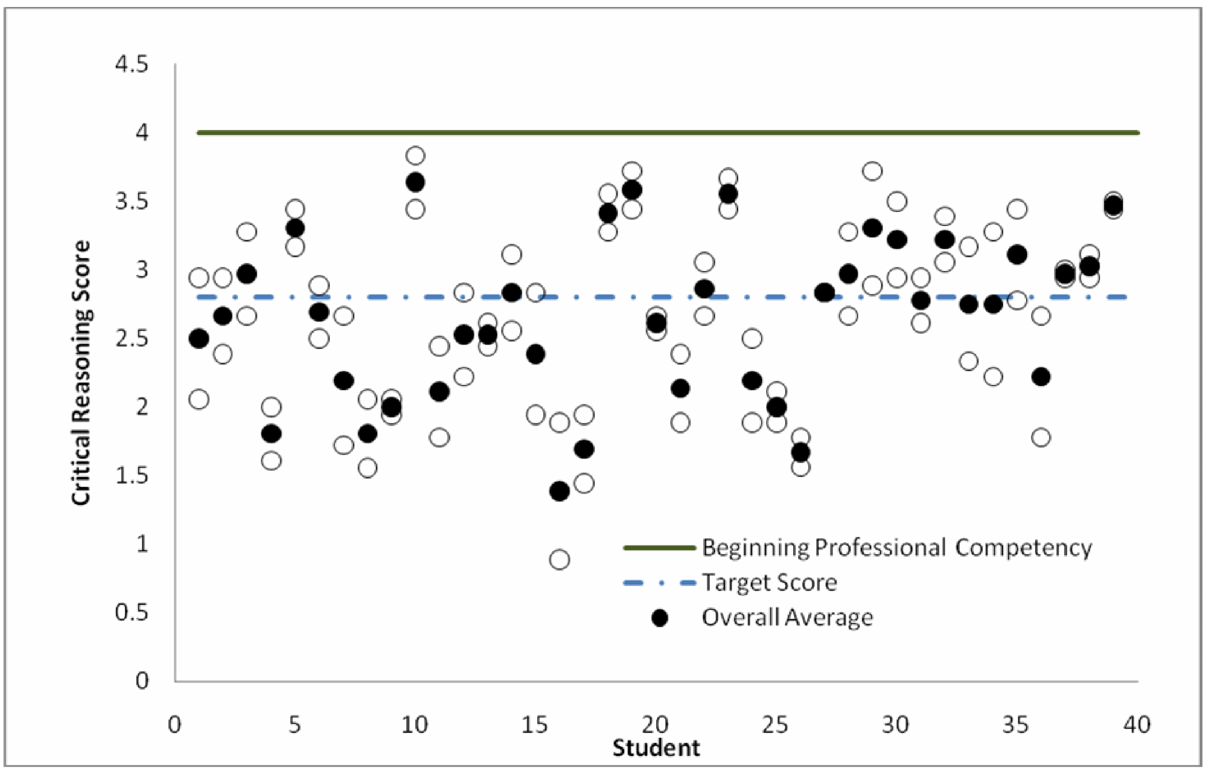

Figure 5: Critical reasoning results of the first Case Study submission. Results shown are the average scores for each individual student. Average scores from each individual rater are included as the hollow markers.

In spite of our observations that students appeared to be taking this assignment more seriously than students in past years, and in spite of the increased familiarity with the rubric due to using it with the case study, the proposal scores were essentially what we would have expected at the beginning of the course. While there were significant delays in getting the case study results back to the students, which may account for some of this, we had not expected that the delay would have had that significant an impact on the score for the project.

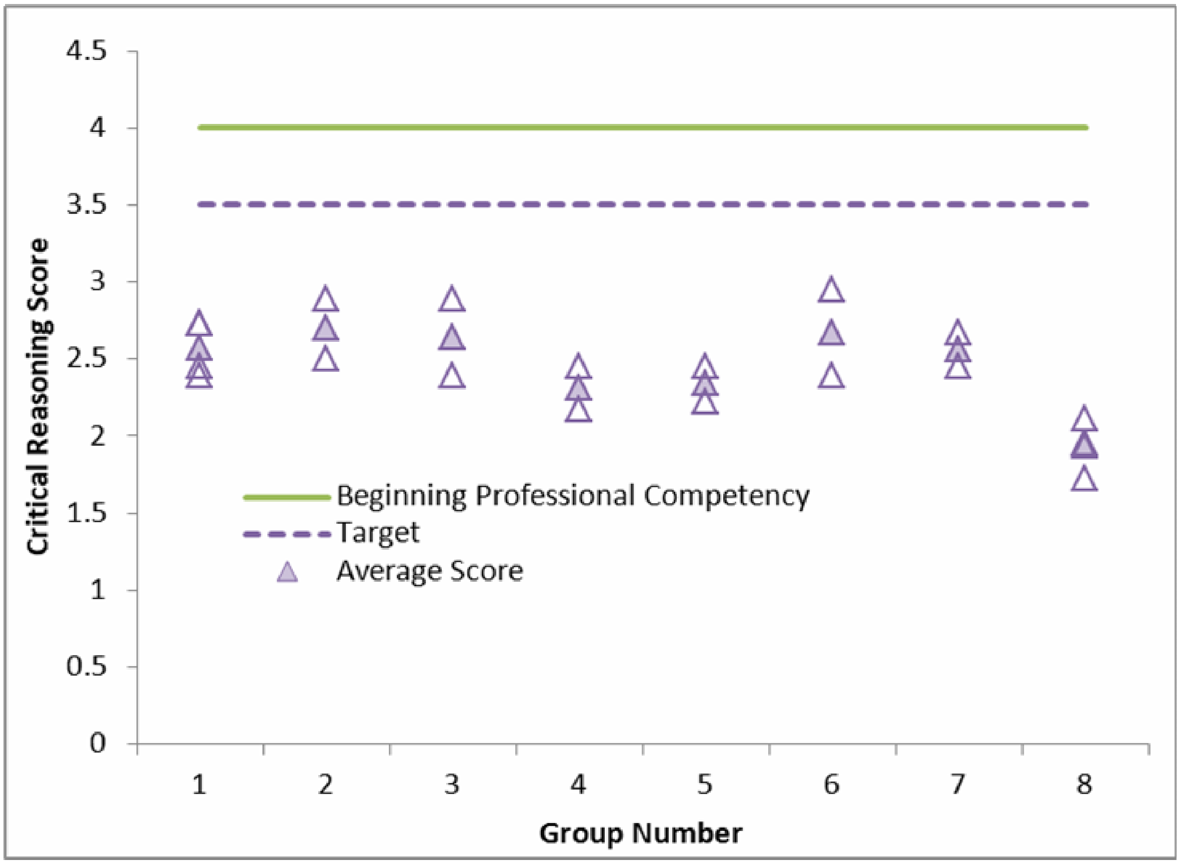

Figure 6: Critical reasoning results of the first Proposal submission. Results shown are the average scores for each individual student. Average scores from each individual rater are included as the hollow markers.

Issues that arose in implementation

One of the first things we have to acknowledge is that this has been quite a bit of work. We have found it difficult to keep up with assessing the amount of written work required for this implementation. The proposals themselves did not take too much time, since they were group assignments and only rated on one of the nine portions of the critical thinking rubric. The case studies however consist of 2 – 5 page submissions by 39 individual students and require assessments and feedback on all 9 criteria; these ratings were accomplished of a period of three weeks. Aside from the time spent doing the rating, we have had to address the issue of how much in the way of written comments to provide. Those of us who are graduate students tend toward brief comments, while those of us have had considerable classroom teaching experience spend a considerable amountof time making very detailed comments. Recently however, we have adjusted our rating approach realizing students need prompt feedback for their diligent efforts and they will benefit more from a simple numerical value under each category in the rubric, a comparison to the class average and brief comment about the best part of their report and about the part that needs the most improvement.We requested that the student groups provide us with some feedback as to which type of comments they would prefer, and the results were split. However the groups were unanimous in wanting to spend some time going over the comments with either the professor or one of the graduate students. All of the groups felt that discussion produced the most valuable feedback.

We also chose to have the students submit their papers to a SharePoint site for ease of distribution among the raters. This is proving to be problematic, as the students' access to the site is intermittent for unknown reasons. In addition to causing stress for the students, this has led to difficulties in organizing the assessments. Some of the assignments have not been in when we divided out the papers for assessment and this has created some confusion and additional delays in dividing the late arriving papers.

Conclusion/ Next Steps

While it is too early in the semesterto draw definitive conclusions about value of our design driven pedagogy and rubric rating protocol, the preliminary results show promise in that the improvement seen in the project proposals are significant. It is clear that students are showing improvements on measures that are closely linked to the course emphasis and valued for their grade. Based on this, we expect to see continued improvements in the project and case studies over the semester. That being said, probably the best test of the effectiveness of this semester will be how the students perform next year in unit operations lab and senior design.

References

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ETS. (2010). Retrieved 9-9-9, from http://www.ets.org/portal/site/ets/menuitem.3a88fea28f42ada7c6ce5a10c3921509/?vgnextoid=85b65784623f4010VgnVCM10000022f95190RCRD.

Golter, P. B., B. J. Van Wie, et al. (2006). PRACTICAL CONSIDERATIONS FOR MINIATURIZED HANDS-ON LEARNING STATIONS. American Society for Engineering Education Annual Conference, Chicago, IL.

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Appendix

ChE 332: Fluid Mechanics and Heat Transfer, Spring 2010

Department of Chemical Engineering, Washington State University

Prerequisites: ChE 201, 310, ChE major

Instructor: Bernie Van Wie

Office Hours: Tues, Th. 3-4p, by e-mail or by arrangement

Office: EME B57

Contact Info:

Prof. B.J. Van Wie: phone, 5-4103; email: bvanwie@che.wsu.edu, mailbox in ChE main office

Text: Thomson, W. J. Introduction to Transport Phenomena, Prentice Hall, 2000.

Program Level Outcome

Creating chemical engineers that individually understand the conceptual and practical aspects of the discipline with the professional skills needed to develop a rigorous multi-component process design in a team setting.

Course Goals

The goal is to prepare you to be a capable chemical engineer, so we will treat you as practicing engineers in industry. By the end of the course you should be competent to analyze and design fluid mechanics and heat transfer systems in a simulated "real world" environment.

Procedure (How do we plan to achieve our goals?)

This course will center around two activities. First, a case study will be analyzed that represents a completed 'real world' design encompassing the individual course concepts. Secondly, a design project which spans the semester will provide the framework for integrating the various course concepts. Just as in industry, most of your work will be in groups. We will employ the common industrial practice of having responsibilities divided out by area in the plant. You will need to submit weekly group status report memos.

Learning Outcomes (How to show you've attained the necessary knowledge and skills?)

The ability to think critically and creatively and to apply quantitative reasoning skills will be evidenced by your ability to:

- Design a piping system to accomplish a particular task.
- Size a pump to handle a specified fluid-transfer task.
- Analyze an existing heat exchanger and be able to predict its performance for specified inlet fluid properties and flow rates.
- Design a heat exchanger to perform a specified task in an optimum way. You should consider tradeoffs and different heat exchanger designs.
- Explain, in terms of fundamental principles, how a heat exchanger works.
- Understand and model pressure losses and heat transfer in packed and fluidized beds
- Understand losses due to natural convection, radiation and evaporation
- Consider safety, and environmental and societal impact.
- Work on teams to design a complex process.

Rubric (The measuring stick to judge competency.)

In this course you are evaluated relative to an absolute standard of competency. We will do everything we can to help you achieve the desired level of competency. This course will not be graded on a curve. The expectations that correspond to the various grades correspond to criteria in a critical thinking rubric that will be used for the course. Approximate scores needed are summarized below.

Grade	A	B	C	D
Proposal I (2%)	3.3	1.7	1.2	1.0
Proposal II (8%)	3.5	2.7	2.4	2.0
Initial Project (10%)	3.5	2.7	2.4	2.0
Final Presentation (40%)	3.8	3.0	2.6	2.2
Case Study Analysis I (5%)	2.8	2.2	1.9	1.6
Case Study Analysis Final II (15%)	3.8	3.0	2.6	2.2

“A” When given an open-ended problem, a student needs to demonstrate the ability to define the problem, determine the underlying principles that apply, make reasonable assumptions, come up with a solution and then be able to discuss the implications of that solution.

“B” When given a well-defined problem the student can identify the appropriate underlying principles, make reasonable assumptions, and solve the problem.

“C” Given a well-defined problem the student can find the appropriate equations, plug in the numbers and come up with the correct answer most of the time.

“D” Is often unable to solve problems. Can stem from insufficient understanding of the underlying principles and/or the inability to reason through from underlying principles to final solution.

“F” Student has failed to grasp the material, does not demonstrate understanding of the underlying principles and does not demonstrate the reasoning ability necessary to solve problems even when given the appropriate underlying principles. An “F” can also stem from simple failure to come to class, complete assignments, or participate in group work.

Supplementary materials and resources

McCabe, W. L., Smith, J. C., and Harriott, P., “Unit Operations of Chemical Engineering, 7th ed.” McGraw-Hill, Inc., New York, NY, 2005.

Streeter, V. L., “Fluid Mechanics, 8th ed.” McGraw-Hill, Inc., New York, NY, 1985.

Perry’s Handbook, any edition, McGraw-Hill, Inc., New York, NY.

Hagen, K. D., “Heat Transfer with Applications” Prentice Hall, Upper Saddle River, NJ, 1999.

Rolle, K. C., “Heat and Mass Transfer” Prentice Hall, Upper Saddle River, NJ, 2000.

Leinhard and Leinhard, “A Heat Transfer Textbook, 3rd ed.” free on-line at http://web.mit.edu/lienhard/www/ahtt.html

Instructional Laboratory Supervisor Paul B. Golter: 5-9634; email: pgolter@wsu.edu

Lecturer Baba Abdul: e-mail: davab@wsu.edu, 5-9625

Course Details

Grading: Project 60% (Group); Case study 10% (Group), Homework 20% (Individual), Final Design Analysis (10%). The part of your grade arising from group work will be multiplied by a factor depending on your participation as judged by your group members, using a rubric based on one Boeing uses to rate groups.

Group Projects:

Design a fluid mechanics and heat transfer system to solve the following problem:

> e.g., a hot waste stream from an ion exchange regeneration process needs to be treated before being discharged.

Group procedures and handling group problems:

(1) You will turn in a group agreement signed by all group members at the start of the semester that outlines your group's expectations of its members.
(2) If conflicts arise within the group notify us as soon as possible. We can meet with the entire group to hear both sides of the issue and we can work together to resolve the problems.
(3) As a last resort a group member can be dismissed and they will have to do independent projects and homework.
(4) Each group member will turn in a confidential peer evaluation that rates their fellow group members in terms of their participation in group work. This will be done after each group project (i.e. twice during the semester).

Homework: A set of homework and design team update will be due by 5 pm on Fridays unless otherwise announced. Penalties are 25% off by 8:00 am the next day, 50% off by Monday at 8:00 am, no credit after that. While group discussion is encouraged on individual assignments copying is not allowed. Problems and solutions must be fully understood by another engineer.

Project Proposal, Status Memo, Reports:

Project Proposal: You should identify a focused, original question and goals and provide a timeline for accomplishing the tasks needed to complete your group's design. These should include process specifications and desired outcomes that are challenging and well defined. Show that you thoroughly understand the constraints for the process solution. For example, if you were designing a hot tub, you might say the design will need to accomplish five complete fluid exchanges per hour with no more than a 2 degree per hour temperature loss, while being used by five people and must fit into a 5 ft x 5 ft space.

Case Study: This is a thorough study of the design approach and critical thinking involved in that design. It will be a two-page single-spaced 1-inch margin 12pt-font analysis done according to the categories outlined in the *Critical Thinking Rubric* at the end of the Syllabus.

Project Report: This should include the following sections:

1) Problem Statement: See Project Proposal (above)
2) Theory & Assumptions: Governing principles & validity of assumptions
3) Detailed Description & Assessment of Solution Quality: Thorough discussion of equipment selection, sizing, alternatives, accuracy, appropriateness, and potential extension to other situations.
4) Supporting Calculations: Must be accurate and thorough.

The organization and communication will be weighted heavily. You should see the Grading Rubric for a thorough understanding of what we will be evaluating.

Status Memo: A brief statement of what your group accomplished this week, concerns or questions about technical aspects as well as non-technical group process issues, how much time you spent individually and as a group since the last memo.

Ombudspersons: Two ombudspersons (rotating among groups) will meet twice during the semester with the instructors to discuss ways to improve the course learning environment.

Academic Integrity: Academic dishonesty, including all forms of cheating, plagiarism, and fabrication, is prohibited as stated in the WSU Handbook (WAC 504-25-015). The instructor reserves the right to take appropriate action.

Students with Disabilities: Students with Disabilities: Reasonable accommodations are available for students with a documented disability. If you have a disability and may need accommodations to fully participate in this class, please visit the Disability Resource Center (DRC). All accommodations MUST be approved through the DRC (Washington Building, Room 217). Please stop by or call 509-335-3417 to make an appointment with a disability specialist.

Class Date	Topic	Reading	Work Due	
			20%	Due Fri. 5 pm; HW = 20% of grade
1/12 1/14	Intro, Permission Forms, CI #1 ME balance & Sample Case Study	Ch. 10, WJT		G: 11-2 I: CI #1 (20 min)
1/19 1/21	Heat Transfer Principles, Applied to Heat Exchangers & Case Study	Ch. 11, WJT	2%	G: Project Proposal #1 I: 12-6; Team Contract
1/26 1/28	Natural Convection, Radiation, Evaporation & Case Study	Ch. 11, WJT		I: Definitions; EC: Learning Styles† I: 12-4; Team Citizenship Report
2/2 2/4	Heat Exchange with Phase Change Case Study	Ch. 11, WJT	 8%	 G: Project Proposal #2
2/9 2/11	Jigsaw Teams – Focus on own Case	Each Team Reads Own	 5%	J: Jigsaw Team Plan 1 page; J: 11-5 I: Case Study Analysis
2/16 2/18	ME Balance Double Pipe Double Pipe Heat Exchange	Assigned by Jigsaw Team	TQ TQ	G: ME Bal. Double Pipe WS I: Heat Transfer Double Pipe WS
2/23 2/25	ME Balance Shell & Tube Shell and Tube Heat Exchange	Assigned by Jigsaw Team	TQ TQ	G: ME Bal. Shell & Tube WS; I: HT Shell & Tube WS; G: Status Report
3/2	Reynolds Expt. / Flow Measurement	JT Assigned	TQ	G: Reynolds & Flow Meas. WS
3/4	Parallel Flow	Handout		I: Parallel Flow WS
3/9	Pipe Optimization	pp. 312-313	10%	**G: Project Report I**; I: Pipe Opt. In Class;
3/11	Project Preparation			*I: Teamwork Achieved Report*
March 14-20 – Spring Break				
3/23	Project Review			Ombudsman;
3/25	Jigsaw Teams			G: Status Report; I: 11-6,12-7;
3/30	Jigsaw Teams			J: 11-11;Jigsaw TeamPlan 1 page
4/1	Heat Exchanger Optimization	Handout		I: 12-9

4/6	Extended Area	Jigsaw Team	TQ	G: Extended Area &Evap./CoolerWS
4/8	Evaporative Cooler	Handout	PPQ	I: Team Citizenship Report
4/13	ME Bal. Packed & Fluidized Bed	Jigsaw Team	TQ	G: ME Packed & Fluid Bed, Status Report
4/15	HT Packed & Fluidized Bed	Jigsaw Team	TQ	I: HT in Packed & Fluid Bed
4/20	Boiling / Condensing	Jigsaw Team	TQ	G: 12-13
4/22	Final Project Preparation			I: Boiling & Condensing WS
4/27	Project II presentations		40%	**G: Project Report II** (Due Tu 4/28, 8am)
4/29	Project II presentations			*Teamwork Achieved Report*; CI #2 (Fri. 5p)
5/4	Final – Design Analysis - Due by 1 pm		15%	Case Study Analysis – Due by 1 pm

Legend: CI - concept inventory, TQ - take-home quiz, HW - homework, PPQ – Pre & Post Quiz

G - Group assignment, I - Individual assignment, J - Jigsaw-group assignment

†Learning Styles Inventory: http://www.ncsu.edu/felder-public/ILSpage.html

"*Measure what is measurable, and make measurable what is not so." – Galileo*

Critical Reasoning Criteria in Fluid Mechanics & Heat Transfer

For rating design project problem statements, case studies, and design reports

Dimension	0	1	2	3	4	5	6	Score
1. Problem / Question		Does not identify a specific question or necessary and appropriate system or systems. The question or system, if identified, is confused or simplistic. Little evidence of understanding of salient constraints (e.g, cost of water, available space, etc). Little evidence that goals or potential/useful outcomes identified and understood.		Identifies a somewhat focused question/goal that is interesting but not particularly challenging or is simplistic, tends to ignore essential constraints. Problem/goal vaguely defined & characterized. Consideration of goals or outcomes is vague or suggests important omissions of key considerations.		Identifies a focused, unique, original question/goal that is challenging and well defined Thoroughly understands constraints. The question/goal is thoroughly defined and characterized. .		
2. Fluid Mechanics Principals / Equations How chosen/appropriateness Depth of Use / Integration Completeness		Analysis of fluid mechanics principles is absent, incomplete or inappropriate relative to the presenting problem—or insufficiently related to the challenge the project entails There is little Interpretation of fluid mechanics principles, or there may simply be a restatement of inherited facts.		Analysis of fluid mechanics principles is essentially correct; perhaps some is off tangent or barely related to the presenting problem, but generally in the vicinity of the challenge the project entails Interpretation is adequate & clear, though perhaps not fully integrated with other sources or perspectives. Barely extends, if at all, beyond routine exploration.		Analysis of fluid mechanics principles is thorough and correct. Interpretation is well integrated with other chemical engineering principles, sources and professional perspectives.		
3. Heat Transfer Principals / Equations How chosen/appropriateness Depth of Use / Integration Completeness		Analysis of heat transfer principles is absent, incomplete or inappropriate relative to the presenting problem—or insufficiently related to the challenge the project entails There is little Interpretation of heat transfer principles, or there may simply be a restatement of inherited facts.		Analysis of heat transfer principles is essentially correct; perhaps some is off tangent or barely related to the presenting problem, but generally in the vicinity of the challenge the project entails Interpretation is adequate and clear, though perhaps not fully integrated with other sources or perspectives. Barely extends, if at all, beyond routine exploration.		Analysis of heat transfer principles is thorough and correct; Interpretation is and well integrated with other chemical engineering principles, sources and professional perspectives.		

4. Fluid Mechanics Assumptions	There is little or no synthesis from literature; or what is presented is incoherent or patched together without explanation or demonstration of underlying fluid mechanics assumptions. Assumptions tend to be confused or perhaps contradictory. Key aspects of the challenge are neglected.	Application of material discerned from literature or outside reading is adequate in scope and accuracy, though perhaps slightly confused at times or partially inaccurate. Sometimes questions and attempts to support the validity of assumptions.	Application of material discerned from literature as well as from outside reading is complete and accurate. Questions and supports the validity of assumptions.	
5. Heat Transfer Assumptions	There is little or no synthesis from literature; or what is presented is incoherent or patched together without explanation or demonstration of underlying heat transfer assumptions Assumptions tend to be confused or perhaps contradictory. Key aspects of the challenge are neglected.	Application of material discerned from literature or outside reading is adequate in scope and accuracy, though perhaps slightly confused at times or partially inaccurate. Sometimes questions and attempts to support the validity of assumptions.	Application of material discerned from literature as well as from outside reading is complete and accurate Questions and supports the validity of assumptions.	
6. Other Assumptions	There is little or no synthesis from literature; or what is presented is incoherent or patched together without explanation or demonstration of underlying heat transfer assumptions Assumptions tend to be confused or perhaps contradictory. Key aspects of the challenge are neglected.	Application of material discerned from literature or outside reading is adequate in scope and accuracy, though perhaps slightly confused at times or partially inaccurate. Sometimes questions and attempts to support the validity of assumptions.	Application of material discerned from literature as well as from outside reading is complete and accurate Questions and supports the validity of assumptions.	
7. Equipment Specification	Improper or superficial equipment selection. No attempt at sizing, evaluating alternatives, etc. Equipment selection demonstrates little depth, attention to or understanding of professional conventions. Simple list of equipment.	Proper equipment selection, but limited in terms of evaluation of alternatives, sizing, etc. Equipment selection demonstrates some use of professional convention (rules of thumb) Some systems level thinking.	Equipment selected and optimally sized after a thorough evaluation of alternatives. Thorough use and understanding of appropriateness of professional convention. Integrated systems thinking	
8. Solution Quality	Solutions are missing or inaccurate / unreasonable. The implications of the solutions are absent.	Solutions are reasonable, though perhaps incomplete or limited. Solutions relate to the design problem and arise from the analysis presented, though there may be gaps or redundancies. May include speculation about implications -- mostly plausible, but not necessarily reasonable useful or creative.	Solutions are accurate, appropriate, thorough, and clearly linked to design problem. Solutions and recommendations are qualified, balanced and can be extended to other situations.	

9. Organization and Communication	Presentation of problem, analysis, solution and interpretation seems haphazard, inconsistent, or misleading; one or more elements may be missing or confused Organization of ideas / multiple errors obscure meaning, and may misinform or mislead audience. Many parts seem difficult for the audience to follow. Communication style, written and/or oral, is not appropriate to this discipline, or is confusing. Does not use language of the discipline, or uses it incorrectly. Frequent errors may obscure ideas. Media and format are poor choice for content; some materials confusing or distracting, or served as filler. Communicates little or no engagement or ownership of the work.	There is a discernable progression from problem to analysis, solution and interpretation, linked to the problem and solution. Presentation is adequate for intended audience, though there may be occasional gaps, errors, or inconsistencies which require effort from audience in order to understand. Communications style, both written and oral, is appropriate to this discipline; though not at a professional level, communication is adequate Incorporates some language of the discipline, though imperfectly. Some errors may distract audience. Appropriate media and format used for content. Most materials clear and pertinent Communicates some engagement & ownership of	Progression from problem to analysis, solution and interpretation is concise, creative, and clearly ties problem to solution and implications. Needs and interests of intended audience effectively inform presentation's approach and organizations. Audience seems well able to follow the presentation. Communications style, both written and oral, is appropriate to this discipline, and is polished, professional, and virtually error free. Uses language of the discipline fluidly and effectively. Appropriate media and format used for content; all materials clarified, with pertinent or high interest information. Clearly communicates engagement and ownership of the work.	