COMBINING MODERN LEARNING PEDAGOGIES IN FLUID MECHANICS AND HEAT TRANSFER

By

PAUL B. GOLTER

A thesis submitted in partial fulfillment of
the requirements for the degree of

MASTERS OF SCIENCE IN CHEMICAL ENGINEERING

WASHINGTON STATE UNIVERSITY
School of Chemical Engineering and Bioengineering

August 2006

To the Faculty of Washington State University:

The members of the Committee appointed to examine the thesis of Paul B. Golter find it satisfactory and recommend that it be accepted.

Chair

ACKNOWLEDGEMENT

I would like to thank my wife for supporting me through this. I would like to also thank Bernie Van Wie for the opportunity to take part in this. Thank you to Billy Schmuck and Jonathon Windsor for their work on this project.

COMBINING MODERN LEARNING PEDAGOGIES IN FLUID MECHANICS AND HEAT TRANSFER

Abstract

By Paul B. Golter, M.S.
Washington State University
August 2006

Chair: Bernard J. Van Wie

Classroom environments structured in such a way as to shift the responsibility for learning onto the students will be more effective than lectures in preparing students for the workplace. A novel approach used at Washington State University replaces most lectures with a combined cooperative, hands-on, active, and problem based learning pedagogy. Students work in structured groups, with hands-on modules to learn fundamental concepts of fluid mechanics and heat transfer. This enhances involvement and addresses several of the ABET Engineering Criterion concerning communication and life-long learning. An alumni survey indicates that this approach has been successful in enhancing the 'soft skills' of our students compared to traditional lecture courses. A novel apparatus is also being developed at Washington State University that allows hands-on learning experiences to be undertaken in a typical classroom. Thus allowing faculty to use hands-on learning without the need for laboratory space.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

My thesis is that by strategically utilizing alternatives to lecture students can be introduced to situations where they will be encouraged to a) take more responsibility for their learning, b) increase their communication and group working skills, and c) develop skills that will help them in the workforce. The pedagogy we have developed is one such lecture alternative.

In recent years engineering educators have started to realize that lectures are not the most effective method of building engineering knowledge and skills in students. When compared to an environment where people merely watch or listen, people will remember more of what they learn when they are allowed to take an active role in the learning process. This is sometimes represented as a pyramid or cone of learning, such as that in Figure 1 [1]. The traditional lecture format concentrates on the top three tiers of the pyramid, hearing, reading and seeing, and rarely gets to the lower levels that typically lead to more knowledge retention.

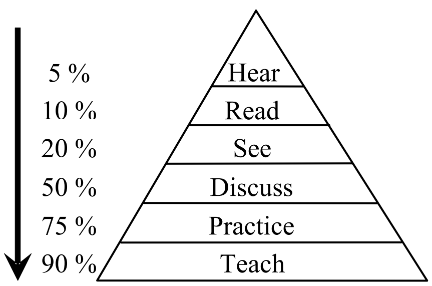


Figure 1. Learning Retention

We have become increasingly aware that the workplace for which we are training engineering students is a dynamic, multi-disciplinary team environment [2]. The lecture format cannot, by its very nature, be used to prepare students for this environment. Also, the workplace is becoming increasingly globalized, and other nations, notably China have stepped up research and teaching activities [3]. How do our graduates distinguish themselves as better prepared for this workplace than an engineering graduate from another nation?

The question becomes; are we as educators supposed to be doing our best to provide students with the skills needed to be successful in the workplace, or merely to impart the core knowledge of our field? As my phrasing probably implies, I believe there is much more to training an engineer than just passing on a body of knowledge. Otherwise, I could be fully justified in just handing a student a copy of *Perry's Handbook for Chemical Engineers*, and telling them to read it.

When I first became involved in engineering education research, I did a lot of reading in preparation for writing a grant aimed primarily at improving and expanding the equipment Dr. Van Wie was using to aid in teaching Chemical Engineering (ChE) 332, Fluid Mechanics and Heat Transfer. This inspired some reflections on my four year career as a process engineer at a pulp mill. Admittedly the mill was an unusual environment, being up for sale three of the four years I was there, I became aware of some disturbing trends in my professional behavior. I tended to rely on superiors for motivation. Rather than looking for problems to fix, I would wait to be told about one. I tried to rely on my superiors for direction and information in problem solving. I have noticed some of these same behavioral trends in students. It is in our students' best interest to aid them in breaking out of these behaviors prior to entering the workplace.

But what does that have to do with lectures? A lecture typically involves the superior, a professor, telling the students how things are done and what the problems are. If there are any questions, the professor is generally the provider of the 'correct' answer. In essence, we are training students to expect this type of knowledge from superiors.

An alternate method of conducting classes is needed if we desire to prepare students to be independent learners who communicate effectively and work well as part of a team. One such method has been developed in the School of Chemical Engineering (ChE) and Bioengineering at

Washington State University (WSU). This pedagogy combines Cooperative, Hands-on, Active and Problem-based Learning (CHAPL) into a single coherent format.

This thesis presents, in Chapter Two, some background information and work that was done prior to my joining the project. It also contains two papers, one on our implementation of the CHAPL pedagogy, Chapter Three, and one about a new direction for the apparatus used in the pedagogy, Chapter Five. Chapter Four contains additional assessments and Chapter Six outlines some future directions for the project. The appendices contain all of the data from the project since its inception, arranged by year. This includes draft and internal reports that are not published or contained elsewhere. The quantity of appendix material is partially because it is referenced throughout the thesis and partially to create a repository of data from this project to date.

Chapter Three presents an article published in the journal *Chemical Engineering Education*. I was the primary author for this paper and performed most of the data analysis and interpretation, all of the equipment maintenance, some equipment re-design and helped strengthen and develop the assessments used in the course. Specifically, I:

1) suggested using student ombudspersons to provide a feedback route so mid-course corrections could be made.

2) co-developed, with graduate student Burton Schmuck, problems written to be specifically related to the equipment used in the course

3) modified the critical thinking rubric developed at the Center for Teaching, Learning and Technology (CTLT) at WSU to be applicable to a technical course.

Dr. Van Wie has been the professor for the course, initiated the change in format, gave direction to the project, provided a tremendous amount of editing, and helped with the data interpretation. Phil Scuderi aided Dr. Van Wie in the first year of implementation, and provided much of the initial theory around which the course was altered. Tom Henderson aided in creating the surveys used to assess the course. Rebecca Dueben spearheaded the focus group and student video interview in 2005. Dr. Brown and Dr. Thomson have provided support and advice necessary to keep the project going over the years.

Chapter Five consists of a paper that will be presented at the 2006 American Society for Engineering Education (ASEE) annual conference. I submitted the abstract, wrote the paper, and contributed about 40% of the ideas presented. Dr. Van Wie edited the paper and contributed 40% of the ideas. Gary Held, from the WSU College of Engineering and Architecture shop, built the apparatus and contributed the last 20% of the ideas. Jonathan Windsor, one of the ChE seniors, performed the design calculations.

REFERENCES

1. NTL Institute for Applied Behavioral Science, 300 N. Lee Street, Suite 300, Alexandria, VA 22314. 1-800-777-5227
2. National Academy of Engineering, *The Engineer of 2020: Visions of Engineering in the New Century,* Washington, D.C.: National Academies Press, 2004.
3. Fogel, D.M., "In Search of a Sputnik Moment", *ASEE Prism* Vol. 15, No. 5, pg 64.

CHAPTER TWO

BACKGROUND

This chapter presents the history of this project prior to my involvement, and discusses the learning styles inventories and terminology used.

Learning Styles

Two inventories were used to help the students determine their learning styles. The Index of Learning Styles (ILS) [1] developed by R. Felder and B. Soloman and the BrainWorks inventory developed by Synergistic Learning Incorporated. I should note that although the BrainWorks inventory is freely available online, I can find neither any information about Synergistic Learning Incorporated or any validation of the inventory. In the first year of the project, the Keirsey Temperament sorter[2], and the Individual Differences Questionnaire [3] were also used.

The ILS categorizes learners in four dimensions sequential-global, visual-verbal, sensing-intuitive, and active-reflective [4]. Sequential learners learn in a step by step manner while global learners seem to 'learn in fits and starts' [4]. Global learners are the people for whom things 'just click' one day and they suddenly understand. Visual learners learn more from seeing sketches, apparatus, and pictures while verbal learners learn more from spoken or written words [4]. Sensing learners are those that prefer to experiment and receive facts, while intuitive learners prefer theories and concepts [4]. Active learners, as the name suggests, prefer to take an active role in processing knowledge, either through experimentation or discussion. Reflective learners, on the other hand, process knowledge internally [4].

The BrainWorks inventory separates along two axis, left brained-right brained and visual-auditory. Left brain dominant people are generally more logical and mathematical, while right brain dominant people are typically more creative an social. The visual-auditory scale is, presumably, similar to the visual-verbal scale in the ILS instrument, with the difference that it does not include the written word in the verbal/auditory side of the scale.

Prior Work

In 1999, Dr. B.J. Van Wie embarked on a process of changing Fluid Mechanics and Heat Transfer (ChE 332) from a traditional lecture course to a format that involves almost no lecture, but instead relies on hands-on learning and group interaction to provide an environment in which the students have an increased ownership of the learning process. Chemical Engineering 332 was first taught as a two credit course in the spring semester of. In 1997, and prior, it had been a three credit fall course. Due to the transition, ChE 332 was not offered in calendar year 1998. This change was made as part of an overall revamp of the transport phenomenon series of courses. The series now consists of a three credit transport theory course, ChE 310 - Introduction to Transport Processes, followed by two two-credit application courses: ChE 332 - Fluid Mechanics and Heat Transfer and ChE 334 - Chemical Engineering Separations.

The new pedagogy was developed in cooperation with the Center for Teaching Learning and Technology (CTLT) at Washington State University (WSU). Phil Scuderi was the initial contact at CTLT and provided much of the guidance. Two draft reports written by Dr. Van Wie and Phil Scuderi cover the 1999 course and are provided in Appendix 1. As these reports were never taken beyond the draft form, I feel that it is important to include them here, so that they can be referenced in the future.

According to Phil Scuderi's report, the goals for the first year were to "…design and implement a learning environment within which:

1. the responsibility for the learning is clearly fixed with the students,
2. the level of student engagement with course content is very high,
3. the instructor can readily use his expertise to mediate with regards to the meaning students are assigning to the concepts and concept relationships present within the study domain."

During this first year, the course started out with four weeks of hands-on cooperative learning time studying fluid mechanics with miniature fluids modules in the unit operations laboratory. This was followed by four weeks of lecture time on fluid mechanics. This process was repeated over the next eight weeks for the subject of heat transfer. The laboratory portions were organized using the 'Jigsaw' concept [5]. In this setup, every student is assigned to both a home team and a separate jigsaw group. The jigsaw groups are composed of one member of each home team and are assigned a concept which they are supposed to learn well enough to teach to their home team. In 1999, the jigsaw groups were not given any class time for preparations, but needed to prepare outside of class time. During the third week of each laboratory section, the students in each jigsaw group presented their concept to their home teams.

During the laboratory portion of both halves of the course, the students started out aimlessly toying with the equipment, rather than taking a systematic approach. Or as Phil Scuderi put it: "In general, they continued to exhibit a kind of random reactive rather than planned approach." During this time, the students were, as a whole, very engaged and active throughout the class time. They spent the class discussing, arguing, questioning each other, manipulating the equipment, and looking things up. Some students remained somewhat outside of their groups, but "did appear to be intently paying attention." When the jigsaw group members presented to their home teams, the students who had remained somewhat disengaged appeared to have a similar level of understanding as that of their more engaged classmates. It is also interesting to note that students universally presented their jigsaw concepts in a lecture format.

During the lecture portion of the course, the same three students asked the majority of the questions. Similarly, a core group of students tended to answer most of the instructor initiated questions that were not directed specifically to individuals. Phil Scuderi did not record whether the three students who asked the most questions were part of the group that tended to answer most of the questions.

There were 18 students in the course in 1999, the majority of whom had senior standing by credit totals but were still junior level in the ChE program, and 13 of the 18 had transferred from another college or university. Learning styles and temperaments were assessed using a series of inventories, including the Felder and Soloman Index of Learning Styles [1], the Keirsey Temperament sorter[2], and the Individual Differences Questionnaire [3]. The results were that 80% of the class were sensing (vs. intuitive), 60% were thinking (vs. feeling), 80% were judgmental (vs. perceptive), 93% visual (vs. verbal), and they were evenly split between introverted and extroverted.

Results from a survey given at the end of the semester indicate that the students felt like they had learned more and were better able to remember and visualize the concepts from the course thanks to the hands-on, cooperative learning environment. They were also aware that the cooperative, hands-on environment was a closer match to their future work environment than a traditional lecture. However, the students also requested more lecture and up-front guidance, and expressed concern about how their grades would be affected by the group work and hands-on setting. The survey may be found in Appendix 1-E.

Dr. Van Wie taught ChE 332 again in 2000; however no assessment data are available from that semester's course. Dr. Van Wie went on sabbatical in 2001, and ChE 332 was taught by Dr. W.J. Thomson. Dr. W.J. Thomson used the hands-on equipment and some portion of the pedagogy, but no assessment data are available. However, it might still be possible to locate the end-of-semester student evaluations for these semesters.

Dr. Van Wie returned from sabbatical and taught the 2002 semester of the course. I became involved at this point in the capacity of maintaining the equipment. Tom Henderson at CTLT also became involved, and Learning Styles inventories and surveys comparing this course with other ChE courses were added to the assessment. Results from these assessments are included in Appendix 2.

The 2002 course included an exit interview between individual students and one of three highly experienced chemical engineering professors, Dr. J. Lee, Dr. W.J. Thomson, and Dr. R.C. Miller. Using a fairly generic scenario, they probed the students' understanding of the key concepts of fluid mechanics and heat transfer. Two key findings from this were that the gap between 'strong' students and 'average' students was less than they had seen in prior years, and that not enough time had been spent on the heat transfer portion of the course.

Since the same students tend to be in any pair of required, junior level, spring semester only courses, identical surveys were given in ChE 332 and ChE 334, Chemical Engineering Separations, which was taught in a traditional lecture manner. The survey was 55 questions and asked the students to rate how various learning outcomes were prioritized in the course, how the hands-on group experience affected their and the instructor's behavior in and out of the classroom, how they preferred to learn and/or study, and general satisfaction with the course. For the traditional course, the wording of some of the questions generated a significant percentage (~50%) of ‘No Basis for Judgment/Not Applicable’ responses. Trends in the learning outcome priorities category were similar between the two courses. However, in ChE 332 and in contrast to ChE 334, students felt that they were better able to visualize the ideas and concepts taught, spent more time studying, where better able to communicate their ideas to o, were more encouraged to exercise their creativity, were more able to work through the learning process to solve problems, were taught how to work in a team/group setting to complete a project, and were less likely to feel hindered by the difficulty of the course’s subject matter. To determine this, I took the differences between the average responses and divided that by the standard deviation of the ChE 332 response. I then called any difference greater than one standard deviation “significant.”

Due to the normal rotation of instructors, another professor taught the course in 2003, returning the course to a traditional lecture format. The following year, after receiving an internal grant to continue the development of this pedagogy, Dr. Van Wie began teaching ChE 332 again and returned it to the new pedagogy. This thesis presents the results of this pedagogy through the 2005 semester of ChE 332.

REFERENCES

1. Soloman, B.A. and Felder, R.M., Index of Learning Styles Questionnaire, Department of Chemical Engineering, North Carolina State University, Raleigh, NC, <http://www.engr.ncsu.edu/learningstyles/ilsweb.html>, accessed December 29, 2004.
2. Keirsey, D, The Keirsey Temperament Sorter –II Personality Instrument <http://www.advisorteam.com/temperament_sorter/register.asp?partid=1>, accessed May 4, 2006
3. Paivio, A and Harshman, R, "Factor Analysis of a Questionnaire of Imagery and Verbal Habits and Skills", *Canadian Journal of Psychology*, **37**, 461-483, (1983)
4. Felder, R.M. and Silverman, L.K., "Learning and Teaching Styles in Engineering Education," *Engineering Education*, **78**, 674-681 (1988).
5. Aronson, E., Blaney, N., Stephan, C., Sikes, J., and Snapp, M., *The Jigsaw Classroom*, Sage Beverly Hills, CA 1978.

CHAPTER THREE

ARTICLE PUBLISHED IN

CHEMICAL ENGINEERING EDUCATION

Vol. 39, No. 4, Fall 2005, pg 280-301

Combining Modern Learning Pedagogies in Fluid Mechanics and Heat Transfer

P.B. Golter, B.J. Van Wie, P.V. Scuderi, T.W. Henderson, R.M. Dueben, G.R. Brown, W.J. Thomson

Keywords: Hands-on Learning, Cooperative Learning, Active Learning, Problem Based Learning, Learning Styles

<u>Abstract</u>

New teaching methods are needed to match the industrial team oriented environment and to accommodate a variety of learning styles. A novel approach used at Washington State University replaces most lectures with a combined cooperative, hands-on, active, and problem based learning pedagogy. Students work in structured groups, with hands-on modules to learn fundamental concepts of fluid mechanics and heat transfer. This enhances involvement and addresses several of the ABET Criterion concerning communication and life-long learning.

INTRODUCTION

Teaching paradigms need to be shifted to address the difference between how engineering students learn, largely inductively, and the traditional deductive teaching style [1, 2, 3]. Research shows that any of the active, cooperative, or problem-based models are more palatable to students than copying lengthy derivations from a board [4]. These alternative pedagogies are also more in line with current needs of industry where chemical engineers work together as part of diverse teams to creatively tackle design problems not found anywhere in standard texts [5]. The disconnect between how students learn best and how we typically teach is also receiving considerable attention [6, 7] from ABET which has revised their Engineering Program Outcome and Assessments Criteria to reflect this concern – the Criteria now include greater focus on multidisciplinary teams charged with experimentation and design to enact solutions within a societal and global context [8].

Many theorists subscribe to the notion that learning improves with increased involvement in the educational process. The idea is often depicted as a cone of learning [9] as illustrated in Figure 1. Percentages are attached that relate knowledge retained as learners are more actively engaged in the education process and as they share learning with others. Varied tactics are used to move pupils to the base of the retention triangle. Yet often they are applied individually, whereas an implication of the increasingly complex activities listed in the 50 – 90% range is that simultaneous use of interactive learning pedagogies would be more beneficial. For example, Cooperative Learning (CL) has been shown effective in a host of chemical engineering (ChE) courses [10, 11], yet the concept is largely restricted to homework

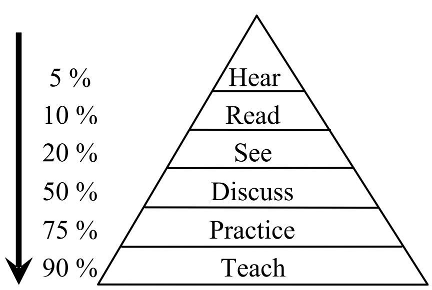


Figure 1. Learning Retention

problems, laboratories, and design courses. Hands-on Learning (HL), though remarkably successful for reinforcing concepts, is typically reserved for laboratories in preparatory science curricula and the ChE senior year unit operations laboratories. The idea is rarely used in traditionally non-laboratory courses. Active Learning (AL) techniques are interspersed within a lecture period to maintain student interest, cement learning by immediate use of material, and provide the instructor with an immediate chance to gauge student understanding [12, 13, 14, 15, 16, 17]. While many AL exercises are group or pair in nature, AL does not provide a CL environment that reinforces student interdependence, individual accountability, and development of collaborative skills [18]. Problem-based Learning (PL) has been used effectively at Virginia Commonwealth University [19] for a student operated consulting firm, yet this approach could benefit from hands-on experiential learning components where consequences of variable changes and process operation decisions are immediately observable.

In this paper we describe a novel approach, referred to as CHAPL, being taken at Washington State University (WSU) which combines several effective pedagogies in a single course including: the forming of Home Teams for conducting projects and solving homework problems (Cooperative Learning - **CL**); manipulating fluid and heat exchanger equipment to observe principles in action (Hands-on Learning - **HL**); conducting brief small group exercises to perform derivations and discuss implications (Active Learning - **AL**); and assigning design problems to stimulate procurement of knowledge about general principles (Problem-

Figure 2. Typical CHAPL Classroom

based Learning - **PL**). Herein we provide a detailed description of the pedagogy, assessment of learning improvement and student receptivity.

CHAPL PEDAGOGY

Over the past six years, we have developed a paradigm for the simultaneous use of all four pedagogies, CL, HL, AL and PL, in a required junior level ChE course, Fluid Mechanics and Heat Transfer. This course is two credits and is offered only in the spring, as it has another junior level course, Introduction to Transport Processes, as a prerequisite. In recent years the class size has varied from 15 – 30. The class meets in two one-hour sessions each week.

The approach has undergone steady refinement so that we are now receiving positive feedback from the majority of the students involved. In this paradigm students work in highly interactive groups to solve problems cooperatively and propose designs as they test concepts using hands-on modules. Fig. 2 shows a typical CHAPL session. There is little lecture; instead the instructor and teaching assistants (TAs) act as preceptors who correct misconceptions and, when necessary, help resolve group conflicts. When student groups are stuck on what to do next or on a particular concept, we ask "Let's hear a sample discussion among your group of what you are thinking so far" – often, with a tip thrown in here and there, the students work out the solution themselves. Other times we will direct the students to a particular section, paragraph, figure, equation, etc. in a text book that succinctly deals with the issue at hand – we'll say, "Someone read this, and then see how that impacts your discussion."

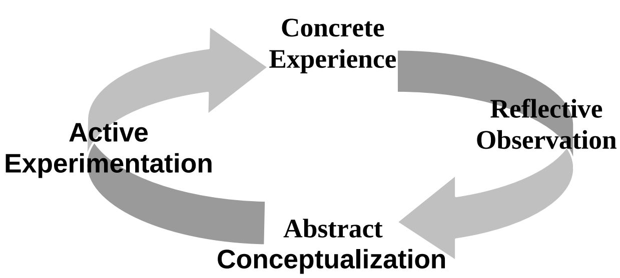


Figure 3. The Kolb Learning Cycle

Our goal in this is to guide groups

through Kolb's experiential learning cycle [20, 21], shown in Fig. 3. This entails: Concrete Experience (CE) or a look at what is happening here and now as module process variables are manipulated, Reflective Observation (RO) or what is the meaning of what was just observed, Abstract Conceptualization (AC) or how can these observations be quantified mathematically, and Active Experimentation (AE) or how can process variables be adjusted, mathematical formulas reduced and new information added to complete understanding of important concepts.

One of the pedagogical tools central to our approach is the "Jigsaw" or "Expert" group member concept advanced by Aronson *et al* [22]. Students are split into Home Teams and each team member is assigned one of the concepts relevant to the broad field of fluid mechanics. New Jigsaw groups are formed and comprised of the students from each Home Team who are assigned the same concept. Each group is provided access to a hands-on module which is set up to allow exploration of their concept. The Jigsaw groups are charged with the task of studying their concept and developing a Kolb Cycle learning exercise involving all four CHAPL components. These exercises will then be used when they return to their Home Team. After two sessions, the Jigsaw group members return to their home teams and take turns guiding the rest of their team members through the exercises they developed. The students then have a homework problem written to correspond to the hands-on module. These problems are not trivial, and frequently require iterative solutions. This promotes individual accountability, as each team member owns a critical piece of the cumulative information puzzle needed to solve assigned problems. The entire process is repeated for the heat transfer portion of the class.

Table 1. Hands-On Modules

• Reynolds No. – dye/flow through clear pipe
• Pressure drop through fittings & valves
• Flowmeters – venturi, orifice, & Pitot tube
• Extended surface heat. ex. – radiator/fan
• Kettle boiler/steam condenser
• 1-2 Shell and tube heat exchangers
• Fluidized bed – compressed air thru sand
• Double pipe heat exchangers

The hands-on modules are designed to allow groups to examine the basic principles behind pressure losses, flow regimes, flow measurement, the application of the mechanical energy balance, thermal energy balances, and the determination of heat transfer coefficients and heat losses. There are currently eight different modules, as described in Table 1. The modules themselves are remarkably simple. For example, a clear plastic shell and copper tube heat exchanger is illustrated in Fig. 4. Two four liter reservoirs mounted about 6 feet up on the pegboard stand provide gravity flow through the system. All connections are flexible tubing with quick-connect fittings. A pitot tube and manometer are provided, again with quick-connect fittings, and can be integrated into the system wherever the students should choose. In addition, the pegboard stand itself provides a flexible arrangement, allowing, for example, the height of the reservoirs to be adjusted. Small whiteboards above each module serve to encourage peer interaction via diagramming flow patterns, heat transfer resistance films, and energy balance inlet and outlet points, and through the writing and reduction of process modeling equations. Thermocouples are installed in the heat exchanger at each inlet, outlet, and at the midpoint of each side, these are read with a digital multi-position thermocouple temperature display. Hot and cold tap water are sufficient to give a measurable temperature change, and are readily available.

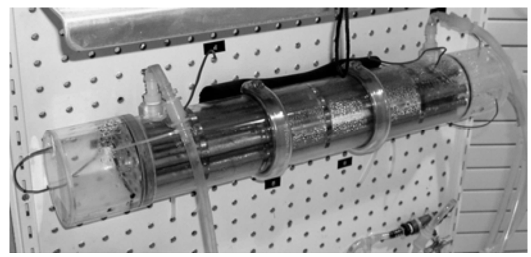


Figure 4. See-through Shell and Tube Heat Exchanger.

To promote student "buy-in" to the model, some initial readings on the subjects of Learning Styles [1] and of Cooperative Learning are assigned [18]. Students also take the Soloman and Felder learning styles inventory (available via Website [23]) and turn in their results. We facilitate a brief class discussion where student groups acknowledge the variety of learning styles among them – they project ways they will use their new knowledge about others to promote better group interactions and learn best from each other. Students are quizzed on the readings to ensure proper understanding of the CL principles [16] of Positive Interdependence (must rely on each other), Individual accountability (they must do their share and master all concepts), Face-to-face Promotive Interaction (must challenge, encourage, and teach others), Collaboration (must develop skills for trust building, leadership, decision-making, and conflict management), and Group Processing (must assess goals and teamwork). These CL principles serve as underlying foundations for integrating the remaining pedagogies into our classroom environment.

Maintaining individual accountability is especially important. As stated above the Jigsaw process does this by nature as each group member gives and grades a quiz and leads a learning module. Also, both group and individual homework assignments are given throughout the semester. The group problems promote interaction while the individual problems reveal how well each person is taking responsibility for learning the material. Another way we do this is by including opportunities for group members to provide feedback about the group learning process. This is done through student ombudspersons. Students were asked to designate ombudspersons to carry student concerns and issues back to the instructor. They are questioned about what's working well in the course, where there are issues to be resolved, how well the Jigsaw groups prepare their modules and how well the Home Teams function while learning modules, doing homeworks and developing group projects together. Half of the Home Teams supply an ombudsperson during the first half of the semester and half during the second half. We meet with the ombudspersons at least twice and use their suggestions to improve the learning process. In this paper we will present results from the ombudsperson interactions as this has proven especially effective in refining course pedagogy.

A final avenue exists for when there is a significant problem with an individual in a group who is not "carrying their weight." We use a three step process: First, group members meet with the individual to attempt to resolve the issue. Second, if that proves ineffective, the group arranges a meeting with the instructor for help. Finally, as a last resort, the group may dismiss a "freeloader". In this case the offending individual is responsible for their own assignments and projects.

Grading and course content are not significantly changed from what would be seen in a 'standard' version of this course. Students are still given individual exams, one midterm and one at the semester's end, worth a total of 40% of the final grade. Homework, which is about 50% group and 50% individual, and quizzes, all individual, are worth 30%, and group projects are worth 30%. In terms of course content, due to the concurrent manner in which subjects are covered, it is impossible to make a direct comparison of the amount of class time dedicated to any given topic. However the topics covered are complete and match the topics covered in this course when taught in a traditional manner.

ASSESSMENT

We use a variety of assessments throughout the semester long course. These include end of semester skills assessments by professors, focus groups, course evaluations, student ombudspersons, learning styles inventories, video interviews, surveys, and an expert evaluation by a noted educational researcher, Richard Felder. We will discuss the results individually.

A. Skills Assessments Conducted by ChE Professors

At the end of the semester all students had individual interviews with one of three experienced professors not associated with the course to compare the skills and understanding of course concepts learned in the CHAPL pedagogy with those of students taught in past years by the evaluators when using the traditional lecture approach. The following are excerpts from written reports submitted over the two years in which we have used this assessment:

> "*They have developed a much stronger foundation than students I have taught in these subjects* (fluid mechanics) *by more traditional methods.*"
>
> "*I was surprised to find that strong students were not significantly better than average students in answering the principles* (of fluid mechanics)."

B. Student Focus Groups

The Center for Teaching, Learning, and Technology (CTLT) at WSU performed a focus group study where a CTLT staff person met with each Home Team to facilitate a discussion around these questions:

1) How did you initially respond to the way the course was planned in the syllabus?
2) How has the way you respond changed as the semester progressed?
3) How did this course change your practice as a learner, if at all?
4) How have your learning habits changed in this class?
5) What did you learn about the field of chemical engineering in this class?
6) What have you learned about yourself as a learner in this class?

Students initially thought the syllabus was confusing and long, and the methodology would be difficult. As the semester progressed, they came to enjoy the course and the hands-on work. When asked about how the course impacted their learning habits there was a general consensus that they had more responsibility and relied less on the professor than in other courses and that they benefited from the group social contact. Question five elicited some responses that showed development of critical thinking skills. The students mentioned they learned how to "figure out" equations and to be open to each student's unique way of finding the answer. They also mentioned that they learned to "discuss a problem for five minutes before answering a question." Some of the students came to the realization that group work would be valuable to their success in later jobs. This illustrates the strength of these methods in producing engineers who are better able to make the shift to the group environment that typifies the modern workplace [6]. The students had a difficult time answering the third and fourth question – most discussed preferences on how they like to learn rather than their learning habits.

The students were also asked for general comments. They reported some difficulty scheduling group meetings due to varying extracurricular and work schedules. Some thought more TAs were needed, as they sometimes had to wait until someone was available. There was one primary instructor and two other preceptors for four groups – this meant at times one group would be without someone with whom to consult at a time when they desired more feedback. We do not see this concern as a major problem however, since the CHAPL pedagogy is one where groups are encouraged to pursue their own solution paths – also, they could find other aspects of a problem which need work while waiting for consultation with a preceptor.

C. End of Semester Course Evaluations

We assess the written comments from the standard end-of-semester course evaluations used in the WSU College of Engineering and Architecture. The comments in our most recent offering fall into six categories: 1) how well students like the course; 2) workload; 3) lecture and active learning balance; 4) number of preceptors; 5) homework; and 6) miscellaneous. In the comments below "CL" refers to "Cooperative Learning" and is a general term used by the students to refer to the CHAPL pedagogy. Here are typical comments from each category:

<u>Category 1 – Liking the course:</u>

"First day of classes … my least favorite, however, it quickly became my favorite"

"CL was much more enjoyable than lecture courses."

<u>Category 2 – Workload:</u>

"CL seemed more demanding on the student, however that also may have had a lot to do with the difficult nature of the course material."

"Too much outside time was needed. Should be worth more than two credits."

<u>Category 3 – Lecture / Hands-on Balance:</u>

"This class would be much better if it were supplemented by a lecture course."

"Meet twice a week in lab and once a week in lecture and make it a 3 credit class."

<u>Category 4 – Preceptors:</u>

"It would be nice if there were as many TA's as there were groups. Because sometimes the groups were left waiting for like 15 minutes without being helped."

<u>Category 5 – Homework:</u>

"Maybe for one of the modules, the class could actually measure all of the variables and solve a related problem."

"Less emphasis on turning in such a huge bulk of paperwork, more time to work w/ the modules & see how they work."

Category 6 – Miscellaneous

"Most of the kinks were worked out over the course of the semester."

"Put together teams by the members schedule outside of class"

The students find their being actively engaged in the learning process far more enjoyable than standard lectures. However, they wrestle with having to construct their own understanding of concepts – they desire better preceptor availability, more lectures and less outside preparation on their part. We conclude that at the very least the pedagogy is successful at shifting the responsibility for learning to the students. Yet, there seems to be a critical balance between the positive impact gained by a total CHAPL paradigm and inserting an expert treatment of the subject at points where the majority of students are at an impasse. Hence, in our more current format mini lectures are inserted to help draw together the major concepts. Also, a better correlation between homeworks and hands-on modules is now used – this reduces some of the outside-of-class time needed to digest and solve new problems – it also provides even more motivation to fully understand the modules being studied. We now make sure Home Teams have complementary schedules. Finally, a few students complained the instructor was not always available during scheduled office hours. One way of interpreting this is to say that when responsibility for learning is shifted to students and their teams they need mechanisms to debrief with field experts (in this case the instructor) to raise their comfort level with the pedagogy. On the other hand we find, because of the group interactions inherent in this course, students in general greatly reduce the times they come by for office hours – so much so that the instructor begins doing other things during those times. Then when students, on occasion, do come by they may not always find the instructor is available. Moving to an e-mail appointment system is helping to solve this problem.

D. Student Ombudsperson Interactions

Twice in the semester we had students designate a pair of representatives to give us feedback on how the course was working and what needed changing (one each from two Home Teams the first time and one each from a different two Home Teams the second time). Overall the students were upbeat about the team approach:

> *"Entertaining" … "learn a lot more" … "Would rather be here than have notes, notes, notes!" … "If you don't work together, you don't survive." … "(improved) work ethic & learning atmosphere for all students; carries over to the other classes."*

This is precisely the kind of effect we hope for – enthusiasm for learning; valuing the group process; changing the learning culture; seeing cooperative learning skills carry over to other classes; and instilling team learning habits that will be usefully over a lifetime.

They also had some concerns, which we took as constructive criticism and devised ways to minimize or alleviate the problems:

> *"Group members were not always prepared to come back to their Home Groups"; "Some members always late; (this) caused problems when they were supposed to be teaching their group"; "Some students were not very serious about the class; (this) caused difficulties due to the interdependence (requirements for the class)"*

As is evident the majority of the concerns deal with group member reliability. This feedback indicates a need for more formal accountability measures regarding the Jigsaw groups. Therefore, in the second half of the semester (and in subsequent courses) we required Jigsaw groups to develop an improved learning module activity plan to include a reading assignment, short quiz, simple hands-on experiment, and group fill-in-the-blank worksheet. The plan is submitted by the groups and evaluated by the preceptors – recommendations for improving the plan are made to create a uniform experience when Jigsaw members return to their Home Teams and take them through a cooperative hands-on learning module. This results in a more uniform student experience in the heat transfer portion of the course. Again this is what we hope for – learners critically evaluating the learning process – "What will make us better?" "How can we improve the atmosphere for everyone, including a project supervisor (preceptors in this case) and co-workers (student team members)?

E. Student Learning Styles Inventory

In the beginning of the semester students take learning styles inventories. Combined with some reading about cooperative learning [18] and learning styles [1] – this gives them a sense of why this pedagogy is helpful. Results from one particular semester typify the WSU Chemical Engineering student with about 80% sensing vs. intuitive learners, 60% thinkers rather than feelers, 90% visual over verbal, and an even split between introverts and extroverts. In particular the sensing and visual category results indicate "traditional lectures **ARE NOT** the best pedagogy for these students [2] – yet that is what the community almost universally does."[1]

Obviously, we deviate from the traditional lecture here. Yet, because lectures are the norm almost everywhere else, students often want to revert to that mode of instruction at some level – we have to continually remind them about how much more they are learning in the present format. We also do much to help groups appreciate the differences between extroverts and introverts – these are sometimes referred to as Active and Reflective Learners, respectively

[1] Phraseology attributed to Eric Schulenberger, University of Washington professional writer, in discussion of the pedagogy.

[1]. We help students understand that the Active Learner is helpful in getting the group thinking about the problem, yet the Reflective Learner often has important insights that if left unshared will allow the group to go down the wrong path. Preceptors constantly challenge groups to encourage "Actives" to acquiesce at times, and for "Reflectors" to take the risk of making their ideas known. We tell the students "If you have left the classroom with your ideas unchallenged today you should feel deprived".

F. Student Video Interview

In our most recent course offering a small group of students volunteered to take part in a videotaped interview for our use in symposia presentations and training materials for other instructors. The interviews reinforced many of the benefits that had been shown in some of the other assessments, and highlighted some issues we need to work on.

Reinforcement of earlier comments:

"(Even) *'Good' students sometimes missed conceptual 'stuff'; others filled in concepts."*

"Groups carried over to other technical classes."

"Didn't skip this class as much as others: you would miss too much."

An issue to work on:

We overestimated the impact of peer pressure to excite all group members to excellence, especially when serving as the Jigsaw point person for a given day. There needs to be more accountability – we need better assurance that students will return to their Home Teams prepared to facilitate learning modules for their group members. We believe this can be addressed in future classes by giving the students examples, both written and acted out on a CD, of an effective student led instruction session, and providing a grade mechanism to hold Jigsaw experts accountable for being prepared and on time.

G. Evaluation by Educational Consultant

Recently two experienced teaching effectiveness strategists, Richard Felder and Rebecca Brent, visited our classroom and brought to our attention that this may be the first instance where all four CHAPL strategies have been effectively implemented in one course. They made recommendations for further refinements including:

- Intermittent mini-lectures to the entire class to clarify misconceptions common to multiple groups and to highlight principles 'just-in-time' for students to use them in discussing modules.
- More verbal affirmation to groups when they finally grasp important concepts.
- Video interviews of students as an evaluative tool.
- Control courses at other universities – this can be accomplished in part by using common exams.
- Wider dissemination of the methodology so that others can benefit from what we are learning.

We have already begun implementing these helpful suggestions. We draw attention to the last point in particular – it is our hope that through publication of the pedagogy and dissemination of results at national meetings that many other universities will elect to adopt the CHAPL approach.

H. Survey Comparing to Traditional Courses

In the 2002 class, the CTLT performed a survey of the students in ChE 332, asking them to compare it to traditional lecture courses. The responses for the more important questions, Fig. 5, show a definite weighting toward increased time on task, more interactions with other students and instructors, creation of their own understanding, and better preparation for industry.

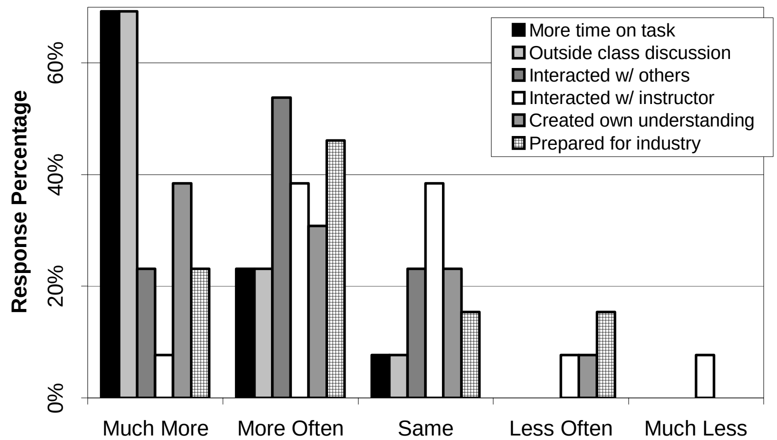


Figure 5. Survey comparing ChE 332 to other ChE lecture-based courses.

Faculty and Resource Inventory

One question that arises when implementing a new pedagogy, especially one which requires equipment and a new teaching paradigm, is: "how much time and resources will it take me to teach this way?" Regarding faculty time there is the initial investment in designing hands-on modules that will work for the course. This can take a couple weeks, but can easily be reduced by acquiring plans from another university (e.g., WSU) which has done something similar. For the most part equipment is a one time investment, though refinements and new processes can be added. A day more of planning is needed to prepare the syllabus and course materials as one thinks through Jigsaw group and Home Team logistics, what key concepts will be emphasized in each module and the format required for Jigsaw modules, what additional reference texts and journal articles will be available to the students, the strategy to be used for homework assignments whether a combination of individual and group (we suggest a combination) is needed, whether some assignments will be done as a Jigsaw group, and whether to include larger group project assignments. We also have special office hours for the Jigsaw experience, two per group, and for Home Team projects, two per group, plus two one-hour meetings with ombudspersons per semester. The extra planning time and office hours, however, are more than offset by eliminating the time needed to prepare lecture notes, review them, make overheads, etc., and because of the strong group interactions that result during the course, students finds the need for regular office hours is reduced.

Regarding financial resources there is the need to develop the hands-on modules. We suggest inexpensive and simple homemade designs, made from clear plastic tubes (for visual observation), with simple manometers (for gauging pressure drops), thermocouples leading to digital readout meters, pitot tubes for measuring flows, 5 gallon plastic carboys for gravity feed to the modules, etc. Maintaining this equipment also represents an additional load on the time of the departmental technician.

Finally, in our instance, we have the privilege of having three individuals, besides the instructor, who serve as preceptors to help guide student groups during class. One of these individuals would be available to most departments – this is our Instructional Laboratory Supervisor, or technician, responsible for designing and maintaining undergraduate lab equipment. A second is a graduate TA who is being supported by a Washington State University grant to assist in implementing and evaluating the new pedagogy. Finally, we have a graduate research assistant who plans to return to his home country to teach – this person volunteers in order to learn the alternative teaching approaches. For the most part, however, these extra persons are only involved during the classroom and have no additional responsibilities. Also, we note this course has been done with only the professor involved in mentoring groups. This works fine, but student feedback is more positive when individual groups are given more attention – the extra preceptors provide exactly that and we think the pedagogy is so valuable that it is worth investing in at least one extra person (preferably a graduate TA) who need not do extra preparation, but is experienced enough with the subject that they add value by coaching of groups during the class.

CONCLUSION

Research has shown that the traditional lectures that dominate the engineering curricula are not well suited to typical engineering students whose learning styles tend to be more toward the sensing and visual ends of the spectrum. This was confirmed in surveys given to junior level students at WSU. Other research has shown that the more students are actively engaged in the classroom experience, the more they will retain. We have presented findings from a recent Fluid Mechanics and Heat Transfer course where small fluid flow and heat transfer modules are present in the classroom. To study these modules and learn concepts represented with the module exercises student teams combine several learning pedagogies namely cooperative, hands-on, active and problem based learning or CHAPL as we refer to it. This collective pedagogical approach has proven effective in engaging the students without sacrificing course content. The method also gives students an opportunity to learn and practice some of the non-technical personal interaction skills that are vital to success in the modern workforce. Outside evaluators confirm that the students taught in this matter turn out uniformly knowledgeable about course concepts. Other feedback shows students are enthusiastic about the pedagogy, feel they learn more, are more interested, and carry the learning methods over to other courses and into industry.

Acknowledgments

We thank Professors Richard Felder and Rebecca Brent for their helpful comments, suggestions, and encouragement after visiting the classroom. We are appreciative for support from the WSU Provost's office which provided funding, through the WSU Assessment & New Curriculum Initiative, for the most recent version of the educational model. The WSU CTLT supplied initial funding, providing a quarter release time to Professor Van Wie to develop the course pedagogy – they also provided valuable feedback that assisted with course design, and spearheaded much of the assessment effort. We are grateful to our Teaching Assistant, Burton Schmuck, who coached groups, assisted with module problem development and assessment aspects for the course. Finally, we thank the students in the classes who were willing to bear with us while we developed this pedagogy.

References

1. Felder, R.M., "Matters of Style," *ASEE Prism*, **6**, 18-23 (1996).
2. Felder, R.M. and Silverman, L.K., "Learning and Teaching Styles in Engineering Education," *Engineering Education*, **78**, 674-681 (1988).
3. Tobias, S., "They're Not Dumb, They're Different: Stalking the Second Tier," *Research Corporation*, Tucson (1990).
4. Felder, R.M., "Changing Times and Paradigms," *Chemical Engineering Education*, **38**, 32-33 (2004).
5. Varma, A., "Future Directions in ChE Education: A New Path to Glory," *Chemical Engineering Education*, **37**, 284-289 (2003).
6. Rugarcia, A., Felder, R.M., Woods, D.R., and Stice, J.E., "The Future of Engineering Education, I. A Vision for a New Century," *Chemical Engineering Education*, **34**, 16-26 (2000).
7. Holmes, J. and Clizbe, E., "Facing the 21st Century," *Business Education Forum*, **52**, 33-35 (1997).
8. ABET, *Criteria for Accrediting Engineering Programs*, Accreditation Board for Engineering and Technology Inc, Engineering Accreditation Commission, Baltimore, MD. Also http://www.abet.org/images/Criteria/E001%2004-05%20EAC%20Criteria%2011-20-03.pdf, 2003
9. NTL Institute for Applied Behavioral Science, 300 N. Lee Street, Suite 300, Alexandria, VA 22314. 1-800-777-5227

10. DiBiasio, D., “Active and Cooperative Learning in an Introductory Chemical Engineering Course,” *Frontiers in Education Conference*, Session 3c2, p. 3c2.19-22 (1995).
11. Felder, R.M., Forrest, K.D., Baker-Ward, L., Dietz, E.J., and Mohr, P.H., “A Longitudinal Study of Engineering Student Performance and Retention, I. Success and Failure in the Introductory Course”, *Journal of Engineering Education*, **84**, 209-217 (1994).
12. Falconer, J.L., “Use of Conceptests and Instant Feedback in Thermodynamics,” *Chemical Engineering Education*, **38**, 64-67 (2004).
13. Watson, K., “Utilization of Active and Cooperative Learning in EE Courses: Three Classes and the Results,” *Frontiers in Education Conference*, Session 3c2, p. 3c2.1-4 (1995).
14. Bonnstetter, R.J., “Research & Teaching: Active Learning Often Starts with a Question,” *Journal of College Science Teaching*, **18**95-97 (1988).
15. Bonnel, C.C. and Eison, J.A., “Active Learning: Creating Excitement in the Classroom,” *ASHE-ERIC Higher Education Report No. 1*, George Washington University, Washington, D.C. (1991).
16. Johnson, D.W., Johnson, R.T., and Smith, K.A., “Active Learning: Cooperation in the College Classroom,” *Interaction Book Company*, Edina, MN (1991).
17. Meyers, C., and Jones, T.B., “Promoting Active Learning: Strategies for the College Classroom”, *Jossey Bass*, San Francisco (1993).
18. Felder, R.M., “Cooperative Learning in Technical Courses: Procedures, Pitfalls, and Payoffs,” *ERIC Document Reproduction Service Report* ED 377038 (1994). Also http://www.ncsu.edu/effective_teacing/Papers/Coopreport.html.
19. Huvard, G., Wnek, G., Crosby, B., Cain, N., McLees, J., and Bara, J., “ChemEngine: Realizing Entrepreneurship in Undergraduate Engineering Education,” *Proceedings of the 2001 ASEE Annual Conference*, Albuquerque, New Mexico, June 2001.
20. Kolb, D., *Experiential Learning*, Englewood Cliffs, NJ., Prentice-Hall (1984).
21. Kolb, D.A. and Lewis, L.H., “Facilitating Experiential Learning: Observations and Reflections,” in *Experiential and Simulation Techniques for Teaching Adults. New Directions for Continuing Education*, Lewis, L.H., ed. No. 50, Jossey-Bass, San Francisco (1986).
22. Aronson, E., Blaney, N., Stephan, C., Sikes, J., and Snapp, M., *The Jigsaw Classroom*, Sage Beverly Hills, CA 1978.
23. Soloman, B.A. and Felder, R.M., Index of Learning Styles Questionnaire, Department of Chemical Engineering, North Carolina State University, Raleigh, NC, <http://www.engr.ncsu.edu/learningstyles/ilsweb.html>, accessed December 29, 2004.

AUTHOR'S BIOGRAPHIES

Paul Golter is the Instructional Laboratory Supervisor for the School of Chemical Engineering and Bioengineering at Washington State University. Prior to that, he worked in the pulp and paper industry. He received his B.S. in Chemical Engineering from the University of Idaho.

Address: School of Chemical Engineering and Bioengineering, Washington State University, PO Box 642710, Pullman, WA 99164-2710; telephone: (509) 335-9634; fax: (509) 335-4806; e-mail: pgolter@wsu.edu

Bernie VanWie is a professor in the School of Chemical Engineering and Bioengineering at Washington State University. He received his Ph.D. in Chemical Engineering at Oklahoma University. His research interests are in biosensors, novel bioreactor design and in transforming learning engineering experiences by employing new teaching pedagogies.

Address: School of Chemical Engineering and Bioengineering, Washington State University, PO Box 642710, Pullman, WA 99164-2710; telephone: (509) 335-4103; fax: (509) 335-4806; e-mail: bvanwie@che.wsu.edu

Phillip Scuderi is currently the Associate Director of Information Systems at Washington State University and formerly the Associate Director for the Center for Teaching & Learning at Washington State University. While at the WSU CTL his research centered on critical thinking and learning. He received his B.S. in Economics and Business Administration from the College of Idaho.

Address: Office of Vice President for Information Systems, Washington State University, PO Box 641035 Pullman, WA, 99164-1035; telephone: (509) 335-6990; fax: (509) 335-1362; e-mail: scuderi@wsu.edu

Tom Henderson is an Assessment Coordinator for the Center for Teaching Learning & Technology at Washington State University. His research interests are in evaluating the efficiency of educational technology and assessment of educational processes. He received his Ph.D. in Interdisciplinary Studies from Washington State University.

Address: Center for Teaching, Learning & Technology, Washington State University, PO Box 644550, Pullman, WA, 99164-4550; telephone: (509) 335-6451; fax: (509) 335-1362; e-mail: tom@wsu.edu

Rebecca Dueben is an Instructional Technologist for the Extended University Services and formally a Hypernaut Coordinator with the Center for Teaching Learning & Technology at Washington State University. Her research is centered on student centered activity based pedagogies. She has a MA in Composition and Rhetoric at Washington State University.

Address: Extended University Services, Washington State University, PO Box 645210, Pullman, WA, 99164-52100; telephone: (509) 335-85881; e-mail: rdueben@wsu.edu

Gary Brown is the director of Washington State University's Center for Teaching Learning & Technology. His research interests are undergraduate learning, assessment, and technology. He received his Ph.D. in Interdisciplinary Studies from Washington State University.

Address: Center for Teaching, Learning & Technology, Washington State University, PO Box 644550, Pullman, WA, 99164-4550; telephone: (509) 335-1355; fax: (509) 335-1362; e-mail: browng@wsu.edu

William J. Thomson is a professor with the School of Chemical Engineering and Bioengineering at Washington State University, and prior to that had been a professor at the University of Idaho. He received his Ph.D. from the University of Idaho. He also authored the undergraduate textbook "Introduction to Transport Phenomena" which is being used in the Fluid Mechanics and Heat Transfer course described in this article. His technical research interest is primarily in catalysis and he has been active as an ABET evaluator of chemical engineering programs at several universities.

Address: School of Chemical Engineering and Bioengineering, Washington State University, PO Box 642710, Pullman, WA 99164-2710; telephone: (509) 335-4332; fax: (509) 335-4806; e-mail: thomson@che.wsu.edu

CHAPTER FOUR

ADDITIONAL ASSESSMENTS OF CURRENT PEDAGOGY

In addition to the work outlined in the previous chapter, we have two other assessment mechanisms that were not included in the article. The first is a 2005 survey of the alumni who had taken ChE 332 between 1999 and 2002. The second is a critical thinking rubric used to rate student presentations in 2005.

Alumni Survey

The students who had taken ChE 332 in 2003 were taught in a traditional manner, while those who took the course in 2004 had not yet graduated. There were 97 students who took ChE 332 between 1999 and 2002. Of these we had contact information for 59 students, 61% of the total students in the sample group. We received 11 responses. Table 2 details the response numbers by class. We did not attempt to characterize the students who responded in terms of GPA. We did, however, request their employment history. Five respondents had gone into industry, five had gone into graduate school, and one left that question blank.

Table 2 Summary of survey response numbers.

Year in ChE 332	*Responses*	Class Size	Response Percentage
1999	0	18	0%
2000	3	23	13%
2001	2	31	6%
2002	6	25	24%
Totals	11	97	11%
Surveys sent out		59	19%

The survey asked alumni to relate whether the CHAPL experience had affected the development of several key ‘soft’ skills, and which courses had been best at inspiring growth in these skills. Specifically, it asked about skills for working in teams, communication, course content, adapting to new situations, critical thinking, independent learning, problem solving, and preparedness for a future career. The results for each category are handled individually in the sections below. It is interesting to note that the quantitative results tend towards the positive, while the comments tend to have more of a negative tone.

Teamworking Skills

Figure 7 below clearly indicates that the alums felt that ChE 332, taught in the CHAPL manner, contributed more to developing teamworking skills than did most of their other courses. The written comments, in Table 3, tend to reflect this also; however they also make it quite clear that the capstone design and unit operations laboratory courses are superior in promoting teamwork skill development.

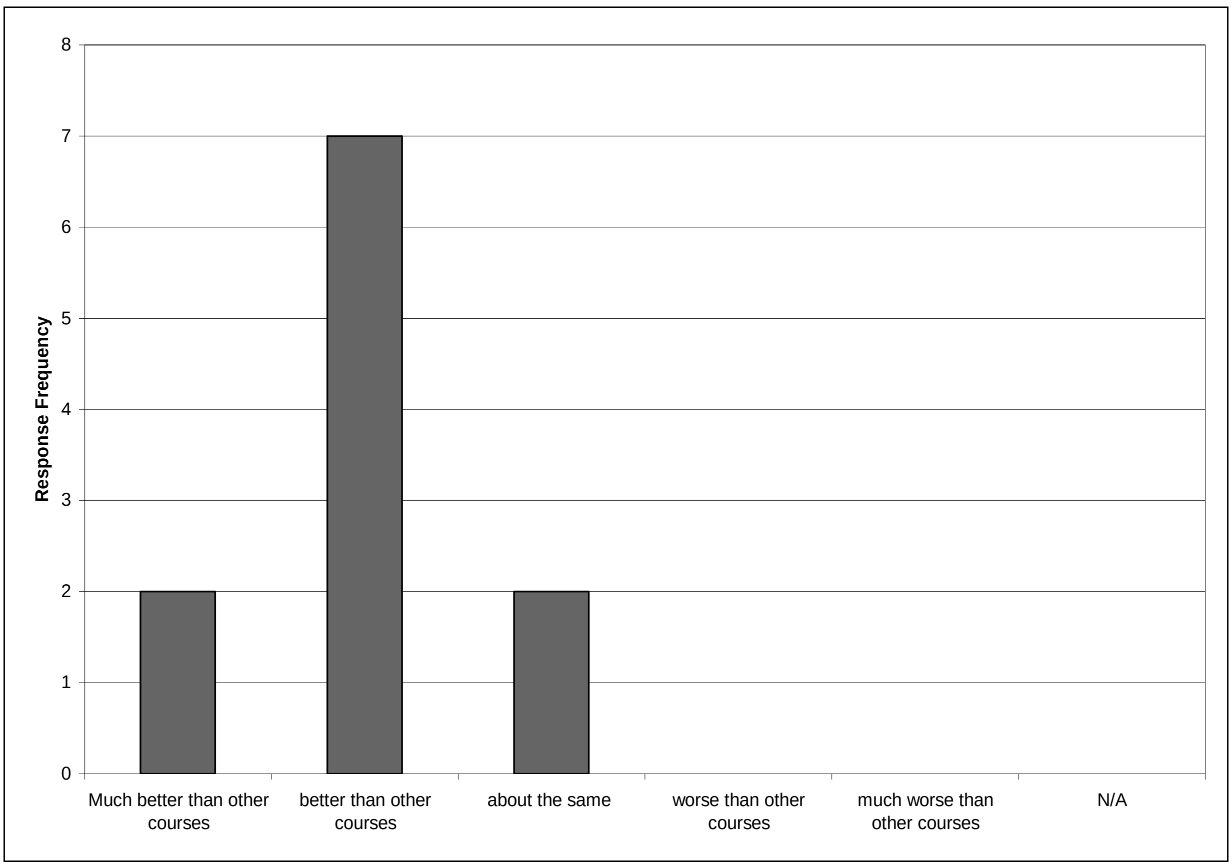


Figure 7: Responses to "How did the hands-on cooperative learning experience in ChE 332 compare with other courses in helping you develop teamworking skills?"

Table 3: Alumni Survey Responses Concerning Teamworking Skills

Classes regarded as "best" at developing teamworking skills:	
Unit Ops lab (both semesters)	9 responses
Design (specifically 2nd semester)	9 responses
Classes regarded as "average" at developing teamworking skills:	
ChE 201	3 responses
ChE 211	2 responses
ChE 310	2 response
All other ChE courses	3 responses
ChE 331	2 responses
Design	1 response
Control	1 response
Comments:	**Year in ChE 332**
Unit Ops Lab and Design II. In both of these courses, students were forced to cooperate- assignments were lengthy enough and broad enough that there is no way they can be completed by 1 or 2 people. The better students, rather than taking on most of the workload themselves, were forced to delegate responsibility and hold other members accountable.	2002
When I was at WSU, the main problem I saw with getting students to develop team working skills is that most of them are too shy. Many of the better students are afraid to step up into leadership roles because they don't want to seem rude or pushy. Students need to learn leadership skills, and know that when you are a team leader, it is o.k. to call shots and make decisions. Once they get into the working world, they are going to be paid to make decisions. Someone is always going to be unhappy with the decision you make, no matter what.	2002
Most of the groups I was in had a leader on paper, but that person rarely took on that role. In most cases the group simply split the problems up, and each person did their share of the work independently. This defeats the purpose of working in groups.	2002
I think it would be helpful if teachers would delegate team leaders, and clearly define their responsibilities. Force them to make decisions. In my career I have found that not making a decision at all is much worse than making an imperfect one.	2002
Senior design was by far the best opportunity to develop team working skills.	2002
Design and Unit Ops Lab were far and above better than 332. Che 332 fails in comparison	2001
Most courses did not have a "hands-on cooperative learning experience" so its not that ChE 332 was good, it is just that the presence of cooperative learning was better than the lack thereof.	2002
Design, Senior Lab, and 332 where the best at developing teamwork. The other classes required us to work together in order to have any hope of getting all of the homework done. Although 201 was easy enough, with Miller, to only rarely need to work together.	2001

Communication Skills

As shown by Figure 8 below, the alums could be described as feeling ChE 332 was at least as good as most other courses in promoting development of communication skills. Alumni comments again show the capstone courses as the useful in developing communication skills.

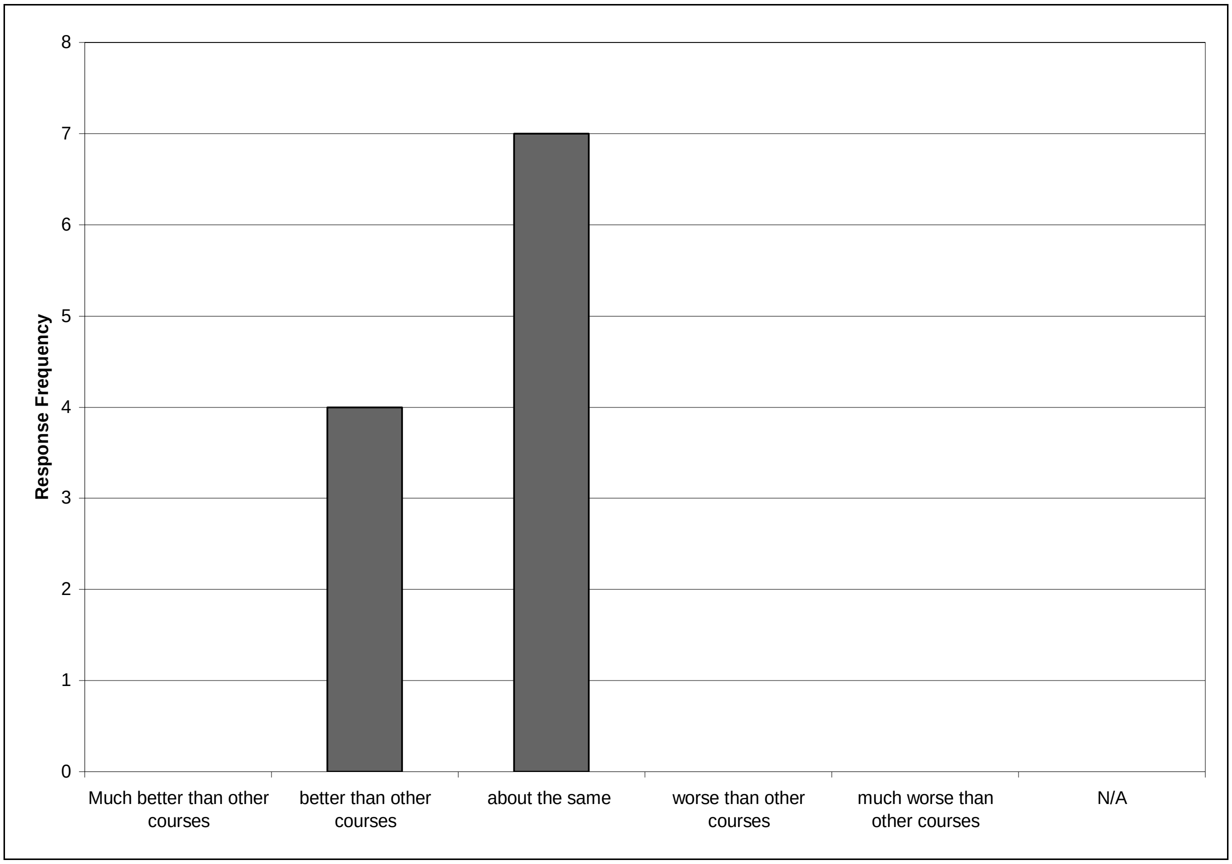


Figure 8: Responses to "How did the hands-on cooperative learning experience in ChE 332 compare with other courses in helping you develop communication skills?"

Table 4: Alumni Survey Responses Concerning Communication Skills.

Classes regarded as "best" at developing communication skills:	
Unit Ops lab (both semesters)	8 responses
Design (specifically 2nd semester)	5 responses
Classes regarded as "average" at developing communication skills:	
All the rest	4 responses
Process Simulation	1 response
ChE 331	1 response
Comments	**Year in ChE 332**
Unit ops. lab was excellent because it forced students to present to a group, while fielding tough questions and criticism. This course could be enhanced by having more training on speaking and presenting- and how to keep your audience awake.	2002
Early in my career (last year) I got the opportunity to present a project I did at a technical conference for my industry. Before going, I spent about 2-3 hours with our plant's training coordinator. This guy was a professional teacher, who did training of hourly personnel. I was amazed at the difference a little time spent with him made. There are so many things about body language, voice inflection, and visual aids that make the difference between being well understood and causing half the professors to nod off during your talk. I think it would be advantageous to bring in an expert on public speaking to spend a few hours with the students. Have them watch a few lab presentations and then give critiques on presentation. Many of the professors could probably even learn something!!!	2002
Communication in Design, Senior Lab, and 332 where required to get things done. In the other class it was only necessary if you needed help with either homework or studying.	2001
I felt the lab class was most helpful developing communications skills and teamworking skills. This mainly because we were forced to work together in a very hands on way. It is a lot easier to avoid working together when everything is done on paper.	2000

Conceptual Understanding of Fluid Mechanics and Heat Transfer

Somewhat alarmingly, as this is the course in which fluid mechanics and heat transfer is taught, some of the alumni surveyed felt that they had gained a better understanding of fluid mechanics and heat transfer from other courses. While positive responses outweighed negative ones, we would have expected that no class would have been better than Fluid Mechanics and Heat Transfer at teaching fluid mechanics and heat transfer. Unit Operations Laboratory was again listed as superior in this regard.

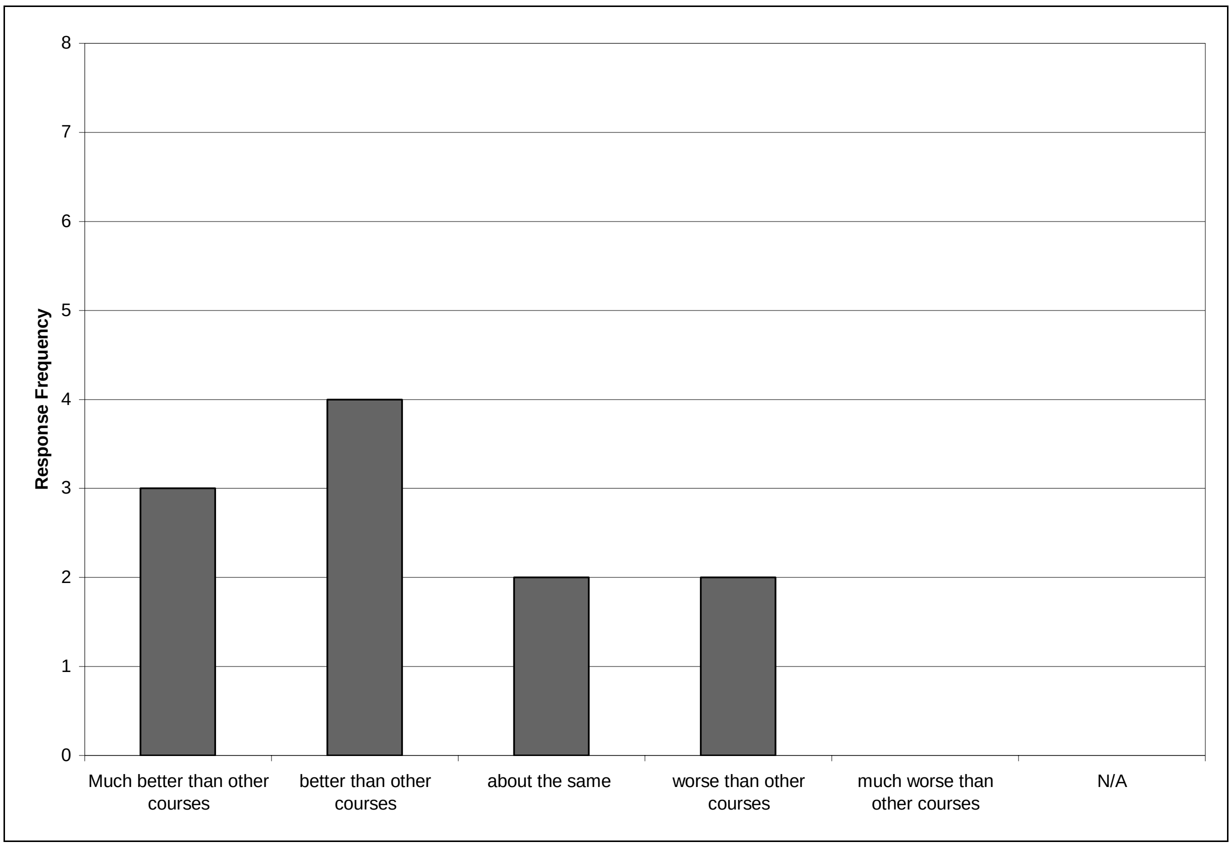


Figure 9: Responses to “How did the hands-on cooperative learning experience in ChE 332 compare with other courses in helping you develop Fluid Mechanics and Heat Transfer concepts?”

Table 5: Alumni Survey Responses Concerning Understanding of Course Concepts

Classes regarded as "best" at developing conceptual understanding of fluid mechanics and heat transfer:	
Unit Ops lab (both semesters)	4 responses
Transport	2 responses
Design	1 response
Separations	1 response
Classes regarded as "average" at developing conceptual understanding of fluid mechanics and heat transfer:	
Thermodynamics	2 responses
ChE 201	2 responses
Intro to Biochemical Engineering	1 response
Separations	1 response
Transport	1 response
Comments	**Year in ChE 332**
Many of the concepts I was taught during my junior year really didn't sink in until I took unit ops. lab.	2002
ChE 332 was not very effective in establishing a basic conceptual understanding of the subject.	2002
I think that this could have been drastically improved with the addition of SIGNIFICANT lecture time. While I think that hands on learning helps one to understand concepts I think that it would have been best utilized to show material that would be introduced in a lecture.	2002
I still don't feel that I learned everything that I should have. It is true that I knew how to solve the problems but I really didn't have a strong understanding of the material. There were a lot of concepts that I didn't really understand until I had design.	2001
Prior experience from a summer internship was most helpful to me in fluids. Also see question 4 *(Most courses did not have a "hands-on cooperative learning experience" so its not that ChE 332 was good, it is just that the presence of cooperative learning was better than the lack thereof)*.	2002
I think it was appropriate for us to learn theory on fluid mechanics and heat transfer. I am not sure if more practical would have been worth the time.	2001
The hands-on examples in both lab and fluids classes helped me to transfer what I was doing in class and it to use in "real life" problems	2000

Adapting to New Situations

According to alumni who responded, the CHAPL experience was essentially neutral with respect to developing skills for adapting to new situations. Unit Operations Laboratory was reported as the best course for developing this skill.

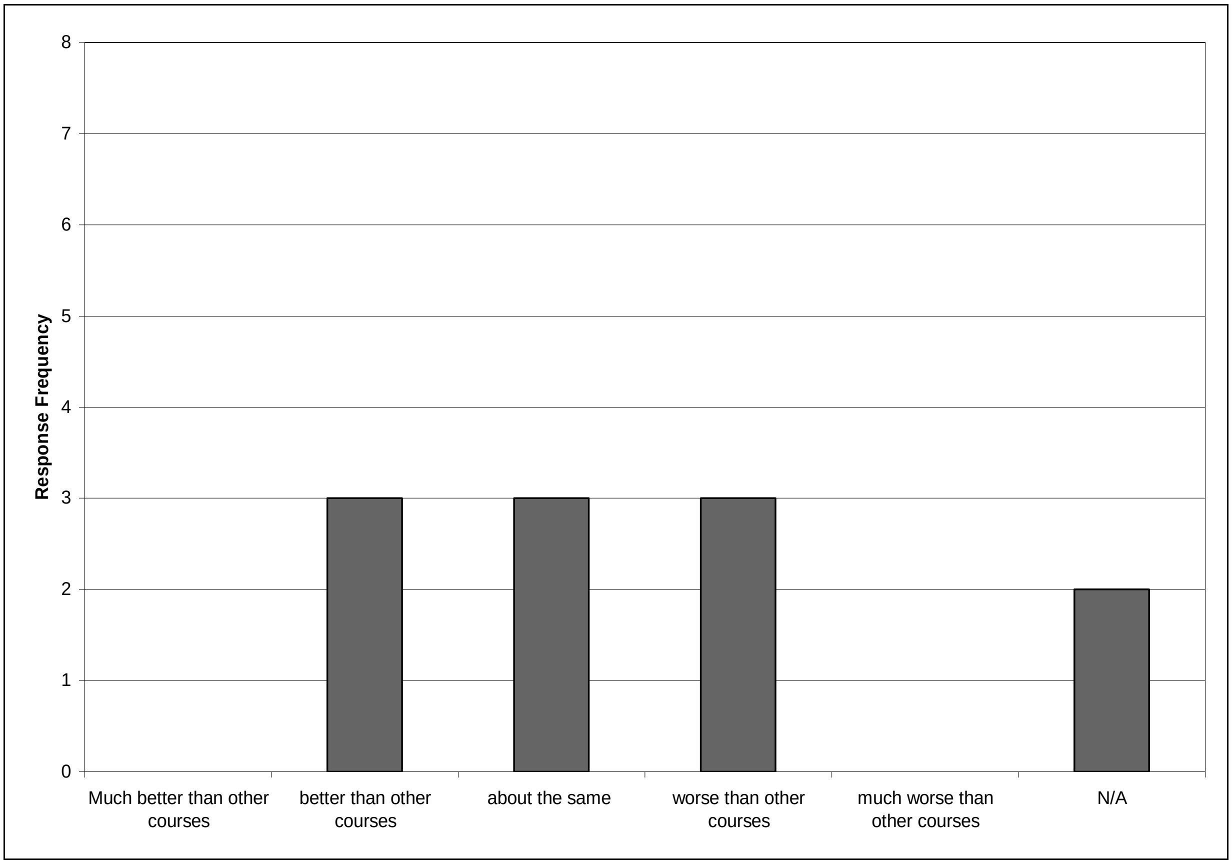


Figure 10: Responses to "How did the hands-on cooperative learning experience in ChE 332 compare with other courses in helping you develop skills for adapting to new situations?"

Table 6: Alumni Survey Responses Concerning Skills for Adapting to New Situations.

Classes regarded as "best" at developing adapting to new situations:	
Unit Operations Lab (both semesters)	3 responses
Kinetics	1 response
ChE 201	2 responses
Design	1 response
None did a good job	1 response
Classes regarded as "average" at developing adapting to new situations:	
ChE 334	2 responses
None did a good job	1 response
All others	1 response
ChE 201	1 response

Comments	**Year in ChE 332**
I'm not sure this is a skill that can be taught in school.	
In all of the new situations I have been in I have had some idea of the direction that I wanted to go and what the end result would be. I didn't feel that was given here.	2002
BVW's "endless loop" questions often created more problems than they solved.	2002
It is impossible for me to differentiate along this dimension. I think the most important thing for me is that we where exposed to a broad range of subjects.	2001
I don't believe any of my course work really had an impact on helping develop the ability to adapt quickly. I have only noticed that the best way to make me get up to speed fast is to set short deadlines with a lot of milestones.	2000

Critical Thinking

As summarized in Figure 11, the alumni reported that ChE 332 tended to be better than other courses at helping to develop critical thinking skills. The comments in Table 7 again show that the capstone courses topped the list of courses thought to be 'best' at developing critical thinking skills.

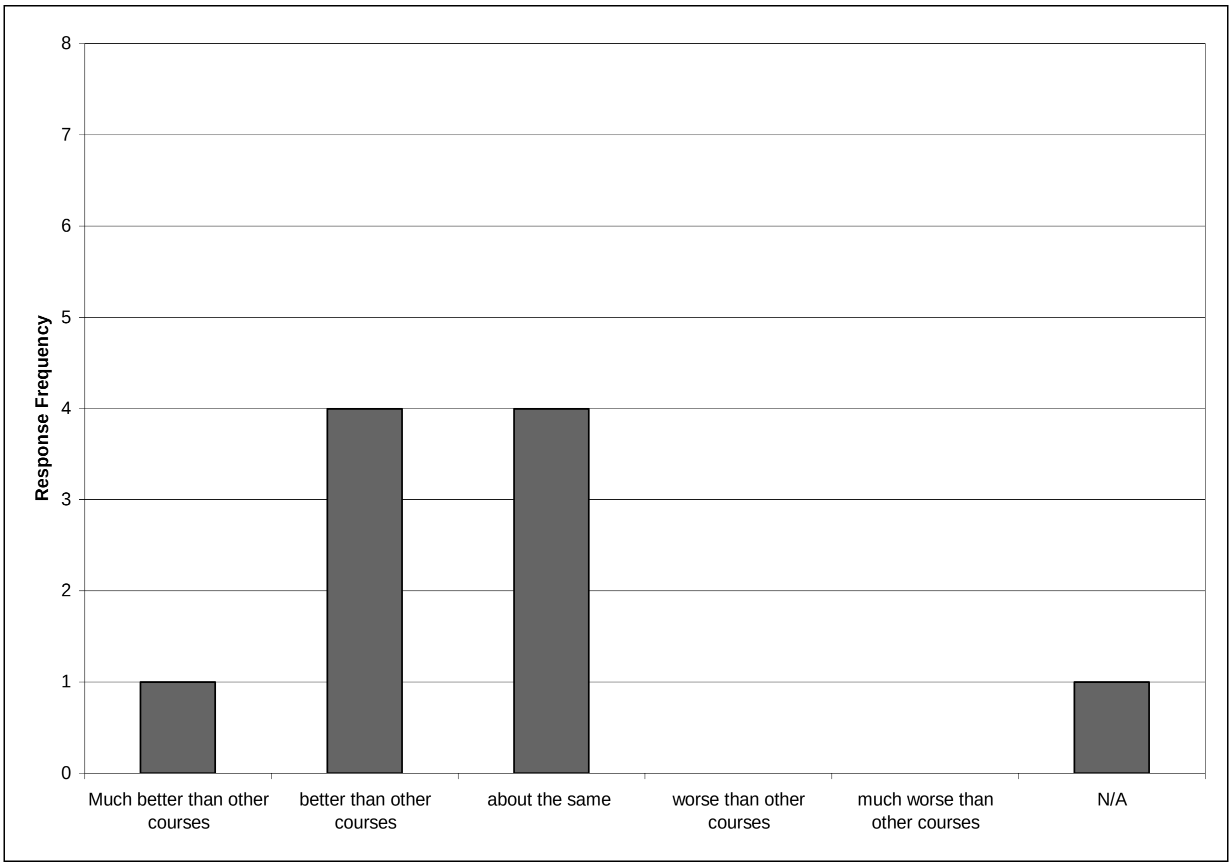


Figure 11: Responses to "How did the hands-on cooperative learning experience in ChE 332 compare with other courses in helping you develop critical thinking skills?"

Table 7: Alumni Survey Responses Concerning Critical Thinking Skills

Classes regarded as "best" at developing Critical Thinking:	
Unit Ops lab (both semesters)	5 responses
Design (specifically 2nd semester)	5 responses
ChE 201	6 responses
Kinetics	1 response
ChE 211	1 response
Classes regarded as "average" at developing Critical Thinking:	
Unit Ops lab (both semesters)	1 response
Separations	1 response
Kinetics	1 response
All others	2 responses
All Junior Level courses	1 response
Design (specifically 2nd semester)	1 response
Comments	**Year in ChE 332**
The only reason this is better than some classes is because the students had to teach themselves. You say cooperative learning, yet there was little cooperation by the professor	2001
none	2002
It is impossible for me to differentiate along this dimension. I think the most important thing for me is that we where exposed to a broad range of subjects.	2001
What helped me the most was to see how much time I would waste redoing projects. If I plan out what I need to do before hand it is always much more efficient.	2000
Again, I feel I got a lot out of unit ops lab. This course has students look at data and interpret its meaning and/or validity, and then defend their analysis. I also developed a lot of critical thinking skills in ChE 201.	2002

Independent Learning

The distribution shown in Figure 12 below indicates that ChE 332 is reportedly slightly superior to most courses in promoting the development of independent learning skills. Once again Design and Unit Operations topped the list of courses thought to be ‘best’ at developing independent learning, Table 8.

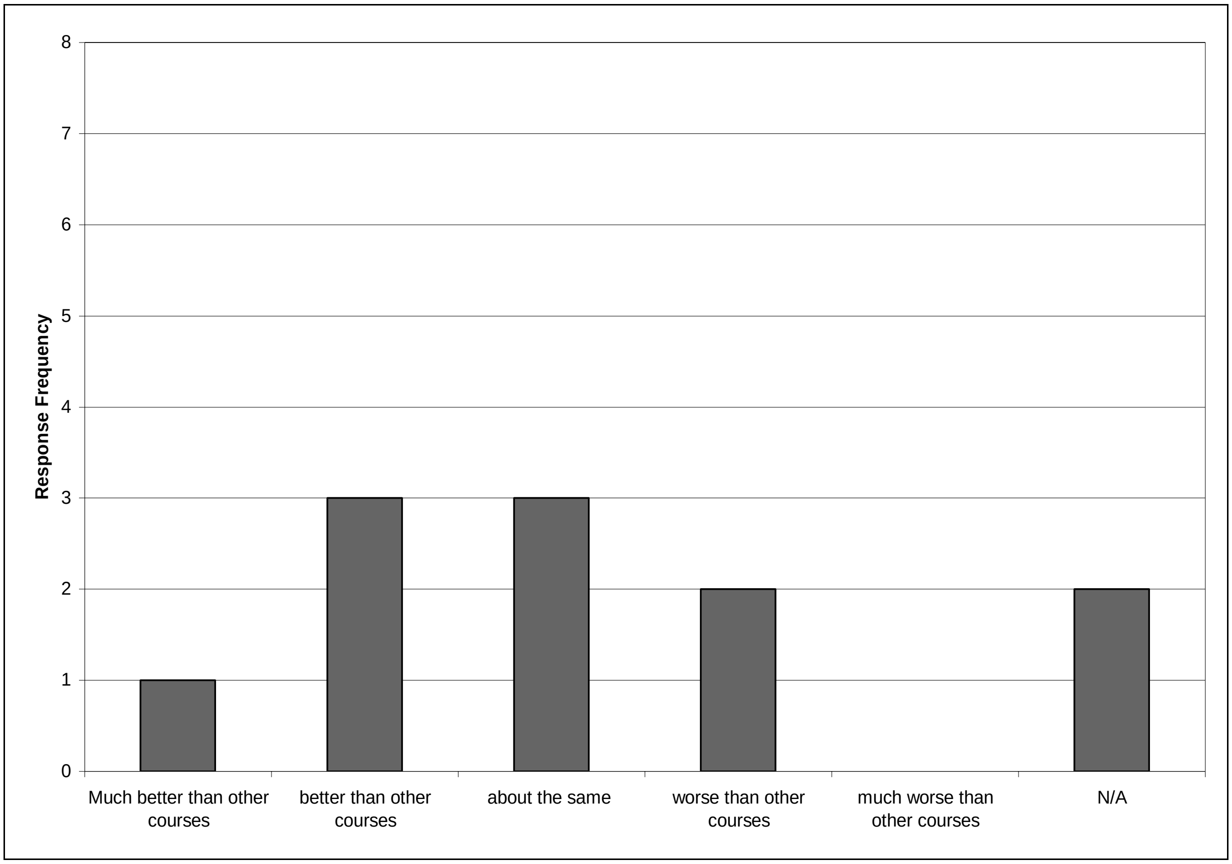


Figure 12: Responses to “How did the hands-on cooperative learning experience in ChE 332 compare with other courses in helping you develop independent learning skills?”

Table 8: Alumni Survey Responses Concerning Independent Learning Skills

Classes regarded as "best" at developing Independent Learning	
ChE 334	1 response
Design	4 responses
ChE 201	2 responses
Transport	1 response
Unit Ops Lab (both semesters)	3 responses
Classes regarded as "average" at developing Independent Learning	
Transport	1 response
Design	1 response
All courses about the same	2 responses
ChE 321	1 response
ChE 334	1 response
Unit Ops Lab (both semesters)	1 response
Comments	**Year in ChE 332**
Unfortunately, you develop independent learning when you have a professor who does not present/lecture well. You don't get anything out of lecture, so you are forced to read the textbook extensively and teach yourself in order to get through the course.	2002
I felt totally alone in my learning with no one to turn to for help, encouragement or input in any way. How was I supposed to know if my thought process was logical or if I was going in the right direction? For all I know I could have been the Pied Piper leading my group over a cliff.	2002
See comment in #20 *(The only reason this is better than some classes is because the students had to teach themselves. You say cooperative learning, yet there was little cooperation by the professor)*	2001
none	2002
It is impossible for me to differentiate along this dimension. I think the most important thing for me is that we where exposed to a broad range of subjects.	2001

Problem Solving

Figure 13 indicates that the CHAPL pedagogy is at least as effective as other courses in developing problem solving skills. In this category there was no clear 'winner' with regard to courses that develop problem solving skills.

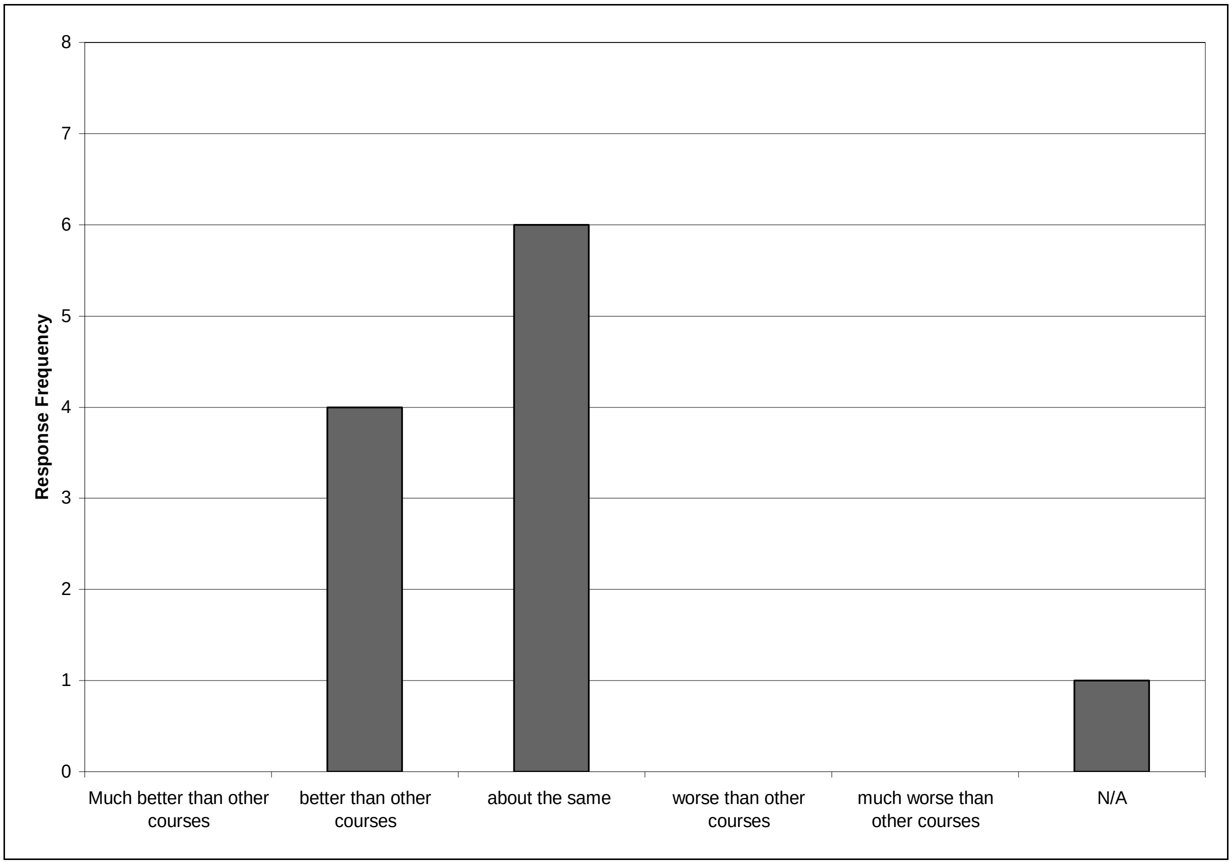


Figure 13: Responses to "How did the hands-on cooperative learning experience in ChE 332 compare with other courses in helping you develop problem solving skills?"

Table 9: Alumni Survey Responses Concerning Problem Solving Skills.

Classes regarded as "best" at developing problem solving skills:	
ChE 201	2 responses
Design	2 responses
Thermodynamics	1 response
Transport	2 responses
Separations	1 response
Unit Ops Lab (both semesters)	2 responses
Classes regarded as "average" at developing problem solving skills:	
Separations	1 response
Thermodynamics	1 response
Kinetics	1 response
Control	2 responses
Unit Ops Lab (both semesters)	1 response
ChE 211	1 response
All others	1 response
Comments	**Year in ChE 332**
See question 4 *(Most courses did not have a "hands-on cooperative learning experience" so its not that ChE 332 was good, it is just that the presence of cooperative learning was better than the lack thereof.)*	2002
It is impossible for me to differentiate along this dimension. I think the most important thing for me is that we where exposed to a broad range of subjects.	2001

Other Comments

The comments in Tables 10 and 11 below show a mixture of strong dislike and moderate like for the way the course was taught. This echoes the tone of the more specific comments in the sections above. They also show a strong desire on the part of the students to return the class to a more comfortable format. Again this echoes the comments from the more specific questions.

Table 10: Alumni Survey Responses On How the Course Prepared them for Industry/Graduate School.

Looking back on the ChE 332 Hands-on Cooperative Learning experience how would you compare it to other coursework in terms of helping you prepare for industry or graduate school?	**Year in ChE 332**
ChE 332 was not one of the better courses I took in the chemical engineering department.	2002
I think I learned the most in ChE 201, 334, Design II, and Unit ops.	2002
It was a very interesting and helpful approach, it made the subject area stick in your mind probably better then a typical lecture class.	2002
Working on team projects and preparing modules to teach others was a good and helpful experience. In terms of working on group projects it wasn't as good as senior design or unit ops lab, but it was beneficial.	2002
I can honestly say that this was the class that has been the most unhelpful to me in my ChE education. I feel that I was ripped off because of many concepts that I should have learned were not learned due to this way to teaching. There are many key concepts that need to be understood in this class and I have had to go back and learn from reading and in talking to others what I should have learned a long time ago.	2002
Little or no help. I think we needed more class time where the professor could develop difficult or complicated aspects of 332. Without this the students are like chickens with their heads cut-off, they're running around but they can't see the direction they should be heading.	2001
I picked up fluids from industry before ChE 332	2002
Doesn't help much given my current position	2002
The class was valuable for me because it developed my ability to make the correct assumption quickly and gave me confidence in doing so. This class significantly added to my breadth of knowledge and did so in ways that other classes did not.	2001
I think it helped. Probably not any more than other courses I had taken that required team projects. I still feel that it is important to have a lot of experience working on projects in groups. Once in the workforce we will always be depending on others to complete projects.	2000

Table 11: Alumni Survey Suggestions for Future Professors and TAs.

What suggestions would you make for professors and teaching assistants who are teaching the course now?	**Year in ChE 332**
If you are going to have students work in groups, you have to do something that forces them to function as a team, rather than as 4 people all working on the same assignment. Put leaders in positions where they must make decisions. Hold all team members accountable. You also have to make sure that the better students are not doing work for other people to save their own grade.	2002
The class could have used some more lecture hours, as it was often difficult to do homework assignments without a little background information on the subject	2002
While it is a good experience for students to come up with problems to teach other students material, in general they do not have the background or knowledge to do so. In order for the fundamentals to be established more professor direction and aid is necessary. It seemed that basic knowledge and understanding was lost in the way the class was set up and organized.	2002
As stated before I would add significant lecture time to the class, at least one lecture hour to every 2 lab hour, if not 1:1. Also I think that goals and objectives should be stated clearly. Those in charge should be willing to answer questions, not ask a question back in return. I also felt that the assistant and the professor didn't understand the modules themselves. I think that they need to more knowledgeable in the equipment.	2002
Not all students learn the same. You need to realize this. Some are hands on and some are lecture learners. You need to incorporate both. If you do not do this you are doing an injustice to everyone.	2001
Continue using this concept of teaching	2000
Use hands-on learning, but adapt to current student needs	2002
It is a great idea. The lab time really helps.	2000
I don't remember learning anything valuable in the lab portion of this class. What I do remember is the lecture portion adding considerably to my knowledge base. It was the only class where we learned much of the information contained in it. So keep the subject matter different than the other classes. Also this class develops ones abilities to make assumptions, so don't take that away by giving to much information.	2001

Critical Thinking Rubric

Using the critical thinking rubric developed by the CTLT as a starting point, we developed a critical thinking rubric more applicable to technical courses problems or presentations. It attempts to quantify critical thinking in four categories: 1) Identifies and understands the **problem**, 2) Identifies and presents the STUDENT'S/Group's OWN **method** as it is important to the solution, 3) Identifies and assesses the key **assumptions, and 4)** Assess the **quality of the solution**. These are each rated on a six point scale with one being low and six being high. Professional competence, being the type of thinking we would like to see in a practicing engineer with a few years of experience, is defined at four, while six is meant to be the level of thinking found in an expert discussing his/her favorite topic, or what we hope our PhD students display in their thesis area. We included examples under each scale point to allow easier differentiation. A copy of the rubric can be found in Appendix 4-E.

The rubric was applied in 2005 to a series of class presentations. The student groups were assigned an initial homework problem and asked to give a brief presentation about their solution. A brief presentation was also added for each of the two project assignments for the course. This gave us a pre-measurement, a measurement halfway through the semester, and a measurement at the end of the semester.

The presentations were observed by Dr. Van Wie, Dr. R. C. Miller (first presentation only), myself, and graduate student B. Schmuck. Shortly after each set of presentations, we met to discuss and resolve any significant differences in our ratings. Significant differences in this case were differences that were larger than one step apart or spanned the professional/student boundary. So, the difference between 2 and 3 was not significant, while that between 3 and 4 or 1 and 3 was. It should be noted that the professors tended to be more generous than the graduate students and gave fractional ratings. One difficulty we observed was due to applying the rubric to a group presentation. Group members demonstrated vastly different degrees of critical thinking, and it was necessary to synthesize an average value for the group.

Figure 14 summarizes the class average results for each presentation. The standard deviation for these averages ranged from zero to 0.7. The class showed growth in critical thinking over the course of the semester, however, it is not clear how much of this can be attributed to the CHAPL pedagogy and how much is a due to other effects (i.e. maturing, other courses, etc.)

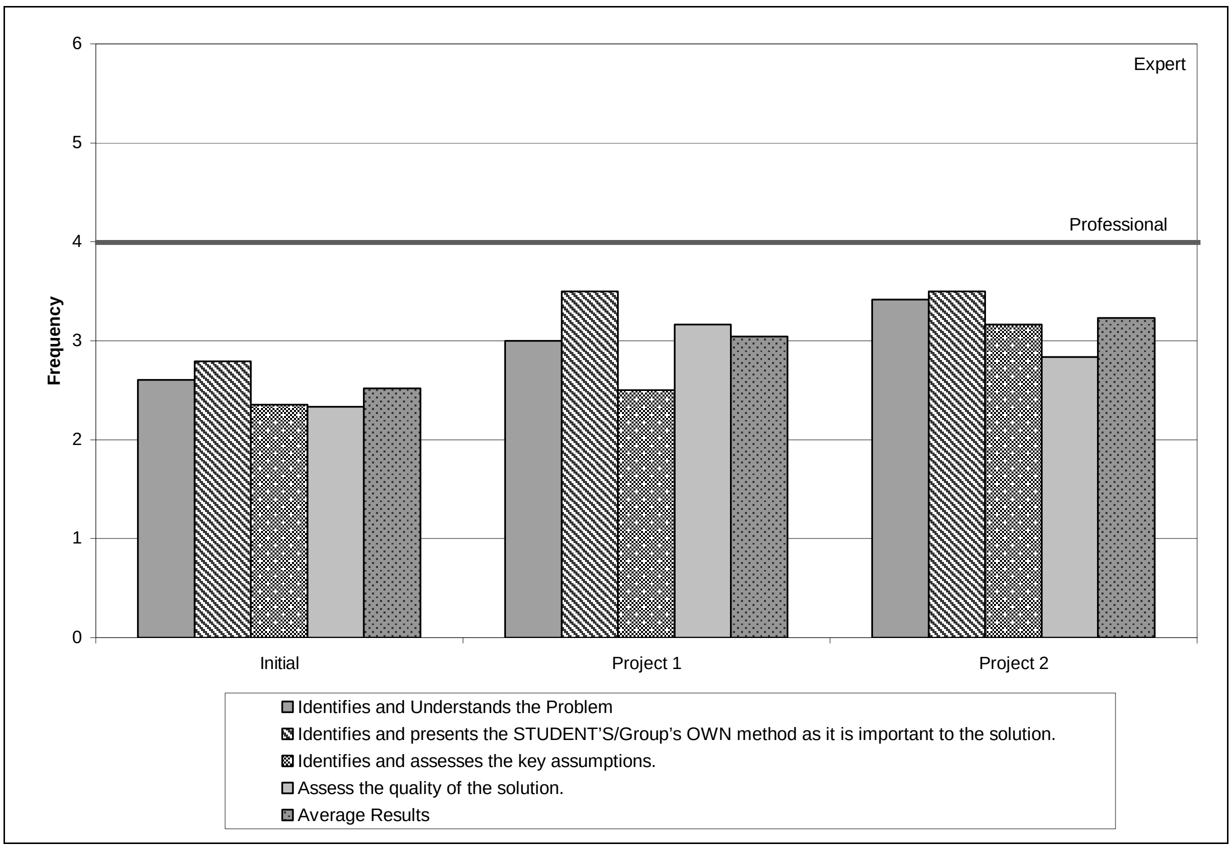


Figure 14: Spring 2005 Class Average Critical Thinking Rubric Results"

Of more interest are the differences between the various projects for the individual groups which are summarized in Figure 15. Error bars represent a 90% confidence interval, based on the Student t distribution, for the differences between scores from the initial presentation to both projects using a 90% confidence interval, t distribution and pooled variances. From this, we see that Group One showed some growth in the areas of identifying and assessing assumptions and assessing the quality of the solution, but was stagnant in the other areas throughout the course. Groups Two and Three showed growth in all areas over the course. Group Four showed growth in three areas, problem identification, method choice, and assessing solutions. However, they were stagnant in assessing their assumptions. The class as a whole exhibited growth in critical thinking over the course.

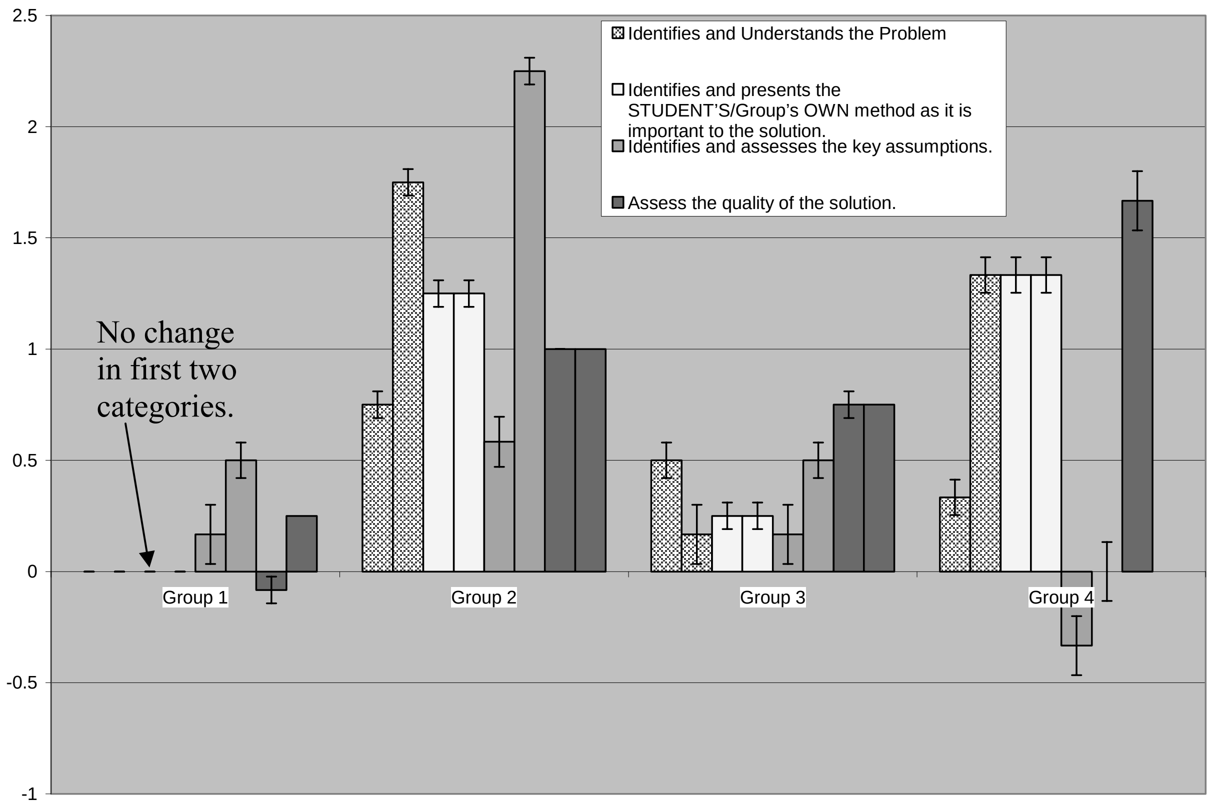


Figure 15: Spring 2005 Critical Thinking Rubric Results Separated by Group. The first column of each color represents the difference between the initial homework problem presentation and the first project and the second represents the difference between the initial homework problem presentation and the second project.

Module Problems

In 2004, and continuing to the present, we developed a series of problems that would directly correlate to the equipment being used in the CHAPL classroom. They are designed to be non-trivial, thought provoking and entertaining. All physical values in the problems correspond to the sizes and flow rates typical for the corresponding piece of Laboratory equipment. This is done so that the students can, if desired, compare correlation based solutions to results from a corresponding physical system. The student groups can also, if given the problems ahead of time, use the problems as a guide for researching the concepts involved in the different modules.

The fluid mechanics problems, while lengthy, are relatively simple. The heat transfer ones, however, sometimes require iterative calculations, and the solution to one is that the the specified equipment is incapable of accomplishing the required heat transfer. In the case of the shell and tube heat exchanger and kettle boiler problems, the problems exactly mimic the design calculations used in designing the apparatus.

CHAPTER FIVE

NEW APPARATUS

Minor Revision of a

Paper Presented at 2006 ASEE Conference in Chicago

Published in *Proceedings of the 2006 American Society for Engineering Education Annual Conference & Exposition*, Session 3513

Practical Considerations for Miniaturized Hands-on Learning Stations

P. Golter, B. Van Wie, G. Held, J. Windsor

Abstract: In order to allow professors greater flexibility in optimizing their classroom environment, there is a need for laboratory apparatus scaled for easy use by students in standard classrooms. Most commercially available equipment is relatively expensive, and at the smallest, is scaled for the laboratory bench. Fluid mechanics and heat transfer equipment also requires utility hook ups. How do we by-pass these obstacles to create low cost units, with no external utility requirement, that can be placed on student desktops? How, for example, do we make a double pipe or shell and tube heat exchanger that a student could use in a lecture hall? Here we describe the considerations involved in designing a hands-on desktop demonstration unit – one that is useful in the standard classroom by small groups of students to quickly demonstrate most of the basic fluid and heat transfer concepts. The system we built serves to enhance qualitative understanding and can be used to measure quantitative information in minutes using hot and cold tap water reservoirs, gravity flow, non-electronic flow meters, manometers, pressure transducers and temperature probes with small-scale readouts.

Introduction

There is a well known need to re-visit the way in which engineers are trained to better prepare the next generation of engineers for the challenges of our changing society.[1] This can be done either by adding more courses, and thus more years, to engineering curricula or by utilizing alternate pedagogical techniques that can simultaneously enhance learning of core concepts and develop traditionally neglected 'soft' skills such as good communication practices.

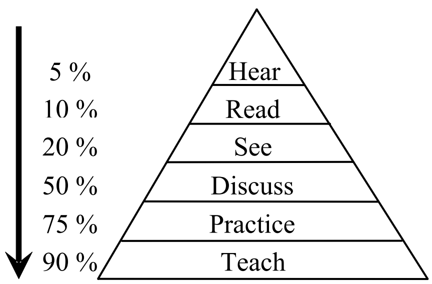


Figure 1. Learning Retention

Alternate pedagogies include cooperative, hands-on, active and problem-based learning. Usually these pedagogies are applied individually. Figure 1 shows the well known 'cone of learning' which links complexity of an activity to the amount of knowledge retained.[2] An implication of the correspondence of increasing complexity of activity with increased retention is that combining alternate pedagogies should increase learning effectiveness. In the Fluid Mechanics and Heat Transfer course of the Chemical Engineering program at Washington State University (WSU), we have developed a novel approach that combines Cooperative (C), Hands-on (H), Active (A), and Problem-based (P) Learning pedagogies. We refer to this pedagogy as CHAPL and have discussed it in depth elsewhere.[3] A significant part of this pedagogy is the use of hands-on learning with dresser-sized modules containing an apparatus, water tanks, pumps, flowmeters, thermocouples, manometers and a whiteboard. Students are assigned an apparatus and must develop a learning exercise, including a reading assignment, quiz, and experiment, to instruct other students in the key concepts demonstrated by that apparatus. Due to the size and number of these modules, classes using this pedagogy must be held in a dedicated lab space. We have come to realize that one of the significant drawbacks to this method is the investment, in terms of space and equipment. Though we designed and built our current modules, it is possible to purchase a bench scale unit with similar attributes from a commercial vender. These units simply are not suitably sized for a typical classroom or lecture hall.

For this reason, we set out to develop a desktop scale version of our current modules. These Desktop Learning Modules or DLMs (patent pending) combine the capabilities of most of our existing units in a single one foot cube. We quickly realized that these new modules can also be used to augment the traditional lecture by providing brief hands-on activities or demonstrations. The biggest challenge was to design a full range of capabilities in a desktop package and to do so without the need of external power or water facilities hook-ups. Herein, we present the design considerations, special accommodations and operating characteristics for the resulting units along with their potential impact on classroom performance.

Considerations for Miniaturization and Combination

The design criteria for such modules are multiple. First they must be small enough that a number of them could easily be transported to most typical classrooms, and easily placed on the writing surface available to students in most lecture halls. Secondly, to avoid tripping hazards, they must not need an external power source. Third, to facilitate adoption they must be relatively cheap. Lastly, they must hold a sufficient water reservoir to operate for about 10 minutes. In addition to these general criteria, in order to replace the existing larger modules, the new ones must be capable of achieving a full range of laminar and turbulent flow regimes. We chose to include modules that reproduce Reynolds' experiment of dye injection into a flow stream; that have multiple flow measurement devices, such as venturi, orifice, and pitot meters; and that contain both a shell and tube and a double pipe heat exchanger sized so a measurable temperature change can be produced using hot and cold tap water as the feeds. Though it may not be possible to completely reach steady state in terms of steady temperature profiles, the units must approach steady state in a relatively short time frame and at least give qualitative results for pedagogical purposes.

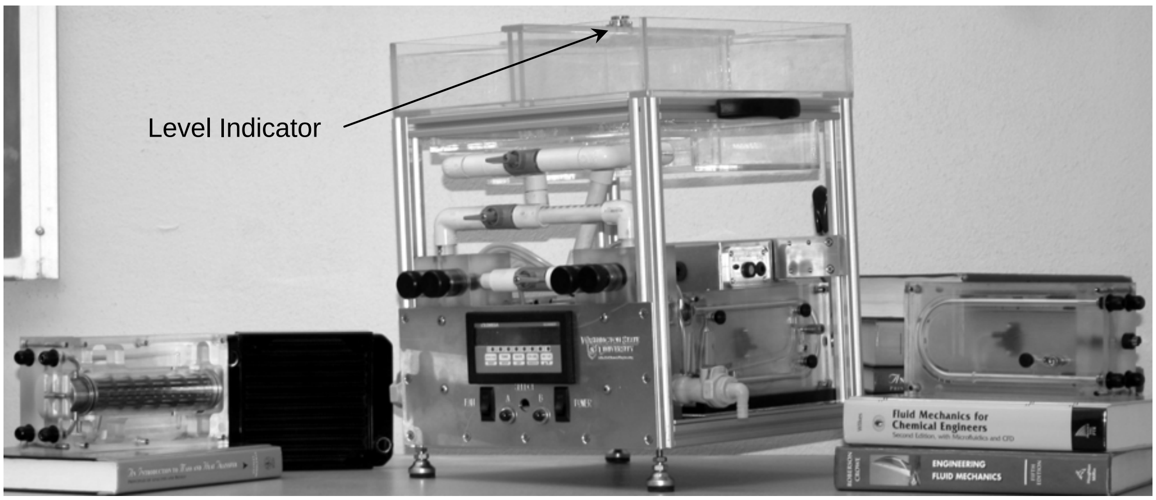


Figure 2: Desktop Learning Module

Such DLMs should have usefulness apart from application of the full CHAPL pedagogy typically used in the past in our laboratories. In other words, one should be able to integrate their use into a standard lecture, where they may be used as a demonstration unit or to facilitate a brief active learning exercise by placing several units in the room, around which small groups of four to five students may gather. Beyond that, of course, they could also be used to facilitate cooperative learning by using the Jigsaw technique, [4] where the original groups split to form expert or jigsaw teams consisting of one member of each group and tasked with learning one concept. After mastering unit concepts, the original groups are reformed, and each jigsaw expert facilitates a learning exercise so that everyone will learn a complete set of course concepts (i.e. completing the learning puzzle picture). Finally, our DLM units could be used as an aid for problem based learning, by having students examine the behavior of the system and then seek to find explanations for what they see. Alternatively, they could be given a homework assignment with equipment sizing and flow and temperature parameters achievable in the DLM.

Results

Since providing power to an electric pump would be awkward, due to lack of outlets, in most classrooms, and hand pumps are likely to produce a pulsating flow, we chose to design the DLMs with gravity feed. We also chose a one foot cube, with feed tanks built on top of the actual fluid or heat transfer module. This provides for convenient refilling and a safe and stable arrangement for locating the units on lecture hall desks. Since most lecture hall and classroom desks are not level, we included adjustable leveling feet and a level indicator bubble (see Figure 2). Our DLM design calls for clear acrylic to allow the students to easily see what is going on (see Figures 3 and 4).

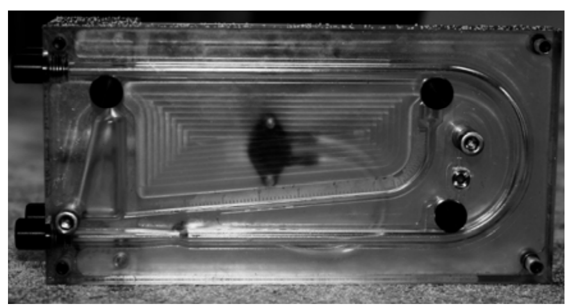


Figure 3: Venturi Cartridge with Dye Injection Port and Built in Manometer

This combination immediately causes design issues in the areas of pressure drop, turbulent flow, and capacity. If we make the tubing large, we will have a low pressure drop and gravity will be sufficient to feed the system. However, this will lead to higher volumetric flow rates, which will empty the feed tanks faster. Larger tubing will also give a lower velocity at a given volumetric flow rate. This, of course, lowers the Reynolds number, making turbulent flow harder to achieve. Conversely, for a given volumetric feed rate, if we make the tubing small, it will be easier to achieve turbulent flow, but the pressure drop will increase making it difficult for gravity to feed the system.

We overcame this obstacle through a few simple modifications to our initial design criteria. First, we realized that if we place the ‘waste’ tank on the floor and prime the waste lines, we can essentially increase the height of the system by about two and a half feet. This provides more head to work with and allows us to overcome a higher pressure drop. We placed the various systems in interchangeable cartridges which allow us to have each unit slightly larger and more visible. This also eases the space burden of using one apparatus for a multitude of fluid mechanics and heat transfer apparatuses.

Figure 4: Shell and Tube Heat Exchanger Cartridge

On the heat transfer side, we are constrained by the fluid temperatures that can easily be provided to an unpowered unit in a standard classroom. We chose to design for operation with one gallon of hot and one gallon of cold tap water, as this could be reasonably found near most classrooms and lecture halls. Hot tap water runs about 120°F and cold tap water runs near 50°F. Is this enough of a temperature difference to get heat transfer on no more surface area than is available in such a small apparatus? If we realize that we aren’t looking for industrially meaningful heat transfer, just a change of as few as 5°F, such that the concepts can be illustrated, then this is enough of a temperature difference for our purposes. Although if more heat transfer is desired, ice could be placed in the cold water reservoir. This would reduce the run time due to the volume occupied by the ice, but provide a larger temperature difference.

The last design issue is how to power the instrumentation. Our initial thought was to build inclined manometers into the unit everywhere we needed a pressure reading, and to use handheld thermocouple readers for all of the temperature measurements. Since we would have needed eleven total manometers, which would have consumed most of the surface of the DLM, we switched to differential pressure transducers and a built-in digital readout. For the alpha prototype we chose a commercial display that could be run off of a 12 volt sealed lead-acid battery and also read the thermocouples. This is probably the single highest cost item ($800) in the unit, and consumes a large amount of space.

At the time of writing, the alpha prototype is nearly complete and has been shown to the class. Heat transfer cartridges have been given out, one per student group, for each group to develop a learning experience for the rest of the class. The students are giving positive feedback, and one even reported that seeing the module corrected her misconception of the shape of a shell and tube heat exchanger.

Conclusions

By paying careful attention to the purpose of the DLMs, we can design an apparatus that will provide a meaningful learning experience for students. It is not necessary to have a large temperature change across a heat exchanger. What is needed is an apparatus that can demonstrate the differences between turbulent and laminar flow, and demonstrate the concepts of heat transfer in each flow regime and allow pressure drop measurements and calculations for all units so students can learn to model these effects. Our apparatus provides this opportunity in a small package that can be used in any standard classroom with a nearby bathroom.

Acknowledgements

We are grateful to the Washington State University Provost's office for providing a Program Development Grant to fund this work.

References

1. National Academy of Engineering, *The Engineer of 2020: Visions of Engineering in the New Century*, the National Academies Press (2004)
2. NTL Institute for Applied Behavioral Science, 300 N. Lee Street, Suite 300, Alexandria, VA 22314. 1-800-777-5227
3. Golter, Van Wie, Scuderi, Henderson, Dueben, Brown, Thomson, "Combining Modern Learning Pedagogies in Fluid Mechanics and Heat Transfer", *Chemical Engineering Education*, **39**(1), 280 (2005)
4. Aronson, E., Blaney, N., Stephan, C., Sikes, J., and Snapp, M., *The Jigsaw Classroom*, Sage Beverly Hills, CA 1978

CHAPTER SIX

FUTURE DIRECTIONS

This chapter briefly outlines the work that needs to be done and the directions that we currently foresee the project taking.

Assessments

We have submitted multiple grant proposals to the National Science Foundation to fund the further development and dissemination of the CHAPL pedagogy and DLMs. If we receive funding, we have recruited six other universities to serve as both control and beta sites. Since we have lacked opportunity to have a control group for the CHAPL pedagogy, due to only offering only one section of ChE 332 each year, this will allow us to determine if the CHAPL pedagogy leads to increased learning and skills, or if the effects we see are due to something else. There will be some difficulty in this due to differences in the backgrounds of the students, and the curricula of the institutions. Our curriculum uses this course as an 'applied' course that follows a three credit transport theory course. If the control sites use a series of mixed application and theory courses, it will be more difficult to compare some of the results, and will undoubtedly involve significant implementation modifications. Some potential ways around this might be to:

a) Compare results of a single site in its beta phase vs. its control phase.

b) Compare results of agreed upon exam questions after an equivalent amount of subject material. That is, after the students at each site have been exposed to both the theoretical and applied content for a subject.

c) Use learning styles inventories as an approximate measure of similarity between the students at each site.

We also need to refine and validate the critical thinking rubric. Further collaboration with CTLT is necessary, and collaboration with our colleges in education and/or the social sciences would enhance this effort. If possible we would also like to develop rubrics and performance criteria for other outcomes including: teamwork, communication skills, lifelong learning skills, and the ability to take initiative. Each of these rubrics could be part of a focused research question such as:

Do students taught in a manner where they are forced to be responsible for their learning develop a greater ability to take initiative in their learning process and future careers than students taught in a traditional manner?

Do students taught in a manner where they are forced to be responsible for their learning develop more lifelong learning skills and attitudes than students taught in a traditional manner?

Do students taught in a cooperative learning environment, such as CHAPL, develop greater teamworking skills than students taught in a traditional manner?

Do students taught in a cooperative learning environment, such as CHAPL, develop greater inter-group communication skills than students taught in a traditional manner?

We have also neglected a significant body of related literature, namely the field of cognitive psychology. For example, although we were aware of Bloom's Taxonomy we did not make any effort to map students to it, and missed an opportunity to measure their growth.

In addition to utilizing and further developing the assessments we have used to date, we will also use the Thermal and Transport Concept Inventory being developed at Colorado School of Mines [1]. This consists of a series of multiple-choice questions designed to probe for common misconceptions and depth of understanding, similar to the Force Concept Inventory for physics [2].

By including answer choices that make sense from the perspective of a misconception, one can identify and address the misconceptions that students hold. This will enable us to determine whether or not we have succeeded in bringing about a deeper conceptual understanding in our students.

Desktop Learning Modules

The desktop learning modules need refinement. The base unit contains space for two cartridges, however the cartridges are built as mirror-image left or right hand models, and so will only work in one side or the other of the base unit. We need to alter the cross section so that a cartridge will be usable in either side. Further, the current electronics are expensive, and should be replaced with a circuit board created specifically for the task. We also need to look into cheaper ways of producing the DLMs, so that we can eliminate price as a barrier to use of the DLMs. We are looking into having an engineering entrepreneurship class pursue these aspects of the project.

Expansion to Other Courses and Fields

We would like to see the DLMs used to incorporate hands-on learning throughout the Chemical Engineering curriculum. To this end, we plan on designing cartridges to expand the range of concepts that can be explored using the equipment. The areas of Fluid Mechanics, Thermodynamics and Heat Transfer are shared, in varying degrees, with Bioengineering, Civil Engineering, and Mechanical Engineering. We expect that some of the existing cartridges are directly applicable to these other branches of engineering, and that some new cartridges will also need to be developed to emphasis the concepts important or unique to these other fields.

Other Project Outcomes

Since it took five iterations before the CHAPL pedagogy was sufficiently refined that we started receiving positive comments in the end of semester course evaluations, we plan on developing a package of materials to ease the transition to this style of classroom. These materials will include a CD containing student interviews and a role-play of a typical class session, references, problems and solutions, assessment tools, and tips and advice from our experience. We will also develop corresponding student materials.

REFERENCES:

1. Olds, B.M., Streveler, R.A., Miller, R.M., Nelson, M.A., "Preliminary Results from the Development of a Concept Inventory in Thermal and Transport Science", *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition*, Session 3230
2. D. Hestenes, Force Concept Inventory, http://modeling.la.asu.edu/R&E/FCIforw.html, accessed 6/15/06

CHAPTER SEVEN

CONCLUSIONS

The traditional lectures that dominate the engineering curricula are not well suited to building the skills needed by engineers in the modern workplace. They are also ill suited for typical engineering students whose learning styles tend to be more toward the sensing and visual ends of the spectrum. Surveys given to junior level students at WSU confirm the tendency towards sensing and visual learning styles. Research elsewhere has shown that the more students are actively engaged in the classroom experience, the more they will retain. We have presented findings from a recent Fluid Mechanics and Heat Transfer course where small fluid flow and heat transfer modules are present in the classroom.

To study these modules and learn concepts student teams combine several learning pedagogies namely cooperative, hands-on, active and problem based learning or CHAPL as we refer to it. This collective pedagogical approach is effective in engaging the students without sacrificing course content. Interviews with experienced professors not associated with the course bear out that the students have indeed gained the required course knowledge. Surveys asking the students to compare their experience in the CHAPL pedagogy to that in traditional courses show that they are enthusiastic about the pedagogy, feel they learn more, are more interested, and carry the learning methods over to other courses and into industry. This teaching method also gives students an opportunity to learn and practice some of the non-technical personal interaction skills that are vital to success in the modern workforce. An alumni survey also indicates that the CHAPL pedagogy, while not perfect, did more to develop non-technical skills than most traditional courses.

Even though the equipment we used was small relative to industrial equipment, it remains too large and unwieldy to bring into a classroom, and so requires lab space. A promising apparatus to take this pedagogy to any desktop has been developed and is in the process of being tested and refined. This apparatus successfully duplicates the range of experiments done using our larger equipment.

We have developed a pedagogy that shows promise of being an improvement over lectures in terms of aiding students in developing skills key to their future success. This work has been largely exploratory, but with the addition of equipment sized for desktops, is now poised for a rigorous examination and large scale dissemination.

APPENDICES

APPENDIX 1:

1999 DATA AND MATERIALS

APPENDIX 1-A

DRAFT REPORT BY DR. VAN WIE

DRAFT

Assessment Report
Chemical Engineering 332
Spring 1999
Professor Bernie Van Wie

Overview of Project

This research was undertaken to examine the change in student behaviors and performance in a hands-on, group work and activity-based course in Chemical Engineering 332, Fluid Mechanics and Heat Transfer.

General Profile of Students in this Course:

- 18 students participated in this required course.
- 72% were seniors and 22% juniors.
- 13 of the 18 students were transfers from another college or university (72%),
- Mean age is 23.9 with 89% of the student's male.
- 83% of the students were from Caucasian backgrounds with 11% Asian/Americans.

Learning Style Summary

<u>Felder's Learning Style Inventory</u>

(http://www2.ncsu.edu/unity/lockers/users/f/felder/public/ILSdir/ilsweb.html)

- 80% were defined as sensing (12, as opposed to 3 intuitive).
- 60% were defined as thinkers (9, as opposed to 6 feeling).

<u>Keirsey's Temperament Sorter</u> (http://www.keirsey.com/cgi-bin/keirsey/newkts.cgi)

- Student's were split between extroverted and introverted (8 and 7 respectively).
- 80% were defined as judgmental (12, as opposed to 3, perceptive).
- The class was significantly more visual than verbal (14 to 1, Pavio @ 93%. Individual Difference Questionnaire (http://www.ctl.wsu.edu/idq/) was developed by Allan Paivio and Richard Harshman (1983) to measure imaginal and verbal thinking habits and skills. The

verbal factor represents a student's ability to use both spoken and written language and the mean of this class was 25.3 (n=9). The visual factor represents a student's ability to use images to remember, solve problems and imagine described events. The class mean was 39.3. In comparing these means to the overall mean, this class was higher in the use of imagery and lower in the use of verbal abilities.)

Flashlight Survey Results

The Flashlight™ Current Student Inventory was used to assess student's perceptions of the different learning environments. Flashlight is a national evaluative survey item bank with established reliability and validity.

Group/Hands-On Environment:

- 70% of students felt they were better able to remember important facts and understand ideas better using this teaching method (n=10, respectively).
- 92% reported they were better able to visualize the ideas presented in the hands-on lab (n=12).
- 86% agreed they were able to work through the learning process to solve problems using the lab setting (n=12).
- 78% of the students felt that this approach taught them how to work in teams or in a group setting (n=11).
- 84% of students found group-work in this course to be useful for understanding the lectures (n=11).

Lectures:

- Students were split about whether the lectures took less time to understand ideas or remember the facts. They were also split on whether they spent more time studying for lectures.
- 92% of the students disagreed that they had more difficulty paying attention to the lectures (n=13).
- 49% felt the lecture technique was overrated; 49% disagreed (n=7, respectively).

Satisfaction Overall:

- 64% were satisfied with the course (n=9).

Student Perceptions

At the beginning of the semester students reported their perception of cooperative learning. The majority of student's felt this teaching method was beneficial to their learning, as expressed in the following comments:

> "Getting to look at real-life situations (vs. theory) has been helpful."
>
> "It has been very helpful to actually be able to see how some of the things we have learned about take place physically in the real world."
>
> "Well- you really have to think so maybe that's been helpful."

- For most this was their first experience working in groups.
- They felt they would learn more as long as everyone was participating equally.
- Two themes were expressed in the student comments, one concerning group participation and the other regarding grades:

> "I am also concerned about the formation of groups. Some people are happy with C's others want A's and a few seem to just not case as long as they pass."
>
> "I think some type of curve should be implemented if no one is happy with their grades."

“Seems to give good results if everybody in the group is willing to participate and you give it time.”

- Students felt increased credits/meeting time was necessary:

  “It almost needs to meet 3 days a week because it seems like there is a lot of outside work associated with the class.”

  “This is a two-credit class. Two!, not three, not four, two. It is not right to put such time constraints on us. This is a two credit class.”

  “Having more time with our jigsaw group would have been beneficial. We didn’t have enough time to really get the concept down. That way we were all tentative when we presented it to our home groups.”

  “During the first part of the course, there was more time given to interact and discuss the material. Toward the end of the semester, everything seemed accelerated and a bit more difficult to understand.”

- Towards the end of the semester, students often wanted more direction or lectures on a topic.

  “Maybe receiving a little bit more background on all the equipment in the lab before we jump right into working with the equipment.”

- *In general, though students reported frustration with the change in teaching method, they also recognized that the approach as more representative of their future work environment and felt the hands-on portion enhanced their learning.*

  “Sometimes it gets a little frustrating when you spend so much time on the topic and then your ideas or theories of why it happens are wrong. Sometimes the outside resources are confusing or we really don’t know the ?-concept that we are looking for to help us explain the results.”

"I struggle with truly believing something another student tells me without the acknowledgement of the teacher that the student is correct, or being able to prove the student is correct by literature or formulas."

Performance Comparisons

In working with a small sample size and determining minimal differences between student performances on the hands-on/group work versus the lecture work, we split the class into two groups based on their prior cumulative grade point average (WSU GPA at the end of the Fall semester 1998). The high group were those students with a 3.0 and higher GPA and the low group were those students with a 3.0 and lower GPA.

Findings

On the midterm:

- High GPA students, as expected, performed better over all than low GPA students on both the hands-on and the lecture portion.
- Students scored higher on the hands-on portion of the midterm exam for both groups (high and low GPA).
- Low GPA students did better on the hands-on portion than high GPA students did on the lecture portion.

On the final:

- High GPA students, as expected, performed better over all than low GPA students on both the hands on and the lecture portions of both exams, though.
- Both groups performed better on the lectures than on the hands-on portion of the exam.
- Low GPA students performed better on the lecture than did high end students on the hands on.

Over all, the results of the two modes of instruction/examination reverted from the outset to the finish of the course as can be seen in the Figure 2 and 3. Since the majority of the second half of the course was hands-on based, the findings may reflect time on task or recency (all assuming the exams are valid measures of student learning).

In addition, we suspected there were significant intervening variables in the design of the exam. Because of this we isolated the students performance on the final exam based on the two questions they answered and examined them separately. The two constituent questions were categorized with the first question considered a "prepared" question since it was based on exams from previous years that the students had access to. The second question was categorized as "new" reflecting the fact that students had no prior exposure to the questions design indicating a student's ability to apply principles to the new situation. Students, in particular the low GPA group, had a difficult time with this task as represented by their scores (high GPA mean of 60.25 and low GPA mean of 39.0 both out of 75.)

Figure 1 Spring 1999 ChE 332 Performance Comparisons

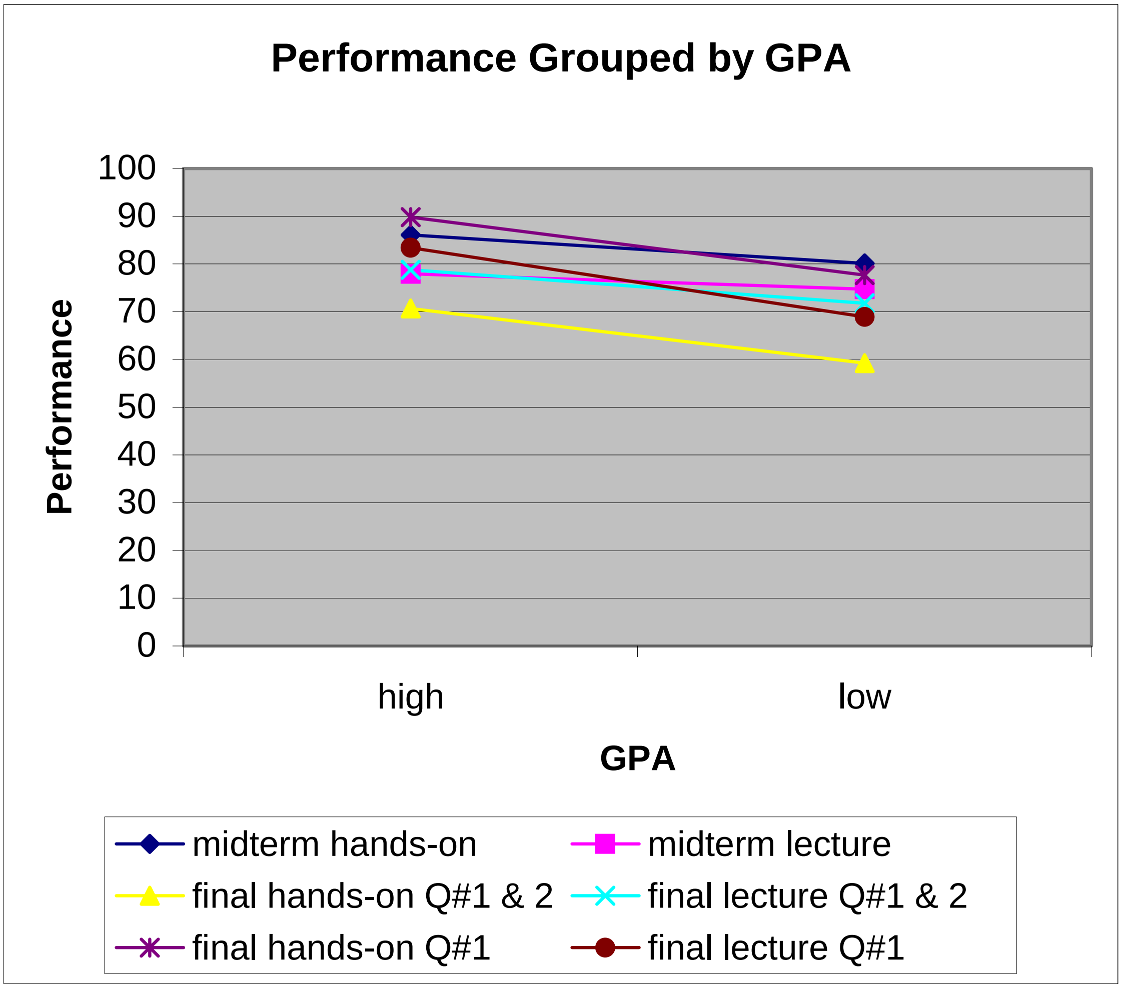


Figure 2 Lecture Performance

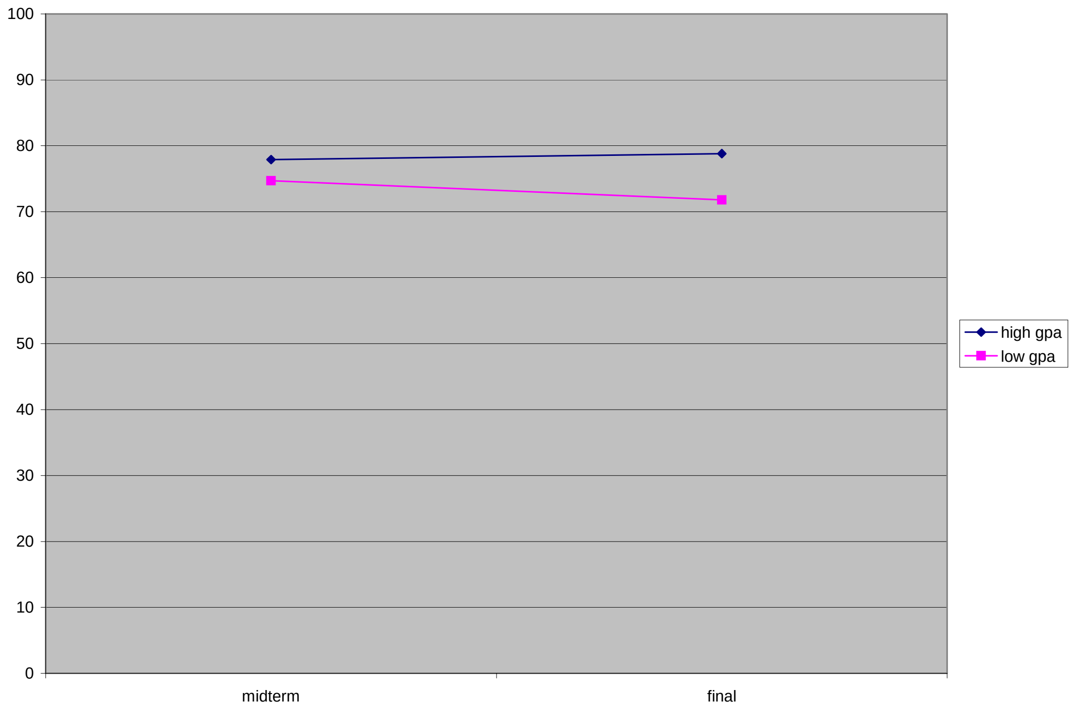
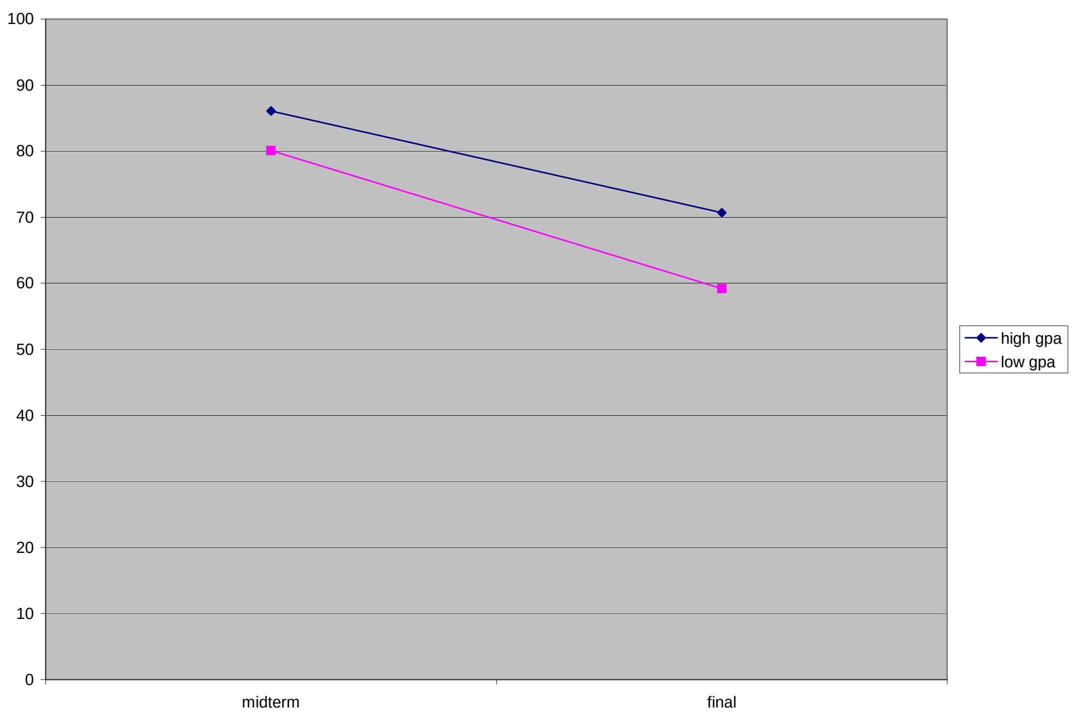


Figure 3 Hands-On Performance



Additional:

- The exam may not have reflected or parsed the discreet skills and content elicited by the different teaching strategies.
- Both groups benefited from the hands-on teaching method, the high GPA students more so and particularly at the end of the semester.

Historical Mean Comparison of ChE 332

Semester	Prior Cum. Class GPA	CHE 332 Class Grade
Spring 1999	2.92	*3.02 (n=18)*
Fall 1997	3.18	2.95 (n=31)
Fall 1993	2.87	2.46 (n=24)
Fall 1992	2.99	2.95 (n=28)

Group Split Comparisons

	High GPA Group	Low GPA Group
SAT Math Score	61.8	53.7
SAT Verbal Score	57.0	43.3
Transfer GPA	3.5	3.1
High School GPA	3.5	3.9 (n=1)
WSU Fall 98 GPA	3.4	2.6
WSU Spring 99 GPA	3.4	2.6
Spring 99 ChemE 334	3.2	2.0*
Spring 99 ChemE 321	3.5	2.4
Spring 99 ChemE 332	3.3	2.5
• Midterm Hands-On	86.1	80.2
• Midterm Lecture	77.9	74.7
• Final Hands-On	79.3	55.2
• Final Lecture	75.1	73.7

In Chemical Engineering 332

- High GPA students were more likely to complete extra credit work.
- Significant differences between the groups were noted on quiz performances.

One aspect of learning style was assessed, active versus reflective learning. A one-way ANOVA was used to determine if significant performance differences existed between active learners and reflective learners. No significant difference was found between the high GPA and low GPA group and their learning style. This information must be kept in context with the small class size and the even smaller number of reflective learners (n=4).

Discussion

The main purpose of this study was to assess students' engagement in different instructional strategies. In addition to observations made during lecture and the hands-on/group work, students learning styles and exam performances were assessed. Learning styles was not a significant predictor of student's performance, due in part to the small class size. The median split based upon student performance on the hands-on portion of the mid-term parallels the median split based upon prior GPA.

A principle educational tenet suggests that students need to be evaluated in ways that are congruent with the mode of instruction. The findings suggest here that the exams may very well have captured valuable information about student learning, but it is problematic the extent to which the exams reflect the learning imparted by the group work.

The perception of student engagement was also an issue. Although a student may display little or no engagement in a topic does not mean they are not reflecting on the issues at hand. More development of the engagement rubric is needed to better understand this phenomenon.

In addition, students commented on their frustration with a new teaching method and displayed concern for grades they did recognize that group work was more representative of their future work environment and felt the hands-on portion enhanced their learning. The skills obtained from the laboratory work were not directly assessed in this course.

Reflections and Implications

It is important to keep the limitations of this study in mind when reviewing the results.

First, for most students this was their first experience in an active learning environment. As students become more comfortable with this environment their perceptions and concerns may change. Many students were concerned with how this type of setting would be graded or affect their grade. Students should also be aware that this type of learning environment is a reflection of their future work environment and have continued encouragement to work in teams.

Second, students liked the course on the one hand but wanted more lecture. This finding is most likely related to student's sense of comfort. Lecture is the format that these students were most comfortable with and knew their own expectations and that of the professors.

Third, student performance based on written exams must be considered with caution. Students were taught in a group/hands-on environment and then were tested in a traditional written format. For future assessment, this type of method would be better tested with a skills or hands-on examination.

The final factor affecting the results is the small sample size of the students (eighteen). Therefore, the results from this study produced interesting findings and should help in future planning of Chemical Engineering 332.

APPENDIX 1-B

1999 DRAFT REPORT FROM PHIL SCUDERI

Draft

Engaging Students in Learning

in

CE 332 – Fluid Mechanics and Heat Transfer

First Year Report

Observations and Evaluation of First Year Goals

Phil Scuderi

September 6, 1999

There has been much interest in student-centered teaching methods as an organizing approach to facilitate student engagement in learning. This project is a multi-year study of a student-centered teaching design which emphasizes student engagement and student responsibility for learning. The hypothesis for this study is that learning will be improved if students are required to make their own meaning of course content and if instructors have as their primary function the mediation of student thinking rather than transferring information.

Emphasis for the first year of the project centered on issues of course design and implementation, and first year start up issues including instructor orientation to the new pedagogy and equipment and labor costs. In the second year of the project some adjustments will be made to the course design but the central focus will center on the hypothetical question and the ongoing costs of the pedagogical approach. This report details the first year's observations and evaluation of first year goals.

Specifically the goals for the first year of the study were to design and implement a learning environment within which:

1. the responsibility for the learning is clearly fixed with the students
2. the level of student engagement with course content is very high
3. the instructor can readily use his expertise to mediate with regards to the meaning students are assigning to the concepts and concept relationships present within the study domain.

The purpose of this report is to review and assess progress toward first year goals and to surface recommendations for the second year of the study that arise out of the first year experience. The report is divided into three sections; study context, course observations, evaluation of first year goals, and underlying assumptions and conceptual framework.

Study Context

The context for the study is a junior level two credit course in Fluid Mechanics and Heat Transfer offered by the Chemical Engineering Department at Washington State University. One section of the course is offered each Spring term serving 15 to 20 students. Previously the course had been taught with a traditional lecture approach. The first year study team was comprised of the course instructor Professor Bernie VanWie of the Department of Chemical Engineering, and Gary Brown, Lori Leveleth and Phil Scuderi of the WSU Center for Teaching, Learning and Technology. Planning for the study began during the Summer of 1998 with initial implementation during the Spring 1999 offering of the course. The project will continue through the Spring 2000 course offering. I and my colleagues in the Center for Teaching, Learning and Technology also collaborated with Professor VanWie on issues of course design. I attended most of the lab and lecture sessions as an observer.

The course naturally divides itself into two topics–fluid mechanics and heat transfer. The semester was divided into two 8 week periods. During the first 8 week period students studied fluid mechanics. In the second 8 week period the focus of the students' study was heat transfer. Each 8 week period was further divided into two four week segments. During the first 4 week segment of each 8 week period class meetings were conducted in a laboratory where the students conducted self-regulated experiments. During the second 4 week segment of each 8 week period class meetings were conducted in a traditional classroom with a lecture format. The two 4 week lab segments constituted the student-centered portion of the course design.

Course Observations

The observations section of this report is divided into four subparts each dealing with what appeared to be a distinct phase of course and student related activity:

1. Course Introduction
2. Orientation to Laboratory Research
3. Student Researchers Taking Command of the Laboratory
4. Return to Classroom Lecture.

Phase I– Course Introduction

On the first day of class students met with the instructor in a laboratory. The students were assigned to four teams of 4 to 5 students each. The laboratory was equipped with eight workstations. Four workstations were equipped with gravity fed manometers–a device for measuring the drop in fluid pressure as fluid flows through a length of pipe. Four other workstations (to be used during the second 4 week lab segment) were equipped with heat transfer devices. Each workstation was also equipped with a whiteboard.

The instructor began by providing a general explanation of how the course would proceed and gave assignments for the fluid mechanics portion of the course. He told the students that they would work in teams and that each team would be making extensive use of the laboratory workstations to complete their course of study. Two types of teams were employed. Students were assigned to "home teams" within which most laboratory activities would take place. Additionally, each student was assigned to one of four "jigsaw teams". The jigsaw teams were comprised of 4 to 5 students with representation from each home team. Each jigsaw team was assigned to collaboratively study (outside the time scheduled for the class meeting) a different topic. The students were informed that after the jigsaw teams completed their study the members would be required to "teach" the topic they had studied to their home team members.

The instructor proceeded to discuss the course requirements. He told the students that they would be developing two systems of thinking–fluid mechanics and heat transfer. He gave the students a list of terms representing the language symbols for the study domain's concepts, and explained that an understanding of the concepts was central to the study of fluid mechanics. He informed them that the concepts represented key aspects of a dynamic fluid system and that they would not only learn the definition of each concept but would also be required to develop a deep understanding of the concepts and concept relationships. More specifically, they were to demonstrate that they could identify manifestations of each concept within the laboratory workstations. He gave them a general mathematical equation which modeled the system under study and told them they would be required to identify where each term of the mathematical model was represented in the observed phenomena as they manipulated the workstations. He further informed the students that they would be required to develop mathematical designs of fluid systems that would operate within specified criteria.

He told them there would be very little lecture during the lab segments of the course and that all the reference books, papers, etc. that they would need to support their study were available in a cabinet in the laboratory. He further informed them that for the most part they would need to rely on these materials and their own individual and group thinking. He gave them a brief introduction to their team workstations and instructed them to begin.

Phase 2 – Orientation to Laboratory Research

The laboratory work orientation phase began on the second day of class. Initially as each team of students approached their workstation there was little discussion. I inferred from their body language a kind of what do we do now question. They were clearly not accustomed to this kind of self-regulated study. However, after a short while and without any additional direction from the instructor they began to examine and work with the manometer.

I noted that the students gave no evidence of thinking aimed at establishing a systematic experimental approach. There was no analysis aimed at determining specifically what issues needed to be addressed. There wasn't any discussion of specifically what questions related to fluid dynamics a manometer could answer. There was no systematic questioning of how the device could be manipulated nor did I observe an effort to identify specific experiments to be undertaken. What they were doing generally appeared to be a kind of random exploration and orientation. At times students could be observed asking the instructor to provide specific directions. Questions of the type, "What do you want us to do?" were typical. The essence of the response from the instructor was, "I want you to learn fluid mechanics". In general the instructor redirected them to rely on; their own and each other's thinking, the lab instrumentation, and the provided reference materials.

During the second four week laboratory segment on heat transfer (weeks 8 through 12) I observed little to no improvement in their recognition that an initial analysis of the problem and the laboratory instrumentation could contribute to the development of a systematic and orderly approach that would improve the quality of their work and save time. In general, they continued to exhibit a kind of random reactive rather than planned approach. (It is important to note that at no time during this course did the instructor direct the students to be systematic in their laboratory activities. During the Spring 2000 offering we plan to provide more direction for the students regarding the need for analysis and planning.)

Phase 3 – Student Researchers Taking Command of the Laboratory

Throughout the laboratory segment the level of course related discussion was very high. Nearly every member of every team was actively engaged in relevant discussion. There were a few students who maintained a predominantly peripheral position relative to the group interaction. The students who were actively engaged could be seen manipulating the manometer (changing the length of the pipe between the manometer taps, adding a pump, etc.), pointing to and discussing various aspects of the systems in action, paging through the reference materials, and addressing questions to each other. I observed them in the process of developing, challenging, and testing explanations. They used the whiteboards to facilitate their discussion by drawing diagrammatic models of the system under study. While the students on the periphery were not as actively engaged as the others they did appear to be intently paying attention.

The instructor could be seen engaged in discussion with the teams or walking around the lab observing student activity. In response to student questions, the instructor would generally respond with a question back to the group, direct students to the reference materials in the cabinet, or engage the students in a short discussion. On one occasion the instructor expressed some concern that he felt at times he may be giving the students more direction than he should.

In general students struggled in varying degrees with the mathematics. From their discussion it appeared that they viewed the challenge of utilizing the mathematics as being one of finding the "right" equation that would accept available data. Their sense of the mathematics appeared to be limited to mathematical equations as machines rather than models of phenomena being studied. (Note: The assignment in the course to identify where each term of the mathematical model was represented in the observed phenomena is intended to address this issue.)

During the third week of each lab segment students "taught" to their home team members the concepts that had been assigned to their jigsaw team. What I observed was something that looked very much like traditional lecture. Each student presented their understanding of the topic they had studied. While the "student teacher" spoke the other students took notes and asked very few questions. There was very little effort on the listeners' part to confirm their understanding of the material presented by the student teacher.

Since the level and meaning of student engagement is important to this study I took special note of some students whose level of engagement in group activities was quite low.

Phase 4 – Return to Classroom Lecture

All together I observed 10 lecture sessions. The classroom was configured with whiteboards at the front, a table for instructor materials, and rows of moveable tablet arm chairs facing the front of the room. The physical layout of the classroom was such that I was able to position myself in a chair on one side of the room where I had at least a profile view of every student.

The instructor's style tended to be to give relatively short lectures (about 15 minutes) after which he engaged the students in discussion. From one session to the next it was generally the same students who attempted to answer instructor initiated questions. At times the instructor directed questions to specific students thus ensuring that all the students were called on from time-to-time.

The lecture discussion tended to deal with two topics–discussion directly related to the course content, and discussion related to scores on tests and quizzes. I kept counts of the level of engagement in the lecture classes related to course content. The number of students present during the lectures ranged from 16 to 18. Both the instructor and students directed questions to each other. The instructor would start questioning on a specific lecture topic with a lead question. If there was no answer or an incorrect answer was offered in response to the lead question the instructor would often ask one or more secondary questions which were either a rephrasing of the lead question or more specific questions on the same topic. I kept counts of lead but not secondary questions. The instructor initiated a mean average of 8.6 lead questions per lecture session.

The mean number of student initiated questions during the observed lectures was 6. Out of the 16 to 18 students in attendance the mean number of students who asked questions was 5.3 each class period. Of the 5.3 students who initiated the six questions three of the questions were asked by the same three students each period while the other 2.3 questions were generally divided among five other students. During any given class period slightly more than 70% of the students did not ask any questions. Occasionally I observed a student exhibiting a kind of non-focused stare, but for the most part students appeared to be paying attention to the lecture (based on observations of things like head movement following the lecturer).

Miscellaneous Observations

Observations of the Review of Examination Results

During one lecture session the instructor went over the results of one of the course exams. He had previously returned the graded exams to the students. The instructor indicated that the average grade on the exam was a B. He reviewed each question on the exam. The review procedure for each exam question provided students an opportunity to review, to reflect, to question, and to correct misconceptions. For each exam question the instructor:

1. Transferred the diagram of the exam problem to the whiteboard.
2. Gave a short lecture on relevant aspects of the problem.
3. Transferred one or more student solution to the board (Each was representative of conceptual problems the students were having.).
4. Relating to the student solution he asked the students if they could see what was in error?
5. He discussed how he approached the problem.

6. He solved the problem.

I observed relatively little response from the students. Those who engaged this discussion were the same few students who were actively engaged in the regular lecture sessions. Overall student responses appeared to be either indifferent or defensive. One student commented, "There was no way we could have known that."

Observations of a Team Quiz

During another lecture session the students were given an open book quiz. The instructor directed them to work on the quiz in their teams. The approach each team took varied. Immediately two of the four Team1 students could be observed actively collaborating. They first discussed their understanding of the quiz question and then began to develop a response. The other two students on this team worked alone.

Initially each of the Team 2 students worked the problem independently. After they had completed working independently they compared answers and for a while had a very active discussion affirming similarities and resolving differences in their work.

All four of the Team 3 students began right off in a collaborative mode. They actively questioned the requirements of the assignment and I could hear them questioning and challenging each other's understanding of relevant course concepts.

The Team 4 students began the process as a low level collaboration with a few questions and mostly what appeared to be individual reflection. However, as time went on the level of interaction picked up. By the end of the time that was allotted for the quiz the students on this team were very actively engaged with each other.

The level of individual engagement on the subject matter during this session was much higher than in other lecture sessions and gave the appearance of being essentially the same as in the lab setting.

Observed Student Response to Teamwork Presentation

During one of the lecture session I gave a presentation on teams and team dynamics. During the discussion that followed one student commented,

> “I really like the idea that to be successful the members of a team need to have a shared purpose and a strong belief that the purpose is valuable. But on many of the student teams I am on the purpose for some of the students is learning while for others the purpose is just to get an adequate grade."

Evaluation of First Year Goals

As previously sated the goals for the first year of the study were to design and implement a learning environment within which;

1. the responsibility for the learning is clearly fixed with the students
2. the level of student engagement with course content is very high
3. the instructor can readily use his expertise to mediate with regards to the meaning students are assigning to the concepts and concept relationships present within the study domain.

Goal 1: Fix the Responsibility for the Learning with the Students

As defined in this study’s conceptual framework the responsibility for learning is clearly fixed with students in situations where there is no instructor or when instructors’ teaching behaviors are consistently in support of the idea that learners must make a significant personal investment in learning. Was the course implementation successful with regards to achieving this goal? From an empirical perspective this question can be answered by addressing the following question, Were the observed student and instructor behaviors consistent with what we would expect as described in the conceptual framework?

As observed during the two four week lab segments the instructor's response to student questions was, in general, to answer student questions with probing questions or to direct the students to rely on their team members and/or the reference materials provided in the laboratory. Under these conditions the students have no choice but to depend on their own thinking. A key aspect of the nature of the thinking students must do under these conditions is that they must each establish a reasoned interconnected system of thinking in order to have the necessary confidence to trust that they will do well on the course exams. In contrast if the role of the teacher is seen as providing answers students can replace the learning process of developing interconnected systems of thinking by a process of getting good at determining what questions will be on the test and by getting the course authority, the instructor, on record regarding the answers to the questions that will most likely be on the test.

Goal 2: Achieve a High Level of Student Engagement with Course Content

From the observations it was clear that a high level of student engagement was achieved in the lab setting. During the lab session most of the students were in continuous dialog with each other on course related topics, working collaboratively with the lab instruments, writing and comparing notes at the whiteboard, or could be observed referencing and discussing the course materials that were available in the lab. There was a small number of students in the lab setting who while apparently paying close attention to the team discussion did not often directly engage in the group activity. Two of these students appeared to do as well or better than the more directly engaged students when it was their turn to "teach" their jigsaw topic. It seems reasonable to speculate that these students may be representative of a type of thinker who would do well in a traditional lecture setting.

Student engagement was lowest in the lecture setting. During these times most students did not engage in questions or discussion with the instructor unless specifically called on to do so by the instructor. There was one "lecture" session in which the instructor assigned the student teams to work collaboratively. During this period the level of student engagement approached that which was observed in the lab setting.

Goal 3: Achieve an Environment In Which the Instructor Can Readily Use His Expertise to Mediate Student Learning

Given the continuous "public" nature of the student discussion observed in the lab sessions the instructor clearly had the opportunity to continuously "observe" the quality of student thinking and to determine if he needed to mediate in some manner to help them with their conceptualization. Such opportunities would occur in a real-time manner when the teaching/learning moment was ripe. Moreover, because of the multi-dimensional nature of the laboratory setting–real time access to a comprehensive set of reference materials, concrete laboratory instrumentation, and student collaborative thinking–the instructor was afforded the opportunity to select form a wide range mediating responses.

Underlying Assumptions and Conceptual Framework

The key assumptions underlying this study are:

1. Learning involves the process of internalizing relatively permanent systems of thinking which are developed in terms of the concepts, concept relationships and

contextual relationships and parameters observed in the phenomena to be observed in a domain of study.

2. For significant connected learning to take place students must be engaged in meaning making dialog with course materials. Making meaning of the course material is facilitated by active dialog.
3. For significant learning to take place the responsibility for constructing the desired systems of thinking must be assumed by the learner.
4. The quality of learning is significantly enhanced when teachers minimize the amount of time talking to the students and maximize the amount of time listening to and mediating the meaning students are making of the situations under study.

These assumptions deal with learning, engagement in learning, taking responsibility for learning and the mediation of meaning-making. The following is an elaboration of the current thinking on each of these ideas and as such is intended to be seen as a conceptual framework for this study.

Learning

As a noun learning is the occurrence of relatively permanent change to internally held systems of thinking. The changes might be the development of new internalized systems of thinking or the refinement and/or correction of previously internalized systems of thinking.

A system of thinking is a well elaborated and interconnected internal representation of an external situation. Systems of thinking are comprised of the elaborated and interrelated meanings assigned to the concepts which are observed in and abstracted from the external situations that they are used to both describe and explain. Accordingly, on one level a system of thinking equips the learner with both descriptive and explanatory power (and depending on the nature of the situation may also equip the learner with predictive power over future occurrences of the situation). Systems of thinking may be elaborated on a second level with internally represented situation transforms. (A situation transform can be seen as an intervention strategy for changing or influencing the process and/or process outcomes of external situations.)

It is important to emphasize this type of learning involves much more than the internalization of simple concept definitions. Rather it involves a significant effort in terms of concept elaboration. The goal of learning is to assign to the concept symbols which represent the salient objects and patterns observed within the problem domain the full range of qualitative and quantitative variance in meaning and relationships observed in the relevant phenomena as the situation context or contextual parameters change.

The process of developing a system of thinking is inherently and unavoidably reflective and iterative since relevant concepts achieve their meaning in terms of each other and in terms of the various contextual settings within which relevant phenomena are observed. The quality of the meaning that a person can assigned to any specific concept symbol is directly related to the current quality of the meaning they have assigned to the other concepts in the problem domain. As the quality of the meaning assigned to any specific concept changes the learner is afforded a new perspective on related concepts. To make matters more complex we use previously developed "secondary" concepts to elaborate new concepts. Consequently, the question of the meaning learners have assigned to previously developed concepts is also at issue.

The implication is clear. While an expert teacher may be able to mediate with regards to the meaning a learner is assigning to concepts it is not reasonable to think that the expert can package and convey to the novice student within a matter of a few short weeks the extensively elaborated meaning he/she has developed over years of study and reflection. It follows then that the primary goal of teaching must be to influence the learner as necessary to achieve a high level of active self-regulated engagement in that which is to be learned.

Engagement in Active Learning

What is engagement in active learning? To be engaged is to be engrossed in one's work. To be engrossed is to have one's attention fully occupied. We want students to be fully engaged in active learning and instructors to be fully engaged in mediating the meaning student are assigning to the phenomena within the study domain.

The specific engagement we are interested is that which leads to well elaborated systems of thinking within our students' domains of study. To be engaged in the study of a particular domain is to be fully occupied in the activity of personally constructing, elaborating and testing systems of thinking within the domain.

What does engagement in active learning look like? Students who are engaged in active learning are involved in a critical thinking dialog. In general, a critical thinking dialog can be recognized as a continuous cycle of observation, description and explanation followed by probing questions, tested answers and thinking refinement leading to more questions and observations and further refinement of prior descriptions and explanations. The goal is to for students to identify and internalize what they need to know to reach a level of self-regulated confidence that the quality of their thinking is at least adequate to meet relevant objectives (whether the objectives be related to a course examination or the development of a new engineering design).

More specifically, if you could hear engaged students thinking (which is the case if they are actively working in groups in your classroom) you would hear their descriptions and explanations of the phenomena under study. In response to one student's explanation you may observe another student offer a competing or elaborating explanation. Students would be heard asking for clarification and for supporting evidence and reasoning. They would seek to identify, articulate and assess underlying assumptions. Many of the questions would be of the "what if" variety intended to test aspects of each other's explanations. They would express an understanding of the tentative nature of reasoned propositions by asking "How could we test the accuracy of that proposition?" possibly leading to an experimental design. It is our assumption that if we achieve higher levels of engagement students learning will be improved.

It is important to note that this type of learning can be very taxing especially for students who are not accustom to the effort. Because students find active learning to be taxing many will not sustain the effort if the teacher assumes the role of the person who will answer their questions. (See Taking Responsibility for Learning)

Taking Responsibility for Learning

It is often said, generally as a lament, "Students need to take responsibility for their learning." But what does it mean to fix the responsibility for learning with students and what does owning the responsibility look like? I would argue that the responsibility for learning is clearly fixed with students in two situations. In the first situation it is absolutely clear that most people will take responsibility for their own learning when they need an answer and when there is no other person to turn to for the answer. In the second situation, in which an instructor is available, a person will also take responsibility for his/her own learning if the instructors' teaching behaviors are congruent with the idea that learners have to think through that which is to be learned for themselves (see Learning). Maybe the single most important aspect of the meaning of taking responsibility for one's learning is that it requires one to judge the quality of one's own thinking in order to achieve the necessary level of confidence to proceed.

From the perspective of an observer the teacher would generally not be available as the person with the answers. All the "answers" needed for the course would be in a comprehensive set of course relevant materials provided by the instructor. Rather than being the person with the answers the teacher would cast his/her expertise in the role of mediating with regards to the meaning students are constructing (see Learning mediation). The observer would recognize student activity as engagement in active learning. At the same time the teacher would be seen observing and listening to the students and would be continuously assessing the quality of their thinking. At times the observer would notice the instructor taking the initiative to interrupt the students with a suggestion that they specifically reconsider the meaning of some specific aspect of the study domain. And when students would ask questions of the teacher the observer would notice that the teacher would seldom provide direct answers to student questions. Instead the teacher's typical response would be to answer student questions with probing questions of his/her own, or direct the students' attention to specific relevant material, or simply suggest that they recommit themselves to their observations.

If the responsibility for learning is successfully fixed with the students you would hear them testing their understanding of the study domain by asking question about the meaning of relevant concepts and concept relationships. They would be offering each other their best descriptions and explanations of the study domain learning to consider relevant contexts and contextual variance. They would be asking each other to identify and share additional perspectives that would serve to affirm or challenge their thinking and provide further clarification. Within their domains of study student behavior would communicate that they have committed themselves to stretch their understanding to the bounds of relevancy, looking for new perspectives that will either affirm or challenge their thinking. In time they would learn to hold tenaciously to a view that there is yet; a better description, a better explanation, and a clearer, deeper and broader understanding to be had.

Engagement in Active Learning Mediation

I see the primary role of the expert teacher as being the mediator of the meaning students are assigning to the problem domains being studied. Specifically, given the complex nature of meaning-making the most effective role for the expert teacher is to;

1. Condition the teacher-student relationship so as to minimize the teacher's traditional role as the grader, the person who holds the only important answers–the answers to the test questions.
2. Provide the students (directly or indirectly) with a set of comprehensive course related materials.
3. Condition the classroom so as to maximize the number of occasions students have to express the state of their thinking.
4. Mediate student meaning-making by asking students to further elaborate and or correct their systems of thinking by directing them to consider and explain specific aspects of the domain of study as represented in the course materials provided.

An observer would notice that the teacher has cast his or herself in the role of expert mediator of student thinking. The teacher will have provided his/her students with all the reference materials they will need to satisfy course requirements. By doing so the teacher has removed his/herself form the position of being the person who will ultimately reveal the questions and answers for the tests. Under these conditions it becomes clear to the student that they are responsible for learning.

The observer would note that the teacher does not assign students the task of learning the fine grained concepts of the study domain. Instead students are assigned the task of learning the systems of thinking which are significant within the discipline and which inherently require that students learn the fine grained concepts in relationship to each other.

The teacher is not lecturing. Instead the teacher is continuously observing the development of student thinking as the students work on their assignments and when appropriate asks relevant questions or offers the students timely expert advice such as directing students to sources of relevant information. Over time it becomes apparent the teachers focus is on formative assessment and he or she avoids summative grading until the end of the term.

The shift in responsibility for learning from the teacher to the student is operationalized when the teacher changes the student-teacher relationship by refusing to be the authoritative source of the "correct" answers to the test questions. This critical shift in student-teacher relationship is compromised if the students and teachers see the teacher's role as providing the answers. Symptomatic of a compromised student-teacher relationship and of student behaviors that avoid the necessary process of meaning-making are questions of the type, "Do we need to know this?", "What will be on the test?" and "What do you want from us?" I have on more than one occasion had students inform me that, "We don't pay you to make us learn we pay you to teach us." Questions and comments such as these are clear signals that students have not taken the responsibility to develop the desired elaborated systems of thinking but rather are expecting the teacher to provide shortcuts (that is provide the answers) in place of the necessary thinking and desired meaning-making which leads to systems of thinking.

APPENDIX 1-C

1999 STUDENT COMMENTS

Below is a list of student comments (anonymous) in response to a question on their perspective on the "Cooperative Hands-On Learning" aspect of the course.

Positive comments = **bold**; Negative comments = *italics*	
1.	**I believe discussing a topic improves one's ability to understand it. The cooperative hands-on [experiences] provided that forum.**
2.	*I learn very little from hands-on learning. I think teachers are often concerned with making their techniques look good to other people rather than with how their students learn.*
3.	There needs to be *compromise* of teacher leading students through projects and leaving them totally learning on their own.
4.	**I like group problem solving and experiencing different ways to look at a problem.**
5.	*The instructor had the ability to teach as well as anybody in this university, but he spent too much time trying to have us learn the material on our own.*
6.	*I would have liked more guidance on the projects,* **but maybe it helped me think more on my own when the teacher said, "What do you think?"**
7.	**The cooperative approach to problem solving helped me gather different views and learn the material in a variety of different ways.**
8.	*I'm not sure I got much out of the hand-on learning.* **I think it might have helped some members of my group, though.**
9.	**The cooperative hands-on problem solving really helped me along with my group to be able to physically understand what was taking place in our mathematical models.**
10.	*A more traditional teaching style may have worked better* **under the constraints of class time.**
11.	*I want less cooperative group work. I did more work for this class than I did for my other classes. We don't have time to sort through countless books looking for information we know or don't know has any relevance.*
12.	**I got a chance to speculate during the cooperative group work and to develop instincts about what should happen.**
13.	**The most helpful thing in this class was the fact that you had to do everything yourself--there was no "spoon-feeding"--that way I learned a lot.**
14.	*I think the instructor needs to find a way of knowing that all members of the group are participating...It's unfair to have only some people always do the work and those that aren't working get the grade too!!*
15.	**I thought the instruction was good. This type of course really put the responsibility of learning on the student. The peer pressure of the group probably motivated more people to study. But, I think if one motivated student got stuck in a group of 3 non-motivated students, it could make for a long semester.**
16.	*The instructor expected way too much, and the lectures never preceded the lab. I need exposure to information before the lab.*

APPENDIX 1-D: ENGAGEMENT RUBRIC

RATING STUDENT ENGAGEMENT

Rating Student Engagement

Draft

The Engagement Rubric is designed to gauge two things; the level of student engagement in learning, and the relationship of instructional strategies that correspond to student engagement.

Explanation

What is engagement? To be engaged is to be engrossed in one's work. To be engrossed is to have one's attention fully occupied. We want students to be engaged in learning and instructors to facilitate student engagement.

The specific engagement we are interested in is an engagement in learning that leads to deep understanding within a particular domain of study. To be engaged in the study of a particular domain is to be fully occupied in the activity of constructing and testing personal explanations of the phenomena within the domain of study. Student explanations must be in terms of the domain's conceptual framework[2] and the relationships among the concepts. In turn the relationships among the concepts are to be supported. Stated in slightly different terms deep learning necessarily includes both an understanding of a study domain's conceptual framework

---

[2] A conceptual framework is the set of key concepts pertaining to a discipline or area of study for which there are agreed upon definitions.

and an internalized explanation of the domain's phenomena expressed in terms of its concepts and concept relationships.

What does it mean for an instructor to be engaging? Instructors are engaging to the extent that their teaching behaviors encourage students to strive to achieve a deep understanding of a domain of study.

Description

What does engagement in learning look like? Students who are engaged in deep learning are involved in a critical thinking dialog. In general, a critical thinking dialog can be recognized as a continuous cycle of observation[3] and explanation followed by probing questions and tested answers leading to more observations and further refinement of the prior explanation.

More specifically, students will be overheard explaining to each other the phenomena under study. In response to one student's explanation you may observe another student offer a competing or elaborating explanation. Students will be heard asking for clarification and for supporting evidence and reasoning. They will seek to identify, articulate and assess underlying assumptions. Many of the questions will be of the "what if" variety intended to test aspects of each other's explanations. They will express an understanding of the tentative nature of reasoned propositions by asking "How could we test the validity of that proposition?" possibly leading to an experimental design.

[3] In this context observation is to be understood as to include information obtained from reading, listening and actual observation.

Scoring Form

Facilitating Engagement Scoring Form

Class or Group ________________

Rater	Activity
Group	Assignment Description (uniform/unique)

Dominion	
Discourse Characteristics	
Reflection	

Comments		
	Total	Mean Total

Facilitating Student Engagement

1) Dominion & distribution of participation

Scant	Substantial
The instructor dominates the discussion as evidenced by duration and control of topic.	The facilitator encourages discussion within the parameter of the discipline, but students share equally in the quantity of talk.
Questions are fast-paced with game show quality. Students have little time to consider.	Students have time to reflect and consider. The facilitator and students appear to be comfortable with silence.
Instructor controls who speaks and when. Students raise hands. Often relatively few students volunteer.	Students participate broadly, actively, and freely in the discussion. The discussion is NOT characterized by the raising of hands
The instructor dominates the discussion as evidenced by proxemic relationship, standing in front of students or sitting on table of desk above students.	The facilitator sits with students in groups or in class.
Student attention is focused primarily on instructor.	Students question and respond to each other directly.
Students are unprepared, have not done reading or thinking about material.	Students have done the reading and there is evidence of significant effort thinking about the material.

2) Discourse & rhetorical characteristics (ownership)

Scant	Substantial
Faculty questions are rhetorical, the instructor clearly holds the answer (hostage). Questions tend to be dichotomous.	Questions are authentic, open-ended rather than yes no. Student opinions are encouraged. Facilitator admits openly that he/she doesn't know everything, and demonstrates process of finding answers.
Faculty clearly holds agenda; coverage of material dominates pace rather than student comprehension of content.	Facilitator is clearly observing and adapting to student progress with material.
Questions of fact	Questions of point and principle
"Correct responses" are rewarded and cap discussion.	Facilitator challenges students to consider implications or to make generalizations, often into other discourse domains. The ability to make reasonable generalizations is essential for higher order thinking.

3) Fostering reflection

Scant — **Substantial**

Students appear to be motivated to please the "teacher" by being in agreement.	Students frequently and comfortably disagree with each other and instructor.
	Students explain what they understand and how they understand the issue, question or task (even if it seems redundant).
Instructor gives students "the answer"	Facilitators respond to questions with real questions, suggestions for further investigation, or may say, "I don't know."
Instructor changes the subject frequently without making a clear and explicit transition or connection to the topic on the table.	Discussion delves into a single topic for considerable time. Topic changes are characterized by clear transitions or connections to the topic on the table.
Instructor accepts students' opinions at face value.	Facilitators do not accept students' opinions at ***face value*** as if they were researched or well thought out positions, no matter how good they sound. Facilitator challenges students to consider and explain positions.
Instructor dismisses student opinions as irrelevant or incorrect.	Facilitators do not give the impression that something is unimportant

Student Engagement In Groupwork
Scoring Form

Class or Group __________________

Rater	Activity
Group	Assignment Description (uniform/unique)
	Score each of the following using a range from 1 (scant) to 6 (substantial)
Dominion	
--Participation	
--Respectful	
--Ethics	
--Preparation	
Discourse Characteristics	
--Concepts & principles	
--Focus	
Reflection	
--Question or challenge	
--Implications	
--Revision	
Content	
--key facts	
--distinguish between fact, opinion	
--conceptual understanding	
--questioning evidence	
--scope & context	
--critical	
--assumptions & ethics	
--implications & conclusions	
--presentation	
Comments	
	Total Mean Total

Assessing Student Engagement Online

April 1999

1) Dominion & distribution of participation

Scant **Substantial**

1 2 3 4 5 6

One or two outspoken students dominate the group discussion	Students **participate** and share equally in the quantity of talk and participate broadly, actively, and freely in the discussion.
Leaders dismiss others' opinions as irrelevant or incorrect.	Groupwork is **respectful.** Does not give the impression that something is unimportant.
Students hitch-hike, letting leaders do work but taking credit for that work. There is other evidence of unethical behavior.	Students distribute responsibility and credit for group work fairly and **ethically**.
Students are unprepared, have not done reading or thinking about material.	Students have done the reading and there is evidence of **significant effort** thinking about the material, including enthusiasm for pursuing research.

2) Discourse & rhetorical characteristics

Scant **Substantial**

1 2 3 4 5 6

Group discussion is perfunctory. Questions tend to be dichotomous and fact-based. The notion of a "correct" response caps discussion. Unknown but necessary information is dismissed.	Questions are authentic, often open-ended, pointed toward **concepts and principles**.
Students change the subject frequently, often off topic, or without making a clear and explicit transition or connection to the topic or task on the table.	Discussion **focuses** on the topic for considerable time. Topic changes are characterized by clear transitions, extensions or connections to related material.

3) Reflection

Scant **Substantial**

1 2 3 4 5 6

Students are reluctant to disagree with others in the group, particularly with group leaders.	Students in the group **question** or ***challenge*** each other to explain what they understand and how they understand the issue, question, or task.
Coverage of material and problem minimization determines pace rather than the group's comprehension of content.	Group is clearly observing and adapting their understanding of the material. Narratives are shared to explore ideas, concepts, positions. **Implications** of material are explored. Group is comfortable with thoughtful silence.
Students do not consider alternatives; they do not alter views during the discussion or experiment.	Students question and **revise** their thinking/project, experiment.

4) Content Accuracy and Critical Thinking

Scant			**Substantial**		
1	2	3	4	5	6

Content is limited to a few facts, is sketchy, or is represented inaccurately.	The discussion reflects a solid grasp of the **key facts**.
No distinction between fact, opinion and value judgments.	Clearly **distinguish between fact, opinion**, & value judgments.
No evidence of conceptual understanding or inter-relationships between facts.	Students engage in discussion of the **concepts** as well as the facts. Evidence reveals a summative progression of facts to concepts, or concepts are increasingly fleshed out with facts.
Students do not support points with evidence, or evidence is incomplete or inaccurate.	Students make points by bringing solid evidence or by **questioning evidence** that is provided.
No evidence that problem has connections to other, larger contexts of the discipline or beyond.	Clear evidence of the issue's or problem's **scope and context**, including a general assessment of the audience, purpose and potential of the task.
Mere repetition of information previously provided, taken as absolute truth. No consideration of alternate possibilities.	Examines the information provided previously **critically**, questioning its accuracy, precision, relevance, completeness, differences between theory and application. Consider sources of information.
Do not surface the assumptions which underlie the issue or task, or do so superficially.	Identify key **assumptions** that underlie the issue or task, and assess the assumptions to explore their validity.
Fail to identify conclusions or the implications of the issue, and/or fail to identify and assess the key logical relationships between the conclusions, implications and key contextual factors, assumptions, data and evidence previously presented.	Identify and logically discuss conclusions and/or **implications**, contextual factors, assumptions, data, and evidence. Students may also turn a critical eye on conclusions and implications of their own assertions.
Presentation of the results is superficial, careless, often in error.	Comprehensive, polished and creative **presentation** of results.

The Holistic Individual Ranking Reinterpretation

Low

Little or no observable evidence of engagement with *material or other students*

Superficial questions

Low-Medium

Evidence of considering the material inferred from high quality (but few) questions

Engagement off to side with course content

High-Medium

Many content related questions

High

Content related questions, confidence, leadership

Scoring Form

Facilitating Engagement Scoring Form

Class or Group Feb 3 Group 2

Rater PVS	Activity
Group	Assignment Description (uniform/unique)

Dominion	+
Discourse Characteristics	+
Reflection	+

Comments
Student Facilitators do not appear to conceive of themselves as facilitators but rather they appear to think of themselves as presenters

Total	Mean Total

Student Engagement In Groupwork Scoring Form

Class or Group Feb 3 Group 2

Rater P/S	Activity	
Group	Assignment Description (uniform/unique)	
	Score each of the following using a range from 1 (scant) to 6 (substantial)	
Dominion		
--Participation		+
--Respectful		+
--Ethics		+
--Preparation		+
Discourse Characteristics		
--Concepts & principles		+
--Focus		+
Reflection		
--Question or challenge		+
--Implications		+
--Revision		+
Content		
--key facts		
--distinguish between fact, opinion		
--conceptual understanding		
--questioning evidence		
--scope & context		
--critical		
--assumptions & ethics		
--implications & conclusions		
--presentation		

Comments ... a positive observation

Students are struggling with the problem of seeing how their observations are represented by the mathematical model.

Total	Mean Total

Scoring Form

Facilitating Engagement Scoring Form

Class or Group ________________

Rater PVS	Activity
Group Feb 3 Group 1	Assignment Description (uniform/unique)

Dominion	3
Discourse Characteristics	3
Reflection	2
Comments	

Total	Mean Total

Student Engagement In Groupwork Scoring Form

Class or Group Feb 3 Group 3	Activity
Rater FvS	Assignment Description (uniform/unique)
Group	

Score each of the following using a range from 1 (scant) to 6 (substantial)

Dominion	—
--Participation	+
--Respectful	
--Ethics	—
--Preparation	
Discourse Characteristics	~~2~~ —
--Concepts & principles	~~2~~ —
--Focus	
Reflection	~~4~~ —
--Question or challenge	—
--Implications	—
--Revision	
Content	
--key facts	
--distinguish between fact, opinion	
--conceptual understanding	
--questioning evidence	
--scope & context	
--critical	
--assumptions & ethics	
--implications & conclusions	
--presentation	

Comments

Total	Mean Total

1-6

Scoring Form

JIGSAW

1-6

Facilitating Engagement Scoring Form

Class or Group Feb 3 Obs 1

Rater ERB	Activity Fluid jigsaw Flow Measurement
Group Feb 3 Obs 1	Assignment Description (uniform/unique)

Dominion	4+
Discourse Characteristics	5
Reflection	5-

Comments

- F knows boundaries of what is to be learned
- Cross group facilitation on topic
- more notions on exploring parameters
- The illustrated dynamic formula

Total	Mean Total

Scoring Form

Facilitating Engagement Scoring Form

Class or Group Feb 3 Obs 2

(1-6)

Rater	GRB	Activity	Hometeam
Group	2/3 obs 2	Assignment Description (uniform/unique)	Pernoulli Eq (4 weeks com)

Dominion	6-
Discourse Characteristics	6
Reflection	6

Comments

less participation from 2, though group sitting exchanges ~~from~~ is each other

· Find myself wrestling with content.... regretting my own abstract talk talk science ed...

· Bernie's restraint is invaluable...

· Term by term

· "No, remember in our homework — it's just like"

· "Challenging, different, out of norm."

Total	Mean Total

Hands on

· "worry if, though we're all putting our heads together, yeah, we're getting to the right answer."

· "Oh, Rho, that's where I messed up"

B · I liked, but not sure they were exactly right" [content obs predominant]

window + application gains

Migration of concept from measurement to mechanics that generate measurement

· "I've seen physics"

APPENDIX 1-E

SURVEY GIVEN IN 1999

Chemical Engineering 332 Spring 1999 Survey

The use of **LECTURE** in this course:

(mark the appropriate circle, select only one response per question)

how likely *are [were]* you to:		Much **More** Likely	Somewhat **More** Likely	About the **Same**	Somewhat **Less** Likely	Much **Less** Likely	No Basis for Judgment/Not Applicable
1.	...ask for clarification when you didn't understand something	❍	❍	❍	❍	❍	❍
2.	...discuss the ideas and concepts taught in this course with other students	❍	❍	❍	❍	❍	❍
3.	...work on assignments with other students	❍	❍	❍	❍	❍	❍
4.	...ask other students for comments on your course work	❍	❍	❍	❍	❍	❍
5.	…feel isolated from other students	❍	❍	❍	❍	❍	❍
6.	...receive detailed comments on assignments from the instructor	❍	❍	❍	❍	❍	❍
7.	…miss comments made during a discussion about the ideas and concepts taught in this course	❍	❍	❍	❍	❍	❍
8.	...tell the instructor when you have a complaint or suggestion about the course	❍	❍	❍	❍	❍	❍
9.	…feel isolated from the instructor	❍	❍	❍	❍	❍	❍
10.	...discuss the ideas and concepts taught in this course with the instructor	❍	❍	❍	❍	❍	❍

The use of **HANDS-ON LEARNING** in this course:

(mark the appropriate circle, select only one response per question)

how likely *are [were]* you to:		Much **More** Likely	Somewhat **More** Likely	About the **Same**	Somewhat **Less** Likely	Much **Less** Likely	No Basis for Judgment/Not Applicable
11.	...ask for clarification when you didn't understand something	❍	❍	❍	❍	❍	❍
12.	...discuss the ideas and concepts taught in this course with other students	❍	❍	❍	❍	❍	❍
13.	...work on assignments with other students	❍	❍	❍	❍	❍	❍
14.	...ask other students for comments on your course work	❍	❍	❍	❍	❍	❍
15.	…feel isolated from other students	❍	❍	❍	❍	❍	❍

16.	...receive detailed comments on assignments from the instructor	❍	❍	❍	❍	❍	❍
17.	…miss comments made during a discussion about the ideas and concepts taught in this course	❍	❍	❍	❍	❍	❍
18.	...tell the instructor when you have a complaint or suggestion about the course	❍	❍	❍	❍	❍	❍
19.	…feel isolated from the instructor	❍	❍	❍	❍	❍	❍
20.	...discuss the ideas and concepts taught in this course with the instructor	❍	❍	❍	❍	❍	❍

Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	Don't Know/ Not Applicable
21.	This course helped me learn to manage large, complex tasks	❍	❍	❍	❍	❍
22.	This course helped me learn to work through a process to solve problems	❍	❍	❍	❍	❍
23.	…I learned from the comments made by the instructor on my assignments and/or examinations for this course	❍	❍	❍	❍	❍
24.	I am more comfortable participating in discussions in this course, than I am in other courses.	❍	❍	❍	❍	❍
25.	I feel comfortable telling the instructor of this course when I disagree with something s/he has said	❍	❍	❍	❍	❍
26.	Assignments for this course helped me understand what will be expected of me as a professional	❍	❍	❍	❍	❍
27.	Assignments for this course are similar to the type of tasks I will face as a professional	❍	❍	❍	❍	❍

Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

Because of the way this course uses Hands-On and Lecture:		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
28.	…it takes less time to understand the ideas and concepts taught in this course	❍	❍	❍	❍	❍
29.	…I am better able to remember important facts	❍	❍	❍	❍	❍

30.	…I have a more thorough understanding of the ideas and concepts taught in this course	❍	❍	❍	❍	❍
31.	...I am better able to visualize the ideas and concepts taught in this course	❍	❍	❍	❍	❍
32.	...I spend more time studying	❍	❍	❍	❍	❍
33.	…I am able to learn at my own pace	❍	❍	❍	❍	❍
34.	I was better able to communicate my ideas to others	❍	❍	❍	❍	❍
35.	I was encouraged to exercise my creativity	❍	❍	❍	❍	❍
36.	I was able to collaborate effectively with peers	❍	❍	❍	❍	❍
37.	I was able to learn at my own pace	❍	❍	❍	❍	❍
38.	I was able to work in a group setting to enhance my learning	❍	❍	❍	❍	❍
39.	I was able to work through the learning process to solve problems	❍	❍	❍	❍	❍
40.	I was taught how to work in a team/group setting to complete a project	❍	❍	❍	❍	❍
41.	The group work helped in the learning of the material	❍	❍	❍	❍	❍
42.	I was more likely to understand the ideas and concepts taught in this course	❍	❍	❍	❍	❍
43.	I have difficulty paying attention to the lectures	❍	❍	❍	❍	❍

To what extent do you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
44.	The lecture technique used in this course was appropriate for performing the tasks required	❍	❍	❍	❍	❍
45.	The first four weeks of lab made it easier to prepare for the second four weeks of lab.	❍	❍	❍	❍	❍
46.	The lecture material in this course helped me to work better in groups.	❍	❍	❍	❍	❍
47.	The first four week lab did not prepare me for the lecture material on that subject.	❍	❍	❍	❍	❍
48.	The lecture technique used in this course is overrated	❍	❍	❍	❍	❍
49.	The first lab/lecture topic made it easier for me to prepare for the second lab/lecture topic.	❍	❍	❍	❍	❍
50.	The hands-on technique used in this course was appropriate for performing the tasks required	❍	❍	❍	❍	❍

51.	The hands-on technique used in this course is overrated	❍	❍	❍	❍	❍
52.	The group work in this course helped me to better understand the lectures.	❍	❍	❍	❍	❍
53.	I would recommend this course to others	❍	❍	❍	❍	❍
54.	I would recommend this instructor to others	❍	❍	❍	❍	❍

In your opinion, to what extent were each of the following given **priority** in this course:

Please rate each of the following from 1 to 5 where: *1 is the lowest priority, and 5 is the highest priority*

(circle the appropriate number, select only one response)

55.	Encouraging students to take responsibility for their own learning	1	2	3	4	5
56.	Building students' confidence in their ability to learn difficult subject matter	1	2	3	4	5
57.	Encouraging meaningful communication between the instructor and the students	1	2	3	4	5
58.	Helping <u>all</u> students in this course learn	1	2	3	4	5
59.	Applying what you are learning to "real world" situations	1	2	3	4	5

(mark the appropriate circle, select only one response)

60. Overall I have been	O very dissatisfied	O dissatisfied	O satisfied	O very satisfied	with this course

What did you like best about Chemical Engineering 332? (please specify)

What did you like least about Chemical Engineering 332? (please specify)

If you could change one thing about Chemical Engineering 332, what would that be? (please specify)

What grade do you expect to receive in <u>this course</u>? (mark the appropriate circle, select only one)

❍ A+ or A ❍ A- or B+ ❍ B or B- ❍ C ❍ D or F

Note: These survey results and comments were in an old database file. The results had already been numerically coded, however the scale used was not included. I have included my best estimate of the scales used. There are, however, two data points that are off scale. Some of the comments were also truncated by the database.

Scale		Because of the Hands-on Group Learning assignments used in this course: how likely were you to:																	Avg.	St.Dv.
Much More Likely	6	... ask for clarification when you didn't understand something	4	4	4	5	4	4	3	3	4	5	4	3	3	3	1	4	3.6	1.0
Somewhat More Likely	5	...discuss the ideas and concepts taught in this course with other students	5	5	3	4	4	5	2	3	4	5	4	4	4	2	1	5	3.8	1.2
About the Same	4	...work on assignments with other students	5	5	4	3	5	5	3	3	4	5	5	5	3	3	4	4	4.1	0.9
Somewhat Less Likely	3	...ask other students for comments on your course work	5	5	3	3	3	4	2	4	2	4	4	4	2	4	3	4	3.5	1.0
Much Less Likely	2	…feel isolated from other students	1	2	2	3	1	1	5	2	4	1	1	2	2	3	3	2	2.2	1.2
Not Applicable	1	...receive detailed comments on assignments from the instructor	4	2	3	4	1	4	1	1	3	1	3		2	4	3	4	2.7	1.2
		…miss comments made during a discussion about the ideas and concepts taught in this course	3	3	5	3	2	3	4	3	3	2	3	1	3	3	9	3	3.3	1.7
		...tell the instructor when you have a complaint or suggestion about the course	3	4	4	5	2	4	4	4	1	4	4	3	4	4	2	3	3.4	1.0
		…feel isolated from the instructor	3	2	5	3	1	2	5	4	2	4	2	3	2	4	5	2	3.1	1.3
		...discuss the ideas and concepts taught in this course with the instructor		3	1	4	1	4	4	2	2	4	4	4	3	4	1	4	3.0	1.3
Scale		**Because of the way this course uses Groups and Hands-on Learning:**																	**Avg.**	**St.Dv.**
Strongly Agree	5	…it takes less time to understand the ideas and concepts taught in this course	3	4	3	2	3	4	2	2	2	2	3	4	3	2	2	3	2.8	0.8
Agree	4	…I am better able to remember important facts	4	4	3	4	3	4	2	4	4	4	4	4	4	3	3	4	3.6	0.6
Disagree	3	…I have a more thorough understanding of the ideas and concepts taught in this course	4	4	3	4	3	4	2	4	4	4	4	4	3	4	3	4	3.6	0.6
Strongly disagree	2	…I am better able to visualize the ideas and concepts taught in this course	4	5	4	4	4	5	3	4		4	4	4	4	4	4	4	4.1	0.5
Not Applicable	1	…I spend more time studying	3	3	3	4	5	4	4	5	3	4	4	3	4	4	4	4	3.8	0.7
		...I am able to learn at my own pace	3	4	3	4	3	1	4	3	4	3	3	4	3	3	2	3	3.1	0.8
		…I am batter able to communicate my ideas to others	4	4	3	4	4	1	4	4	4	4	4	4	3	3	3	4	3.6	0.8
		…I was encouraged to exercise my creativity	4	4	3	3	5	1	4	4	4	4	4	4	4	4	4		3.7	0.9
		…I was able to work through the learning process to solve problems	4	4	3	4	4	4	4	4	4	4	4	4	3	4	3	4	3.8	0.4
		…I was taught how to work in a team/group setting to complete a project	4	5	4	4	3	4	4	3	4	4	5	4	4	3	2	4	3.8	0.8
		…I now have difficulty paying attention to the lectures	3	3	3	2	4	3	3	3	4	4	3	3	3	3	1	3	3.0	0.7

Scale		Because of the way the lectures used in this course: how likely were you to:																	Avg.	St.Dv.
Much More Likely	6	... ask for clarification when you didn't understand something	3	4	3	5	4	3	4	3	3	3	4	3	2	3	2	2	3.2	0.8
Somewhat More Likely	5	...discuss the ideas and concepts taught in this course with other students	3	3	3	3	3	4	2	3	3	2	4	4	2	3	1	5	3.0	1.0
About the Same	4	...work on assignments with other students	4	3	3	3	5	4	2	3	3	2	5	5	3	3	3	5	3.5	1.0
Somewhat Less Likely	3	...ask other students for comments on your course work	3	3	3	3	9	3	3	4	3	2	5	4	2	4	3	4	3.6	1.6
Much Less Likely	2	…feel isolated from other students	2	3	3	3	1	3	4	2	3	3	1	2	2	3	4	2	2.6	0.9
Not Applicable	1	...receive detailed comments on assignments from the instructor	5	3	3	4	1	3	4	5	3	4	3	3	1	3	1	4	3.1	1.3
		…miss comments made during a discussion about the ideas and concepts taught in this course	3	3	3	3	2	3	4	2	3	3	3	3	4	3	9	3	3.4	1.6
		...tell the instructor when you have a complaint or suggestion about the course	3	3	3	4	1	4	4	4	3	3	3	2	3	4	1	3	3.0	1.0
		…feel isolated from the instructor	4	3	3	3	5	2	4	4	3	3	2	3	3	3	5	2	3.3	0.9
		...discuss the ideas and concepts taught in this course with the instructor	4	3	4	4	1	3	4	2	3	2	4	4	2	4	1	4	3.1	1.1
Scale		**Because of the Lectures used in this course…**																	**Avg.**	**St.Dv.**
Strongly Agree	5	…it takes less time to understand the ideas and concepts taught in this course	4	3	4	4	4	3	3	2	4	3	3	3	2	4	2	3	3.2	0.8
Agree	4	…I am better able to remember important facts	4	3	4	4	4	3	3	4	4	3	3	3	3	4	2	4	3.4	0.6
Disagree	3	…I have a more thorough understanding of the ideas and concepts taught in this course	3	3	4	4	4	1	3	4	3	4	3	4	2	4	2	4	3.3	0.9
Strongly disagree	2	…I am better able to visualize the ideas and concepts taught in this course	3	3	3	4	4	3	3	4	3	3	3	3	3	3	2	3	3.1	0.5
Not Applicable	1	…I spend more time studying	3	3	4	4	4	1	4	5	4	3	4	4	3	3	4	3	3.5	0.9
		...I am able to learn at my own pace	3	3	4	4	4	1	4	2	4	3	3	4	3	4	4	4	3.4	0.9
		…I am batter able to communicate my ideas to others	3	3	3	3	4	1	4	4	4	3	4	3	4	4	3	4	3.4	0.8
		…I was encouraged to exercise my creativity	3	3	3	3	5	1	4	4	4	3	4	3	4	3	2	4	3.3	0.9
		…I was able to work through the learning process to solve problems	4	3	4	4	4	4	4	4	4	4	4	3	4	3	4	4	3.8	0.4
		…I was taught how to work in a team/group setting to complete a project	3	3	3	4	4	1	4	3	4	3	4	3	2	3	2	3	3.1	0.9
		…I now have difficulty paying attention to the lectures	3	3	3	2	3	3	3	3	4	3	3	3	3	3	4	3	3.1	0.4

	Scale	Indicate how strongly you agree or disagree with each of the following statements:																	Avg.	St.Dv.
Strongly Agree	5	This course helped me learn to manage large, complex tasks.	4	4	3	4	3	4	4	4	4	3	4	4	3	3	3	4	3.6	0.5
Agree	4	This course helped me learn to work through a process to solve problems.	3	4	3	4	4	4	4	4	4	4	4	4	4	3	3	4	3.8	0.4
Disagree	3	…I learned from the comments made by the instructor on my assignments and/or examinations for this course.	4	3	2	4	3	5	4	3	4	4	4	4	4	4	2	3	3.6	0.8
Strongly disagree	2	I am more comfortable participating in discussions in this course, than I am in other courses.	5	4	4	4	1	1	3	3	3	4	4	4	3	3	2	4	3.3	1.1
Not Applicable	1	I feel comfortable telling the instructor of this course when I disagree with something s/he has said.	3	4	4	4	3	4	4	4	3	4	3	4	4	4	2	3	3.6	0.6
		Assignments for this course helped me understand what will be expected of me as a professional.	4	4	3	4	3	1	4	4	3	1	4	4	4	3	2	4	3.3	1.1
		Assignments for this course are similar to the type of tasks I will face as a professional.	4	4	3	4	4	1	4	4	1	1	4	4	4	3	3	4	3.3	1.2
		The lecture technique used in this course was appropriate for helping me learn the important concepts.	4	4	4	4	3	4	3	4	3	3	3	4	2	4	2	4	3.4	0.7
		The first four weeks of lab made it easier to prepare for the second four weeks of lab.	4	4	4	4	3	3	3	4	3	4	4	5	3	4	3	3	3.6	0.6
		The lecture material in this course helped me to work better in groups.	3	4	3	4	4	1	3	4	3	3	3	4	3	4	2	4	3.3	0.9
		The first four week labs did not prepare me for the lecture material on that subject.	3	3	3	3	3	3	3	3	3	3	3	2	3	3	5	2	3.0	0.6
		The lecture technique used in this course is overrated.	3	4	3	4	5	1	4	4	4	3	3	3	4	3	1	4	3.3	1.1
		The first lab/lecture topic made it easier for me to prepare for the second lab/lecture topic.	4	4	3	3	3	4	4	3	3	4	4	4	3	4	2	3	3.4	0.6
		The hands-on technique used in this course is overrated.	3	3	5	4	5	3	3	3	3	3	3	3	4	4	4	3	3.5	0.7
		The group work in this course helped me to better understand the lectures.	5	4	4	4		4	4	3	4	3	4	4	4	4	3	5	3.9	0.6
		I would recommend this course to others.	5	4	3	4	2	4	4	1	4	4	4	4	4	3	2	4	3.5	1.0
		I would recommend this instructor to others.	5	5	3	4	2	4	4	1	4	4	4	4	3	3	2	4	3.5	1.1

	Scale	In your opinion, to what extent were each of the following given priority in this course:																	Avg	St.Dv.
Highest Priority	5	Encouraging students to take responsibility for their own learning	5	5	4	5	5	3	4	4	5	5	4	5	5	5	4	5	4.6	0.6
	4	Building students confidence in their ability to learn difficult subject matter	5	5	3	5	3	4	4	4	3	4	4	4	1	4	3	3	3.7	1.0
	3	Encouraging meaningful communication between the instructor and the students	5	4	3	3	2	5	4	3	2	4	4	3	2	1	1	4	3.1	1.3
	2	Helping all student in this course learn	5	4	2	4	2	4	4	4	4	5	4	4	4	2	2	3	3.6	1.0
Lowest Priority	1	Applying what you are learning to "real world" situations	4	3	2	3	2	4	4	3	3	4	4	4	3	3	3	5	3.4	0.8
		Overall I have been… with this course																		
		4 - very satisfied, 3 - satisfied, 2 - dissatisfied, 1 - very dissatisfied	4	4	2	3	1	3	3	2	3	3	3	3	2	2	1	3	2.6	0.9
		What grade do you expect to receive in this course?																		
		5 A+ or A, 4 A- or B+, 3 B or B-, 2 C, 1 D or F	3	3	3	2	1	3	3	2	3	2	2	2	2	2	3	3	2.4	0.6

In what way has the emphasis on hands-on coop learn been helpful
I think it has brought me closer to the classmates and allowed for some hands on experience and given us trials and errors with the positive results also.
It has been very helpful to actually be able to see how some of the things we have learned about take place physically in the real world. I have enjoyed working down in the lab as opposed to just lectures.
Getting to look at a real-life situation has been helpful (as opposed to theoretical). Looking at the apparatus after learning the material would be more helpful.
Makes us learn, understand and articulate a certain aspect of fluids and to portray our learning to others.
To be able to relate the eqns in the book to a visual concept. It was more important for me to understand my concept thoroughly because others depended on me.
It has forced me and my fellow group members to read and try to understand the readings. This is instead of listening to lectures and then trying to understand. Also, by trying to teach the material I have found I understand it better.
Sense of responsibility. We are responsible for group learning the material, so we need to make sure we know what we are supposed to teach them.
It is easier to visualize concepts I have seen in action. When questions arise I can remember back to what happened when we did it in class. Working in groups has gotten more out of me.
The hands coop learning was help fully for the group but I thought the subject could have been covered a little better with more lecture time.
The hands on learning has helped apply the book knowledge to something tangible. I believe I will probably remember concepts better as I was able to actually experience them.
It has been helpful for the basics. Would be nice to be taught something useful though.
I like working with machines, things that I can hold and touch and feel; this actually makes a world of difference to me. When I can point @ something, I understand it better.
It has been helpful for me to see how fluid mechanics works within my own jigsaw group.

In what way has the emphasis on hands-on coop learn been helpful (cont.)
It forces you to learn everything about the given subject.
Well- you really have to think so maybe that's been helpful.
Ways to Improve things
It almost needs to meet 3 days a week because it seems like there is a lot of outside work associated with the class.
Maybe receiving a little bit more background on all the equipment in the lab before we jump right into working with the equipment.
Learn by our-selves and need more help from our professor.
A lecture backing up what we have learned in this lab, or pointing out what we need to look for or gain information on during the lab would be very helpful. Having more teacher assistance would be very helpful.
To have a session where you answer the questions that we can't answer.
Give more time for finding and reading further information.
While cooperative learning is somewhat helpful, I think the class could be greatly improved if the instructor lectured on the same material. Also, the instructor working out example problems would help a lot.
I think this is great with the hands on learning but I don't think it should be the primary source of our knowledge. A few days of lecture could clear up all of these concepts and then do hands on learning to see what was taught in lecture.
A little more direction in the beginning would have been useful. At first I didn't know what was going on.
A couple of lectures on the topic.
Having more time with our jigsaw group would have been more beneficial. We didn't have enough time to really get the concept down. That way we were all tentative when we presented it to our home groups.
There is more emphasis put on learning techniques than there is on subject matter. This might be better for a Freshman class, but juniors are already pretty much set in their ways. A lot of us don't have a lot of extra time OUTSIDE of class to teach OURSELVES what we need to know.

Ways to Improve things (cont.)
This is a two-credit class. Two!, not three, not four, two. It is not right to put such time constraints on us. This is a two credit class.
I think that some lecture is necessary before and after the cooperative learning sessions to point us in the right direction for learning the material and to give those outside of certain jigsaw groups a better understanding of the material.
If you would guide each jigsaw group to what is really important, and clear up any incorrect thinking on the subject matter.
If we could discuss homework problems in class - it would really help.
What aspects do you struggle?
Sometimes it gets a little frustrating when you spend so much time on the topic and then your ideas or theories of why it happens are wrong. Sometimes the outside resources are confusing or we really don't know the ?-concept that we are looking for to help us explain the results.
I missed the day on impact of flow regime so I am still struggling to understand that.
I didn't have enough time and information of the subject.
Trying to figure out what I am supposed to be learning or what I am supposed to know is problematic.
The structure of presentations were different for all of us and getting use to those variances are difficult for me.
We have only discussed two topics so far…So far, so good.
I believe I understand the theory well, but using the equations and numbers is a bit sketchy.
How it all fits together.
Mechanical Balance has been difficult for me to apply I understand where it came from and why it works.
Fluid friction was confusing. The no lectures really bothered me.
The whole aspect of teaching each other everything and not knowing if it was all correct. Also spending the amount of time we have is more than a class of this type should need.

What aspects do you struggle? (cont.)
I feel like other than doing the homeworks I haven't learned all that much.
Motivation. I feel like I am going to get "whacked" anyway, so why put any effort into it, especially when that effort takes hours and hours?
I had a hard time understanding some of the lectures given in my home team.
I struggle with truly believing something another student tells me without the acknowledgement of the teacher that the student is correct, or being able to prove the student is correct by literature or formulas.
The homeworks - I don't think we should talk about them in class before they are due.
What is your impression of cooperative learning?
I think it is a new and inventive way of learning. This is the first time I am experiencing this method of learning, although I have worked in groups before. I do believe that I will learn more because this type of studying strongly emphasizes that each member fully understand everything.
I believe that cooperative learning could be very helpful. Especially in times where the instructor is not always available. I think some type of curve should be implemented if no one is happy with their grades.
It sounds pretty good, but it seems like you need more than just one semester to get all the kinks worked out. I like a lot of the in-class exercise ideas, but some of the other things I don't know about like one student getting a grade for the whole group.
Seems to give good results if everybody in the group is willing to participate and you give it time.
Potentially it could provide a better learning experience as well as provide experience on how the "real world" works.
Cooperative learning sounds like the way I would like to learn. I usually get bored when a teacher stands up in front of the class and lectures all the time.
Seems to be a really effective learning system. I personally like working in groups but this seems more involved than our normal group study or group homework. I am concerned that the benefits seem to be more long term and we are going to be doing the CL process for just one semester. Are we going to get the full benefits in such a short time? I also am concerned about the formation of groups. Some people are happy with C's others want A's and a few seem to just not care as long as they pass. How do you deal with a person in a group of C's and I don't care who wants or needs A's?

What is your impression of cooperative learning? (cont.)
Just like in the reading, I don't know if it is a good idea or not. I usually seem to get lost in groups, but I do know from other courses that group cooperation is essential in some cases. Most professors don't want to take the time to get it to work.
I like it, I usually benefit from it.
I think that with the atmosphere it can create, I.e., less stress, higher participation, less likely to give up on homework, etc., that it will allow most of us to reach our full potential toward our academics. Without the fear of being kicked out of the program.
Felder describes CL as a proven method to increase students grades and their understanding of course material. I am all for CL as long as most of Felder's guidelines are carried out. If the instructor doesn't assist in resolving group disputes, the group will suffer. Aside from that aspect, I think that CL is a good idea.
I think it is a very good learning tool. We have already done a little of this and with some of the new group ideas it should work even better.
I feel that it would be a positive experience. I have nearly participated in CL, but not to the extent Felder reaches in his article. I do like what I have seen myself.
Cooperative learning is a resicble good technique. It required all individuals in the group to learn the information. The group must feed off of each other to perform well. It gets more people involved in the lectures. I'm looking forward to see how it works.
Sounds cool
It seems that CL is a great way to learn engineering. The more people working on something, the better it can be.
Additional comments
It was a fun class with a great instructor. I learned a lot about heat transfer and fluid mechanics. I also learned how to work better in a group that depends on me for instruction.
I have learned a lot from the hands on portion. I like relating all the theories and equations to something in the real world … heat exchanger, manometer, etc. Bernie is really positive.
I really enjoyed the hands-on learning in the lab and being able to mess around and work with all the lab equipment. I wasn't fond of the lecture portion but I feel like the lab parts made up for it. Even though the projects were long and arduous they rea

Additional comments (cont.)
While I think that the methods employed in this course are very effective, I feel the real reason behind the additional learning is the result of mandatory extra time and effort put forth by the students and if we had several of these cooperative learning
I thought the class improved with time. Since it was the first time the professor taught the class this way, I think it took an initial adjustment period before the professor clearly understood his role. I think he got better at realizing when the student
I did like the hands-on learning technique presented but I think more lectures were needed. I definitely think more Chem E classes should have a lab to along with the lecture. I believe it has helped me visualize and learn the material better then the cou
Too much time was spent in the lab. The material didn't receive much emphasis because of a lack of lecture time.
This course could have been great. Van Wie simply needs to decide what is necessary to learn from this class under the context (understanding) that ChE332 is a 2 credit class. Also, sometimes a student simply needs an answer to a question. For instance, th
During the first part of the course, there was more time given to interact and discuss the material. Toward the end of the semester, everything seemed accelerated and a bit more difficult to understand.

APPENDIX 2

2002 DATA AND MATERIALS

APPENDIX 2-A

ASSESSMENT OF INDEPENDENT FACULTY

From: Reid Miller

Sent: Monday, April 29, 2002 3:33 pm

To: Bill Thomson

Subject: Assessment of Bernie's Course

Bill,

I met with seven of the eight students today (one no-show). I was very impressed with their knowledge of fluids and heat transfer. They have developed a much stronger foundation than students I have taught in these subjects by more traditional methods. All seven would rate an "A" in applied fluids, with 5 A's and 2B's in applied heat transfer. As you know, my class grades never look like this.

At the same time, the students uniformly reject the course pedagogy as currently applied. This ais a real problem for Bernie, as it is no longer acceptable for us to say "we know b est: how you should learn. These are his "customers", and they are not "contented". Some feel cheated, in that they believe they spent too much time for a 2-credit class. Perhaps more importantly, all of them think they could have learned more with a bit more guidance up front and during the process.

He really needs to think this through and come up with a strategy to overcome this difficulty. In my opinion, he would not need to change much, but he needs to bring them along a bit more slowly with this approach, rather than a sink-or-swim approach, which is their perception.

By the way, I believe that getting the students to buy in to both the method and the outcomes is not restricted to the approach he is taking. It is a general problem in engineering education, and many faculty do a particularly poor job of it. Most just don't try, not thinking it is worth spending their time thinking about. If we are trying to attract the best and brightest into our programs, I believe it is something we have to address.

Reid

Technical Assessment

Of eight students………..

Student knowledge of fluid mechanics concepts was superior. Essentially all of the students, both weak and strong, had an excellent grasp of the basic concepts of mechanical energy balances. All were able to identify the major technical aspects needed to design a piping system and size a suitable pump. In my 30 years of teaching chemical engineering, I have never seen such a wide-spread understanding of fluid mechanics from

The students were universally weak in heat transfer. Only one of the eight was able to identify the critical parameters required to size a heat exchanger, and this student was taking the course for a second time. While all the students were quick to see the disadvantages of using small tubes (pressure drop), only one of the eight realized that the design is a trade-off between surface area and pressure drop. Four out of the eight students were not able to identify the three modes of heat transfer. Upon questioning, the students indicated that so little time was spent on heat transfer, that they didn't feel they had an understanding of heat transfer principles.

(Note: This is W.J. Thomson's assessment)

From: James Lee

Sent: Tuesday, May 28, 2002 4:57 pm

To: William Thomson

Subject: Re: Assessment

Dear Bill,

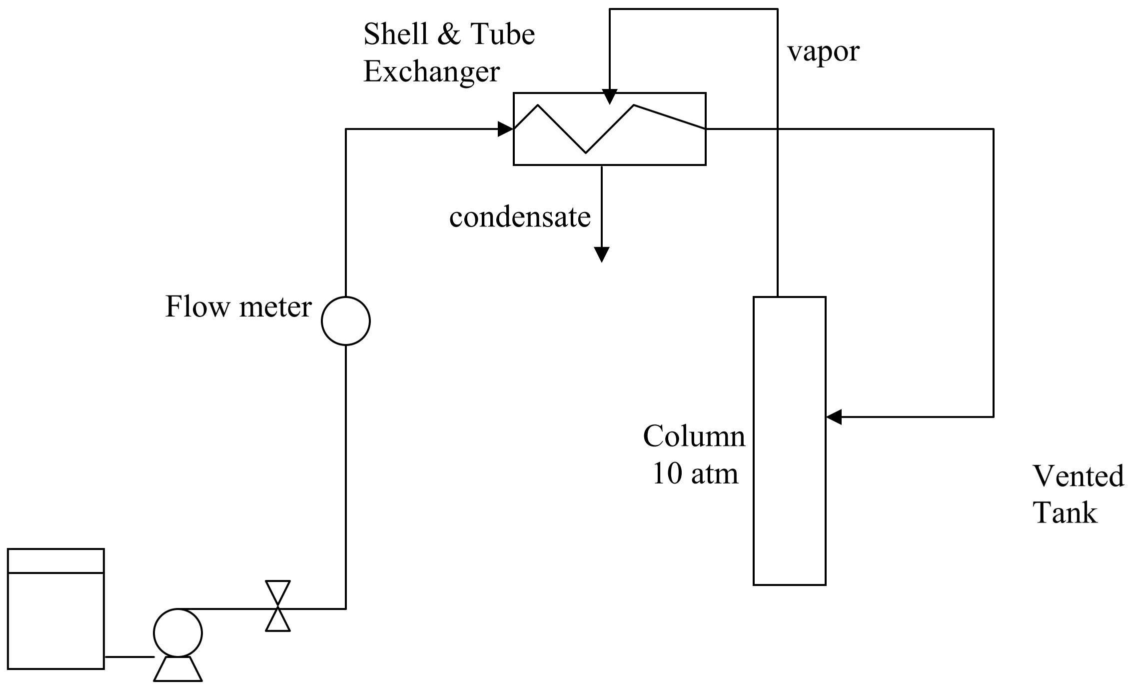
Here are my comments.

Students answered adequately when I asked them about friction factor, mechanical energy balance, flow meter, and heat transfer coefficients. Weak students still did not have clear understanding of the basic principles, but they seem to feel more confident about their knowledge.

I was surprised to find that strong students were not significantly better than average students in understanding the principles.

As most students suggested, I think that the best way is to give more lectures and use the hands-on learning only for several important concepts that can be easily demonstrated.

Scenario used to probe students understanding.

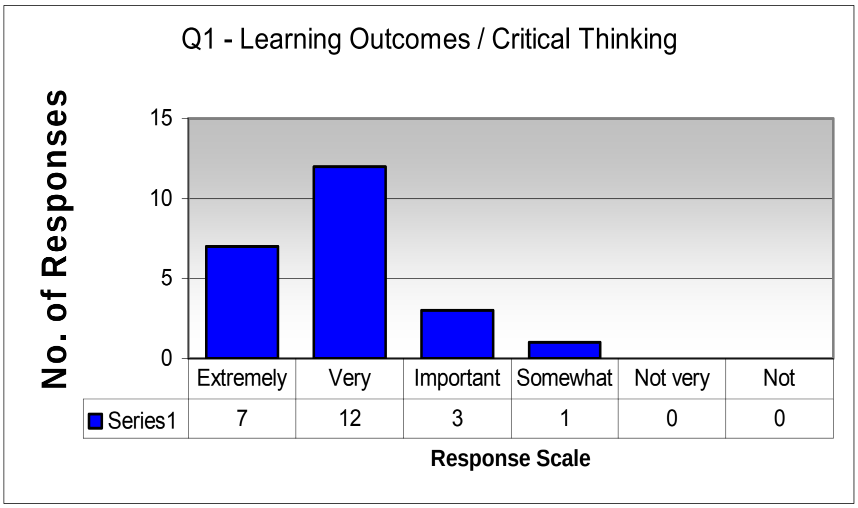


APPENDIX 2-B

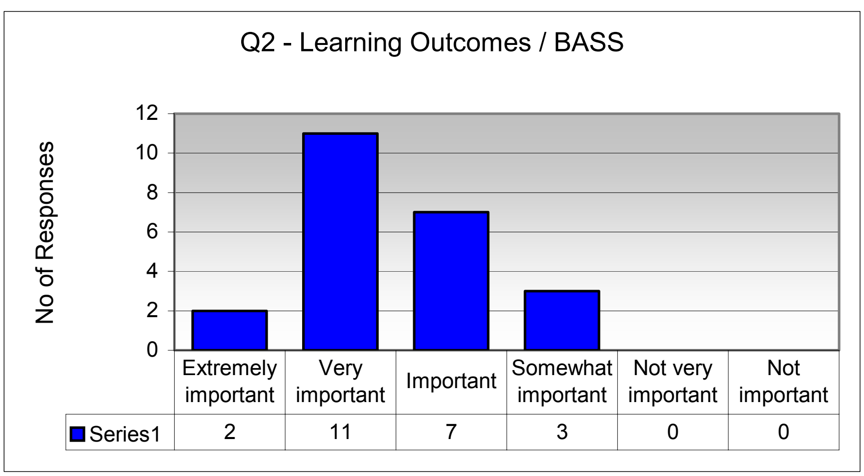
SURVEY GIVEN IN 2002 TO CHE 332

Chemical Engineering 332 Spring 2002 Survey

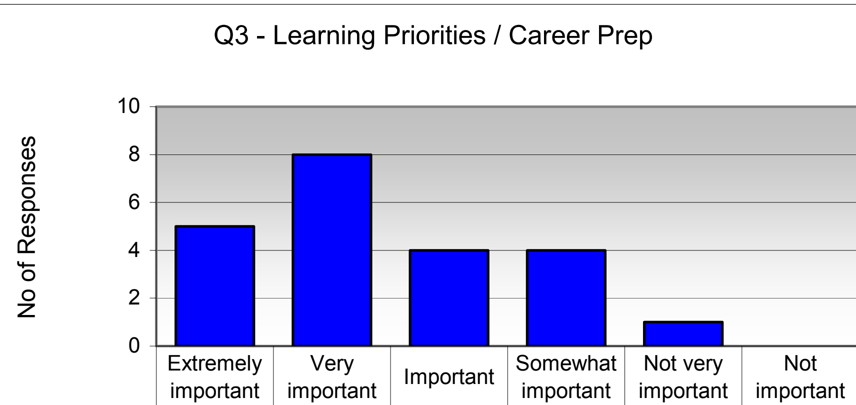
Please indicate the priority you place on the following learning outcomes in this course.							
	(mark the appropriate circle, select only one response per question)						
		6 Extremely important	5 Very important	4 Important	3 Somewhat important	2 Not very important	1 - Not important at all
61.	critical thinking skills	❍	❍	❍	❍	❍	❍



Please indicate the priority you place on the following learning outcomes in this course.							
	(mark the appropriate circle, select only one response per question)						
		6 Extremely important	5 Very important	4 Important	3 Somewhat important	2 Not very important	1 - Not important at all
62.	basic academic skills	❍	❍	❍	❍	❍	❍

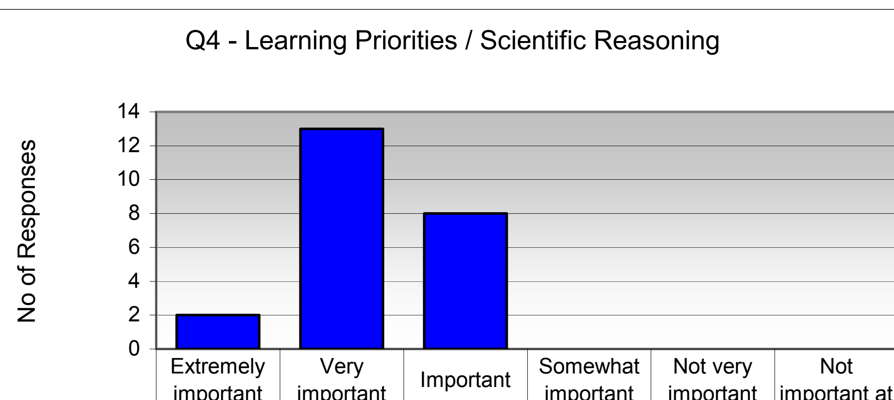


Please indicate the priority you place on the following learning outcomes in this course.							
(mark the appropriate circle, select only one response per question)							
		6 Extremely important	5 Very important	4 Important	3 Somewhat important	2 Not very important	1 - Not important at all
63.	career preparation or advancement	❍	❍	❍	❍	❍	❍



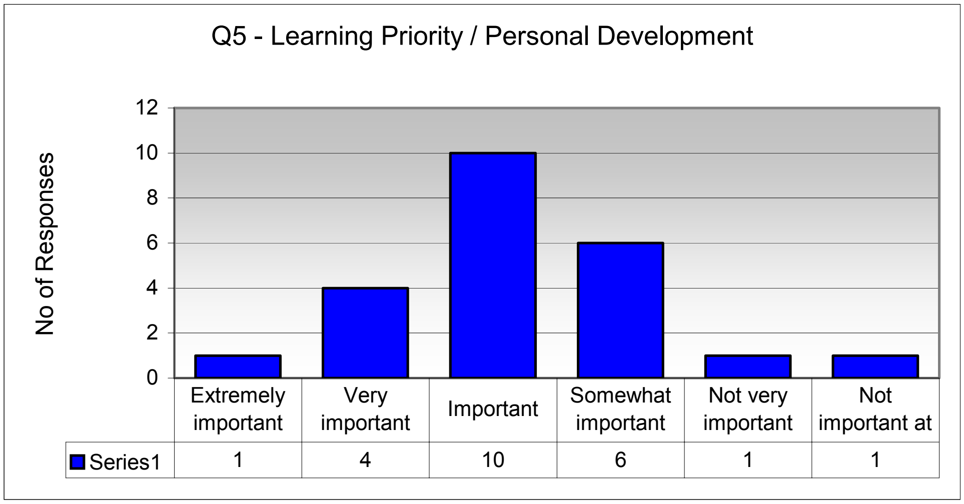
	Extremely important	Very important	Important	Somewhat important	Not very important	Not important
Series1	5	8	4	4	1	0

Please indicate the priority you place on the following learning outcomes in this course.							
(mark the appropriate circle, select only one response per question)							
		6 Extremely important	5 Very important	4 Important	3 Somewhat important	2 Not very important	1 - Not important at all
64.	scientific reasoning	❍	❍	❍	❍	❍	❍

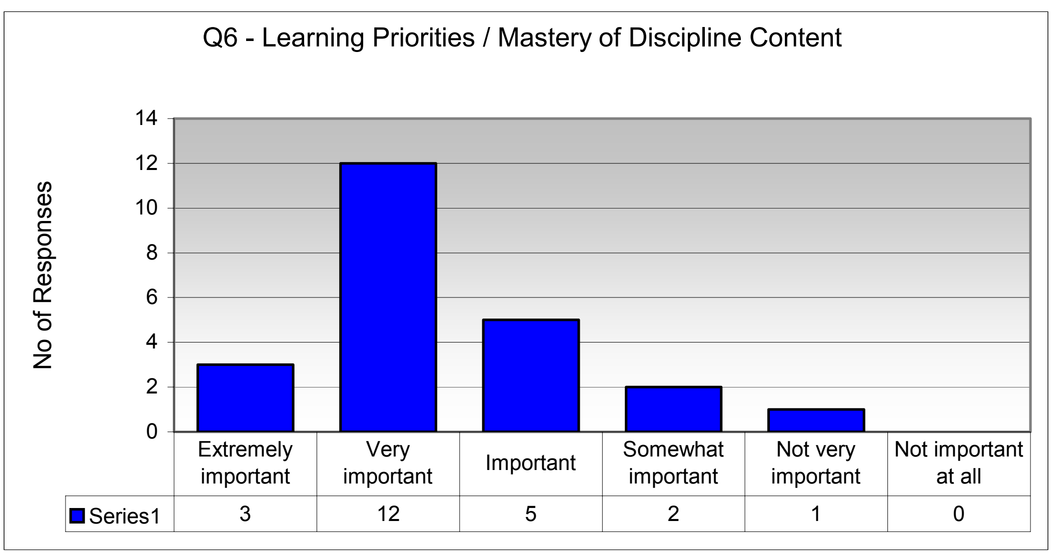


	Extremely important	Very important	Important	Somewhat important	Not very important	Not important at
Series1	2	13	8	0	0	0

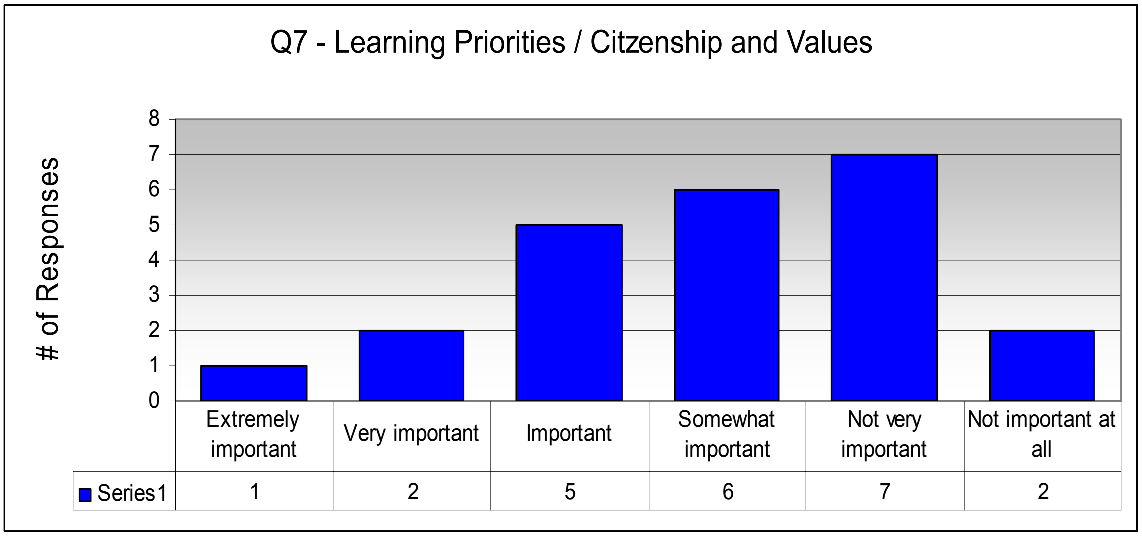
Please indicate the priority you place on the following learning outcomes in this course.							
(mark the appropriate circle, select only one response per question)							
		6 Extremely important	5 Very important	4 Important	3 Somewhat important	2 Not very important	1 - Not important at all
65.	personal development	❍	❍	❍	❍	❍	❍



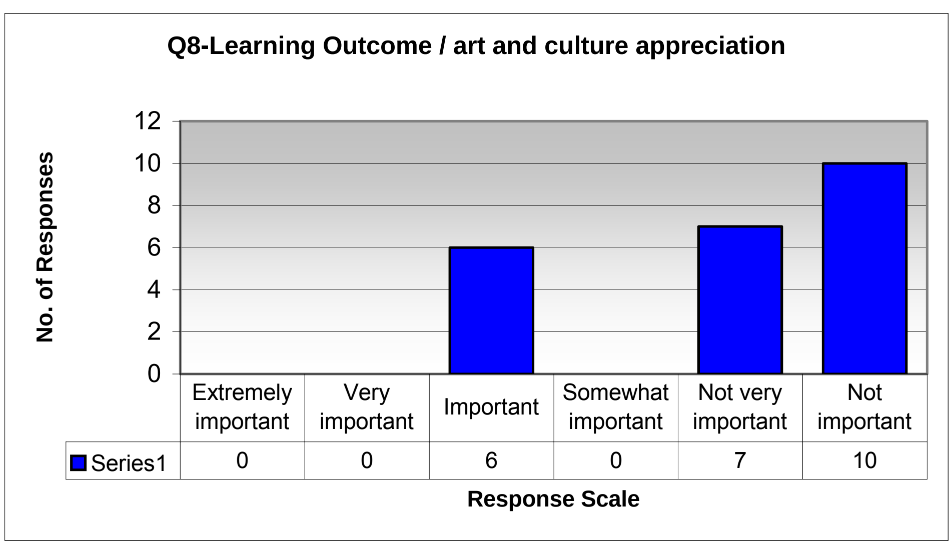
Please indicate the priority you place on the following learning outcomes in this course.							
(mark the appropriate circle, select only one response per question)							
		6 Extremely important	5 Very important	4 Important	3 Somewhat important	2 Not very important	1 - Not important at all
66.	mastery of discipline content	❍	❍	❍	❍	❍	❍



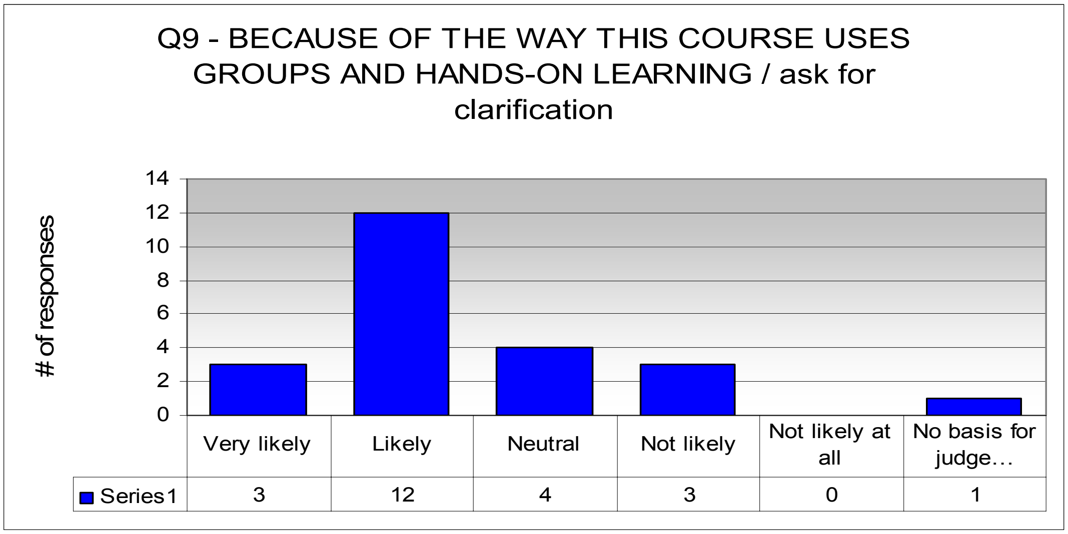
Please indicate the priority you place on the following learning outcomes in this course.							
(mark the appropriate circle, select only one response per question)							
		6 Extremely important	5 Very important	4 Important	3 Somewhat important	2 Not very important	1 - Not important at all
67.	citizenship and values	❍	❍	❍	❍	❍	❍



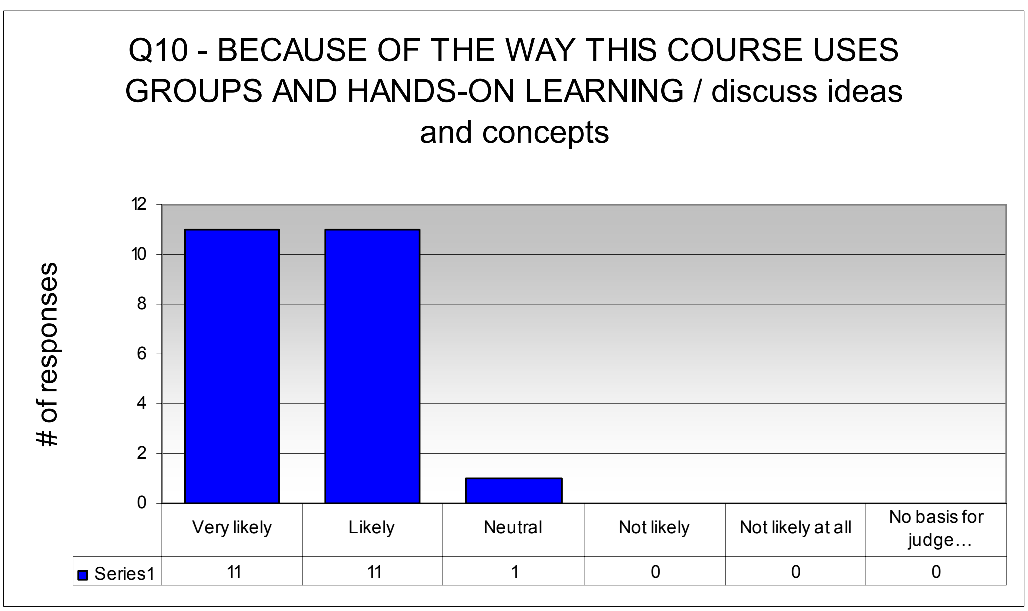
Please indicate the priority you place on the following learning outcomes in this course.							
(mark the appropriate circle, select only one response per question)							
		6 Extremely important	5 Very important	4 Important	3 Somewhat important	2 Not very important	1 - Not important at all
68.	art and culture appreciation	❍	❍	❍	❍	❍	❍



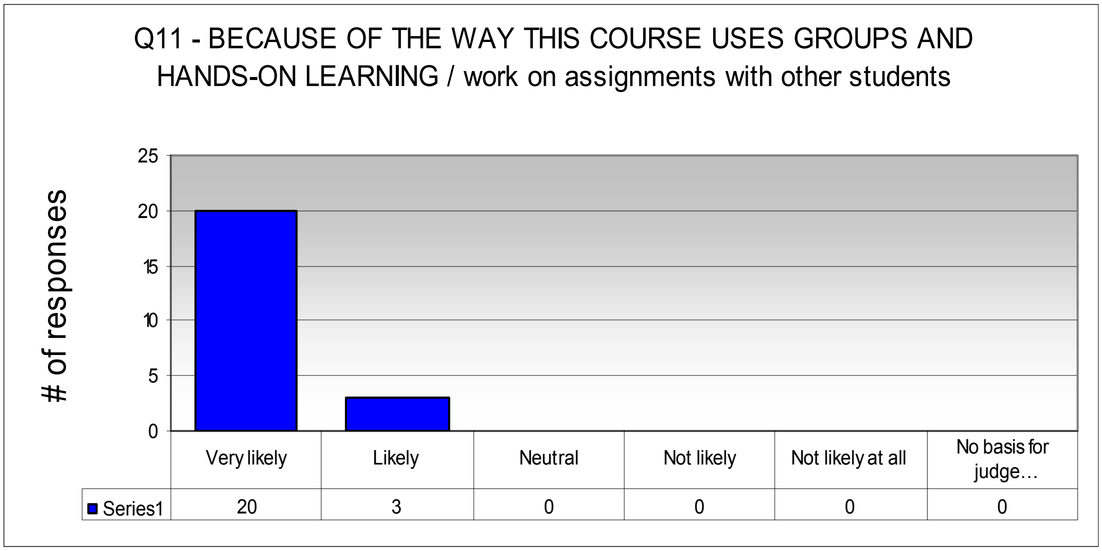
Because of the **HANDS-ON GROUP LEARNING** assignments used in this course: (mark the appropriate circle, select only one response per question)							
how likely *were* you to...		Very Likely	Likely	Neutral	Not likely	Not Likely at all	No Basis for Judgment/Not Applicable
69.	ask for clarification when you didn't understand something	❍	❍	❍	❍	❍	❍



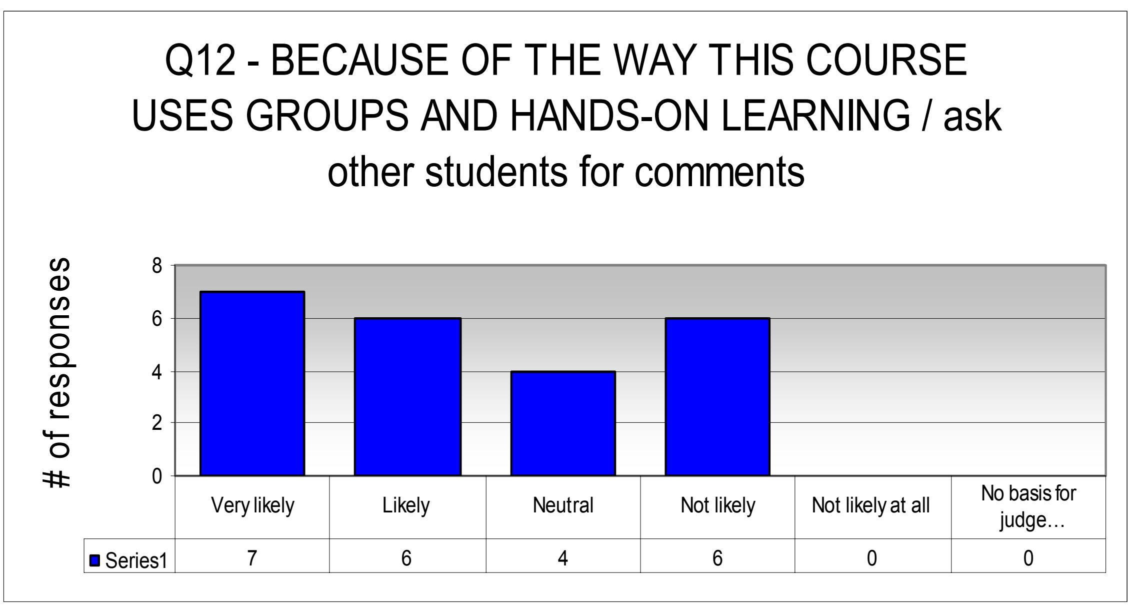
Because of the **HANDS-ON GROUP LEARNING** assignments used in this course: (mark the appropriate circle, select only one response per question)							
how likely *were* you to...		Very Likely	Likely	Neutral	Not likely	Not Likely at all	No Basis for Judgment/Not Applicable
70.	discuss the ideas and concepts taught in <u>this course</u> with other students	❍	❍	❍	❍	❍	❍



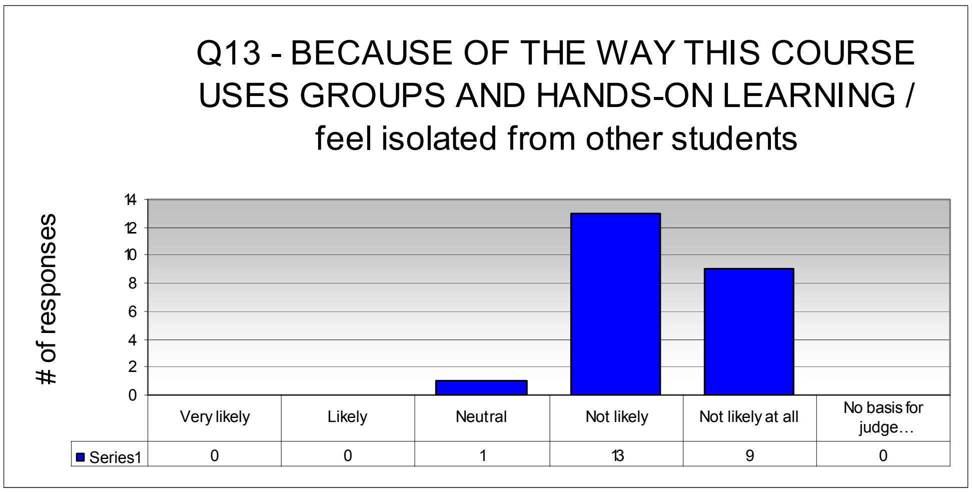
Because of the **HANDS-ON GROUP LEARNING** assignments used in this course:						
(mark the appropriate circle, select only one response per question)						
how likely *were* you to...	Very Likely	Likely	Neutral	Not likely	Not Likely at all	No Basis for Judgment/Not Applicable
71. work on assignments with other students	❍	❍	❍	❍	❍	❍



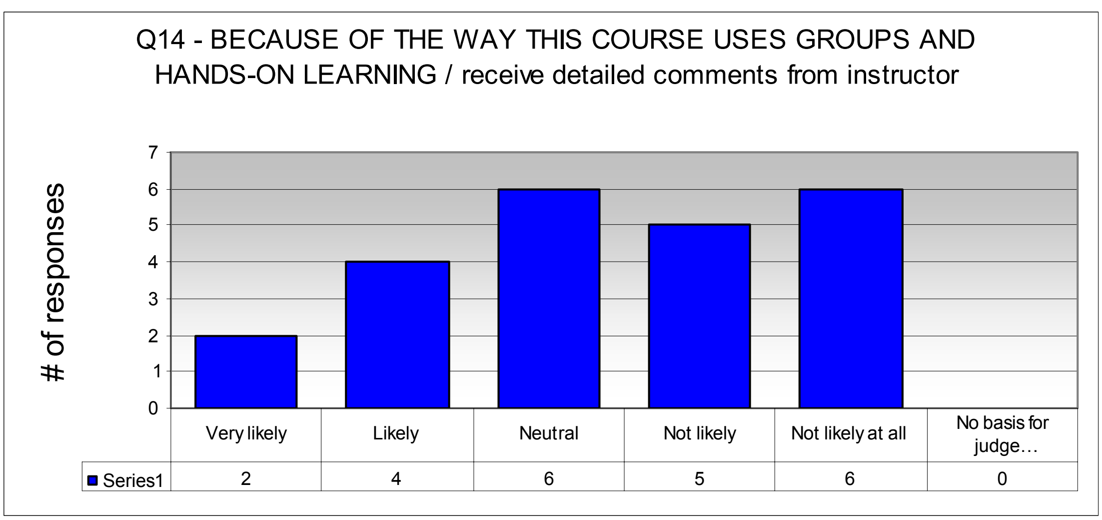
Because of the **HANDS-ON GROUP LEARNING** assignments used in this course:						
(mark the appropriate circle, select only one response per question)						
how likely *were* you to...	Very Likely	Likely	Neutral	Not likely	Not Likely at all	No Basis for Judgment/Not Applicable
72. ask other students for comments on your course work	❍	❍	❍	❍	❍	❍



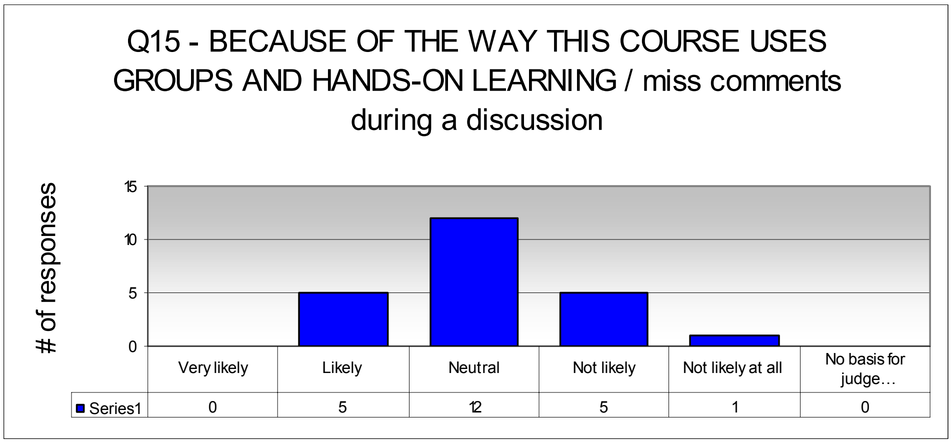
Because of the **HANDS-ON GROUP LEARNING** assignments used in this course:							
(mark the appropriate circle, select only one response per question)							
how likely *were* you to...		Very Likely	Likely	Neutral	Not likely	Not Likely at all	No Basis for Judgment/Not Applicable
73.	feel isolated from other students	❍	❍	❍	❍	❍	❍



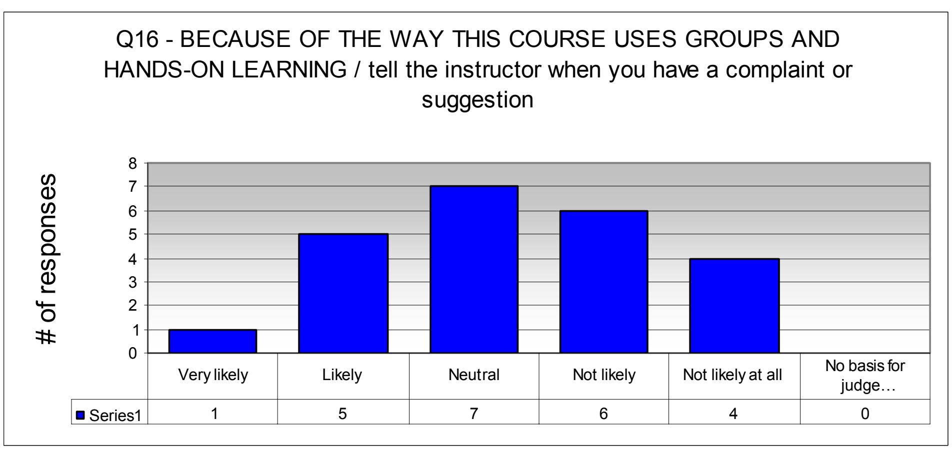
Because of the **HANDS-ON GROUP LEARNING** assignments used in this course:							
(mark the appropriate circle, select only one response per question)							
how likely *were* you to...		Very Likely	Likely	Neutral	Not likely	Not Likely at all	No Basis for Judgment/Not Applicable
74.	receive detailed comments on assignments from the instructor	❍	❍	❍	❍	❍	❍



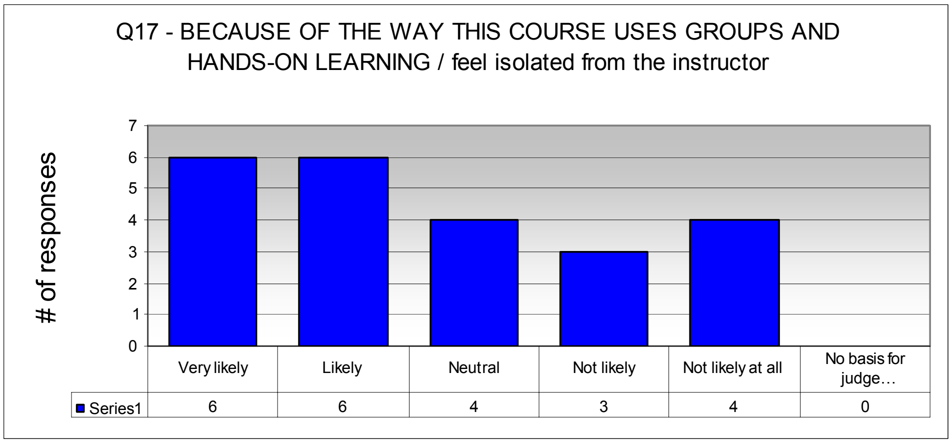
Because of the **HANDS-ON GROUP LEARNING** assignments used in this course:						
(mark the appropriate circle, select only one response per question)						
how likely *were* you to...	Very Likely	Likely	Neutral	Not likely	Not Likely at all	No Basis for Judgment/Not Applicable
75. miss comments made during a discussion about the ideas and concepts taught in this course	❍	❍	❍	❍	❍	❍



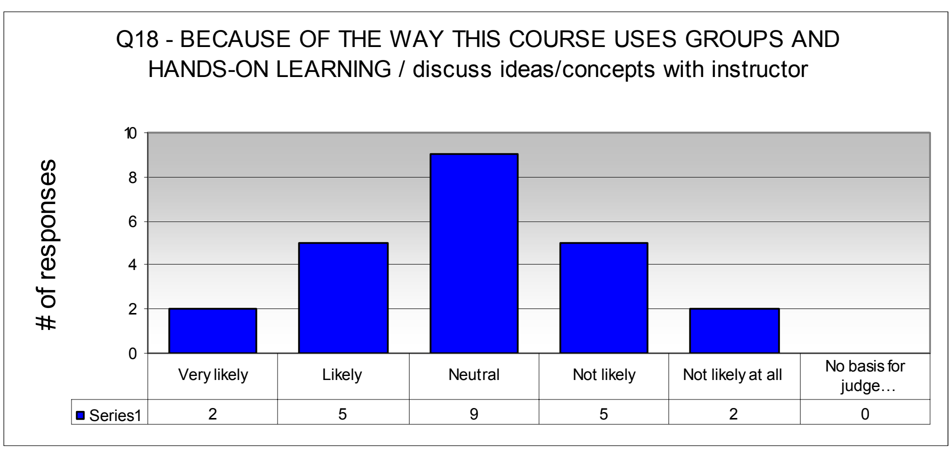
Because of the **HANDS-ON GROUP LEARNING** assignments used in this course:						
(mark the appropriate circle, select only one response per question)						
how likely *were* you to...	Very Likely	Likely	Neutral	Not likely	Not Likely at all	No Basis for Judgment/Not Applicable
76. tell the instructor when you have a complaint or suggestion about the course	❍	❍	❍	❍	❍	❍



Because of the **HANDS-ON GROUP LEARNING** assignments used in this course:							
(mark the appropriate circle, select only one response per question)							
how likely *were* you to...		Very Likely	Likely	Neutral	Not likely	Not Likely at all	No Basis for Judgment/Not Applicable
77.	feel isolated from the instructor	❍	❍	❍	❍	❍	❍



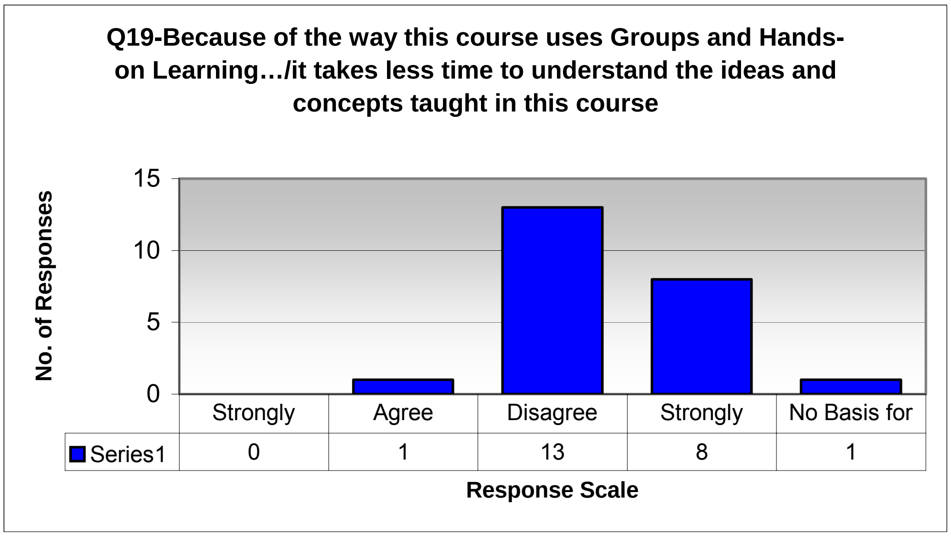
Because of the **HANDS-ON GROUP LEARNING** assignments used in this course:							
(mark the appropriate circle, select only one response per question)							
how likely *were* you to...		Very Likely	Likely	Neutral	Not likely	Not Likely at all	No Basis for Judgment/Not Applicable
78.	discuss the ideas and concepts taught in this course with the instructor	❍	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

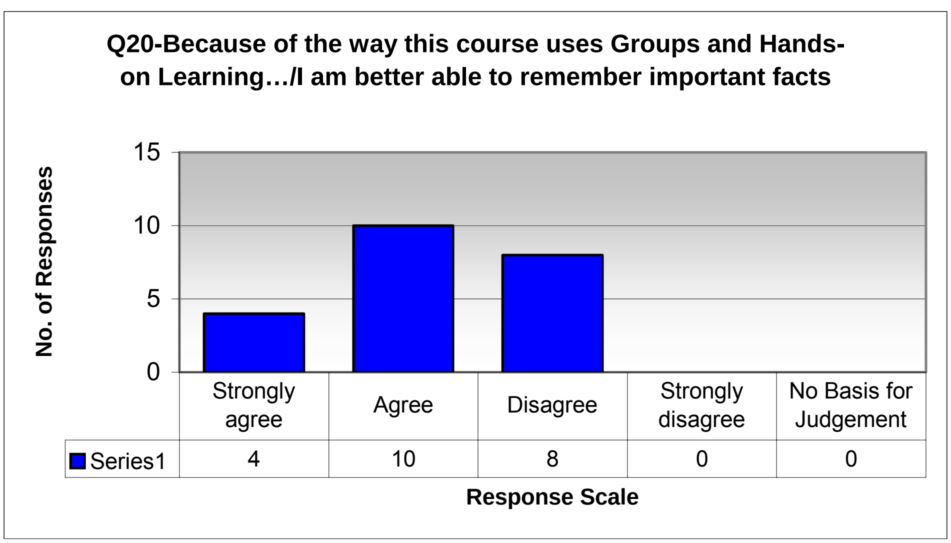
	Because of the way this course uses Groups and Hands-on Learning...	Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
79.	it takes less time to understand the ideas and concepts taught in this course	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

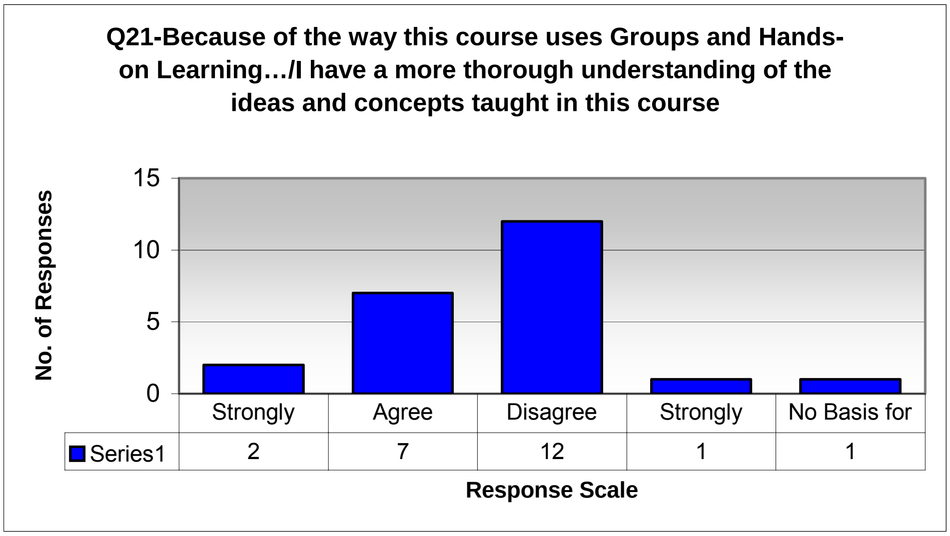
	Because of the way this course uses Groups and Hands-on Learning...	Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
80.	I am better able to remember important facts	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

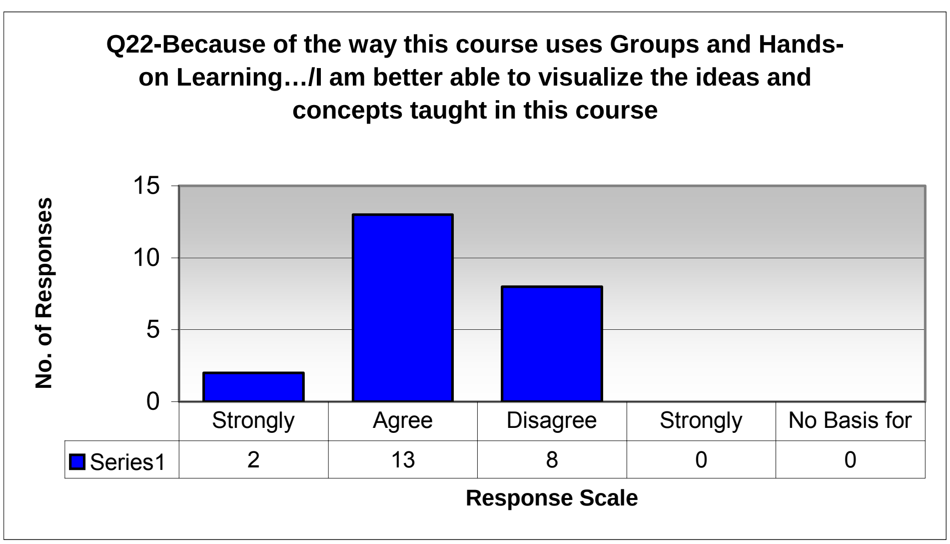
Because of the way this course uses Groups and **Hands-on Learning**...		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
81.	I have a more thorough understanding of the ideas and concepts taught in this course	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

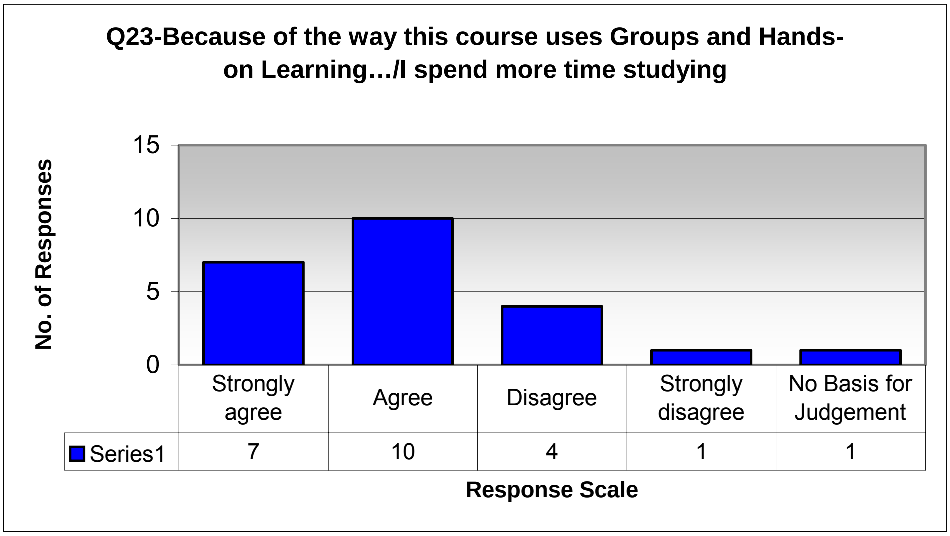
Because of the way this course uses Groups and **Hands-on Learning**...		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
82.	I am better able to visualize the ideas and concepts taught in this course	❍	❍	❍	❍	❍



Indicate how strongly you agree or disagree with each of the following statements:

(mark the appropriate circle, select only one response per question)

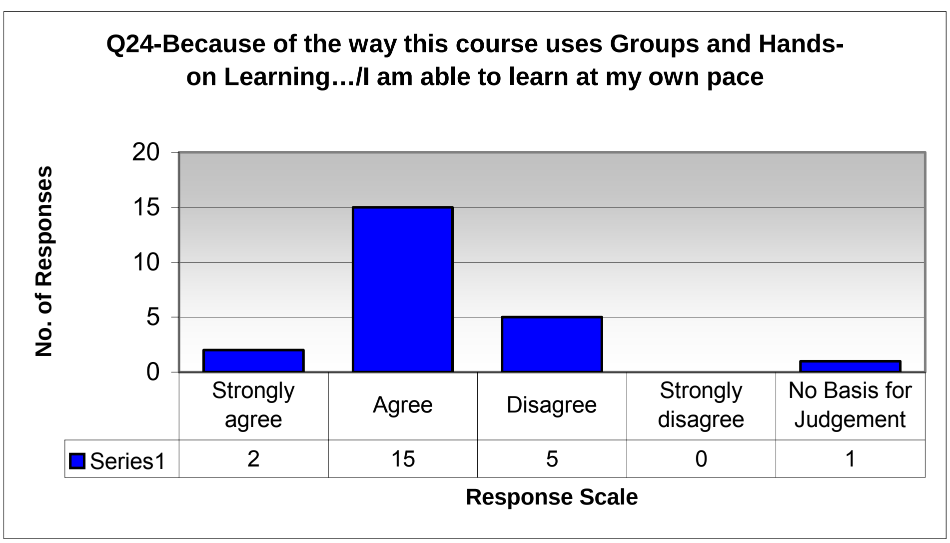
Because of the way this course uses Groups and **Hands-on Learning...**	Strongly Agree	Agree	Disagree	Strongly Disagree	No Basis for Judgment/ Not Applicable
83. I spend more time studying	❍	❍	❍	❍	❍



Indicate how strongly you agree or disagree with each of the following statements:

(mark the appropriate circle, select only one response per question)

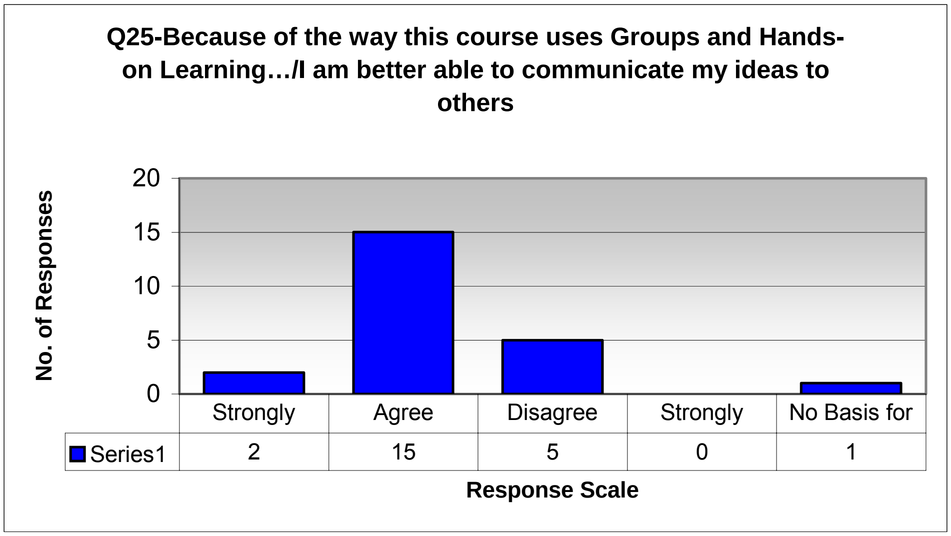
Because of the way this course uses Groups and **Hands-on Learning...**	Strongly Agree	Agree	Disagree	Strongly Disagree	No Basis for Judgment/ Not Applicable
84. I am able to learn at my own pace	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

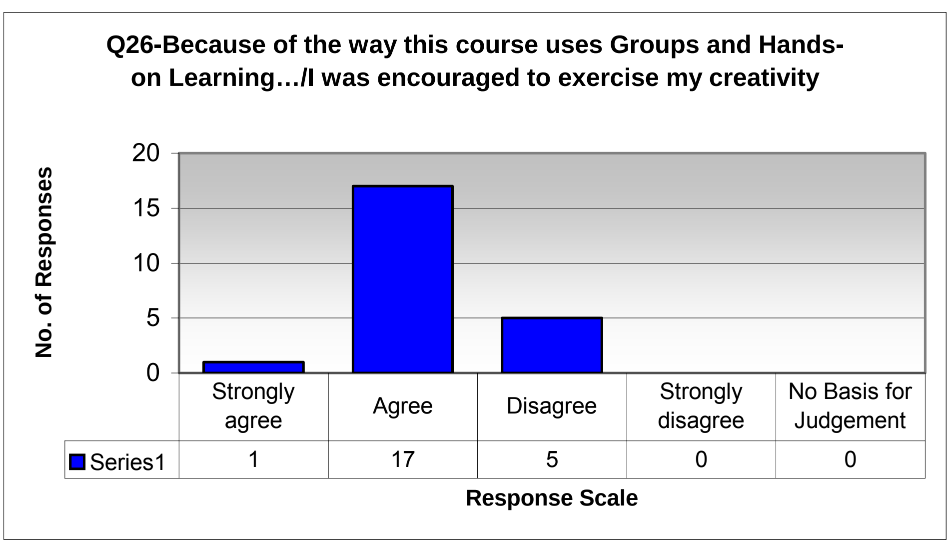
Because of the way this course uses Groups and Hands-on Learning...	Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
85. I am better able to communicate my ideas to others	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

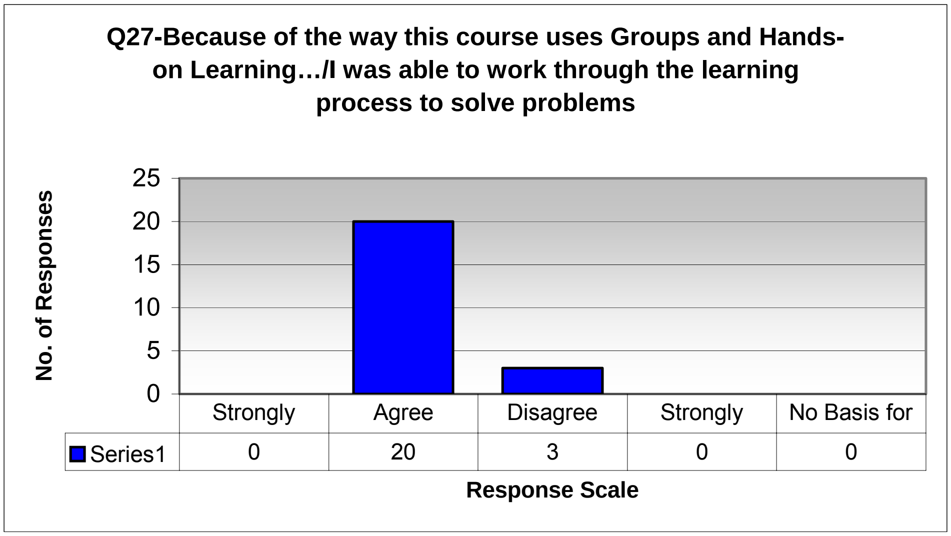
Because of the way this course uses Groups and Hands-on Learning...	Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
86. I was encouraged to exercise my creativity	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

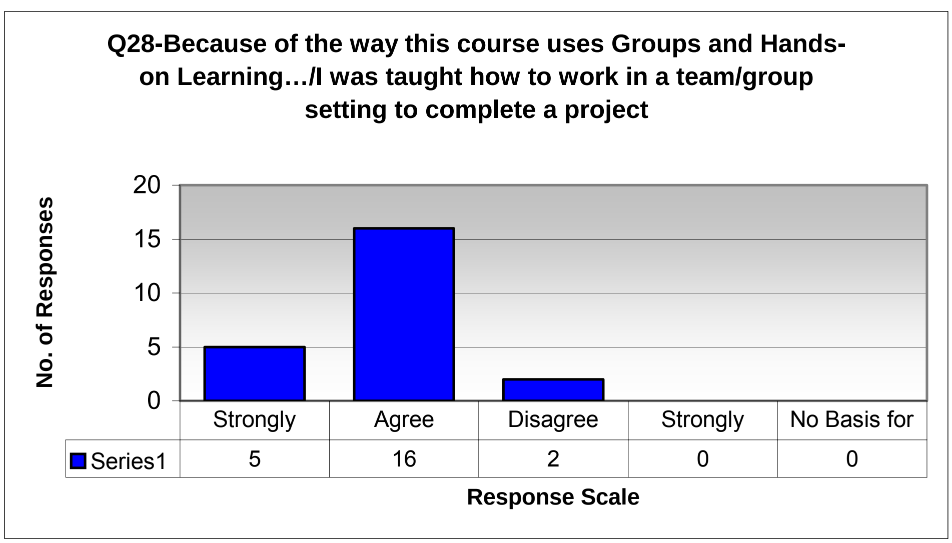
Because of the way this course uses Groups and Hands-on Learning...		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
87.	I was able to work through the learning process to solve problems	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

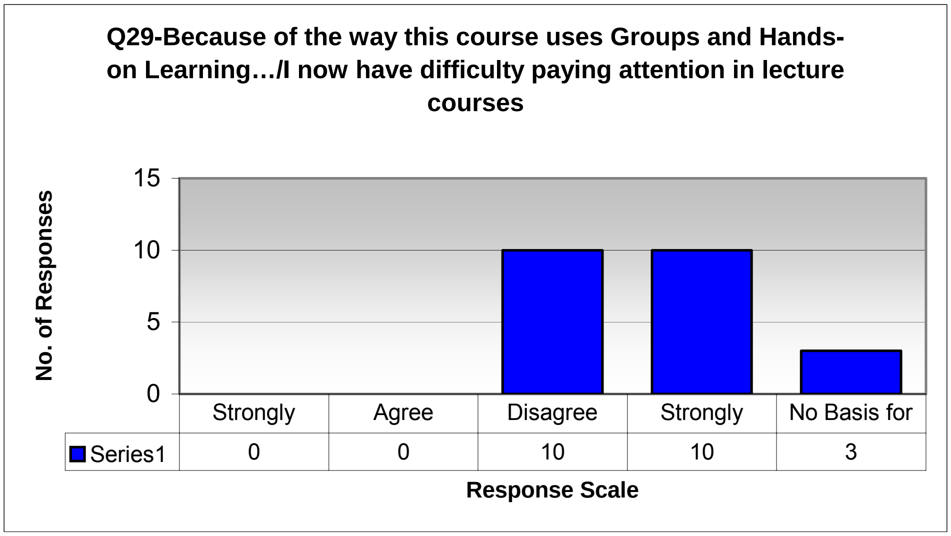
Because of the way this course uses Groups and Hands-on Learning...		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
88.	I was taught how to work in a team/group setting to complete a project	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

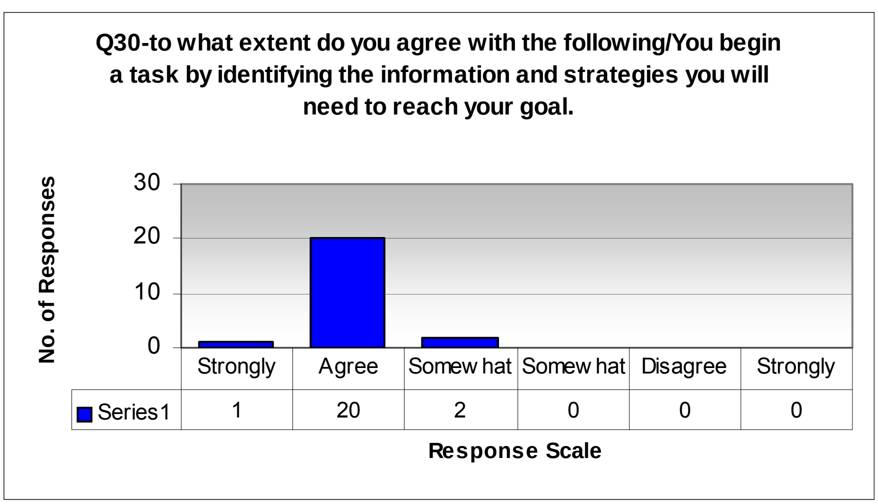
	Because of the way this course uses Groups and Hands-on Learning...	Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
89.	I now have difficulty paying attention in lecture courses	❍	❍	❍	❍	❍



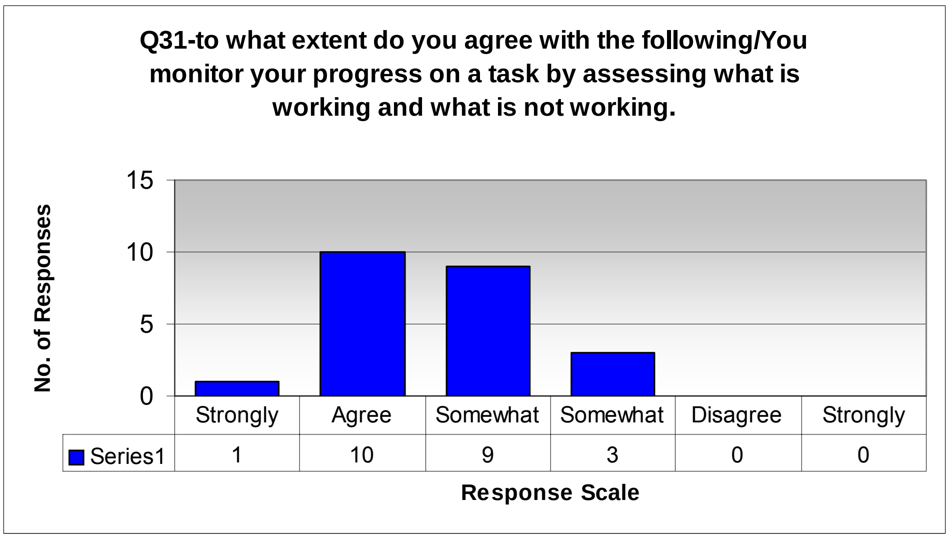
In an effort to meet your intended learning outcome, to what extent do you agree with the following?

(mark the appropriate circle, select only one response per question)

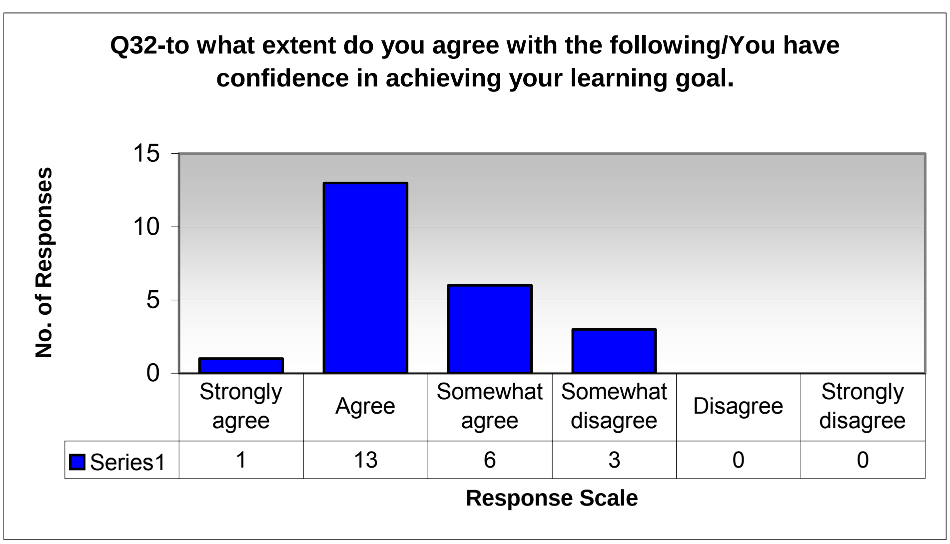
		Strongly agree	Agree	Somewhat agree	Somewhat disagree	Disagree	Strongly disagree
90.	You begin a task by identifying the information and strategies you will need to reach your goal.	❍	❍	❍	❍	❍	❍



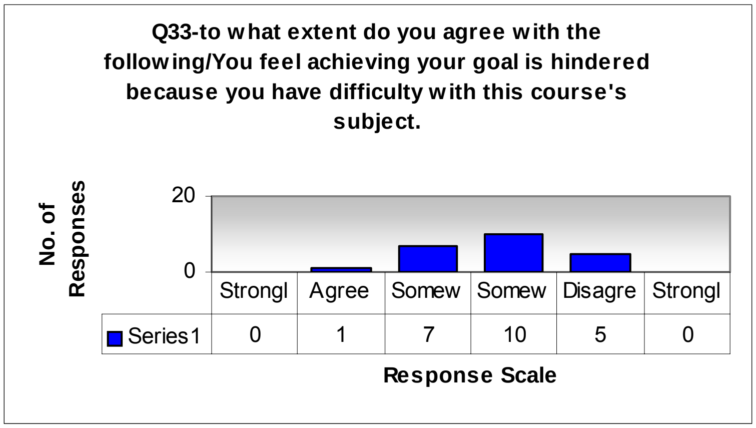
In an effort to meet your intended learning outcome, to what extent do you agree with the following?						
(mark the appropriate circle, select only one response per question)						
	Strongly agree	Agree	Somewhat agree	Somewhat disagree	Disagree	Strongly disagree
91. You monitor your progress on a task by assessing what is working and what is not working.	❍	❍	❍	❍	❍	❍



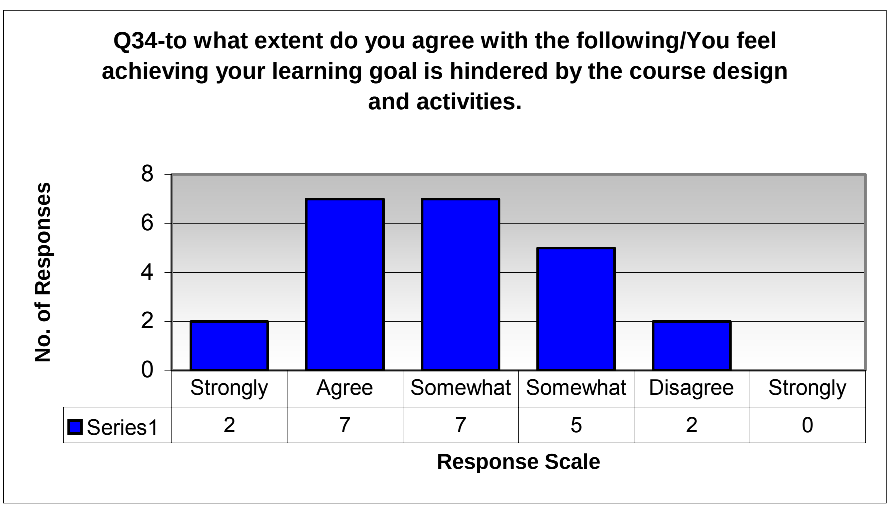
In an effort to meet your intended learning outcome, to what extent do you agree with the following?						
(mark the appropriate circle, select only one response per question)						
	Strongly agree	Agree	Somewhat agree	Somewhat disagree	Disagree	Strongly disagree
92. You have confidence in achieving your learning goal.	❍	❍	❍	❍	❍	❍



In an effort to meet your intended learning outcome, to what extent do you agree with the following?						
(mark the appropriate circle, select only one response per question)						
	Strongly agree	Agree	Somewhat agree	Somewhat disagree	Disagree	Strongly disagree
93. You feel achieving your goal is hindered because you have difficulty with this course's subject.	❍	❍	❍	❍	❍	❍



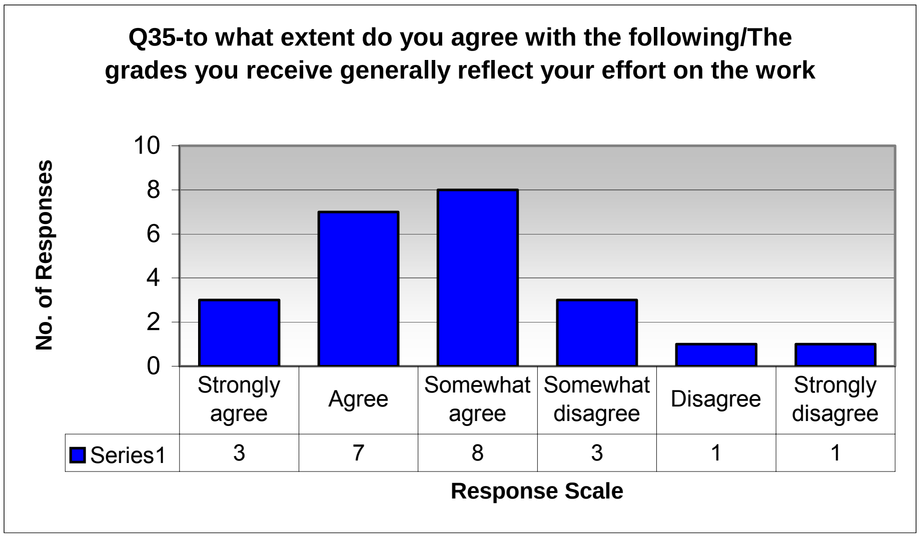
In an effort to meet your intended learning outcome, to what extent do you agree with the following?						
(mark the appropriate circle, select only one response per question)						
	Strongly agree	Agree	Somewhat agree	Somewhat disagree	Disagree	Strongly disagree
94. You feel achieving your learning goal is hindered by the course design and activities.	❍	❍	❍	❍	❍	❍



In an effort to meet your intended learning outcome, to what extent do you agree with the following?

(mark the appropriate circle, select only one response per question)

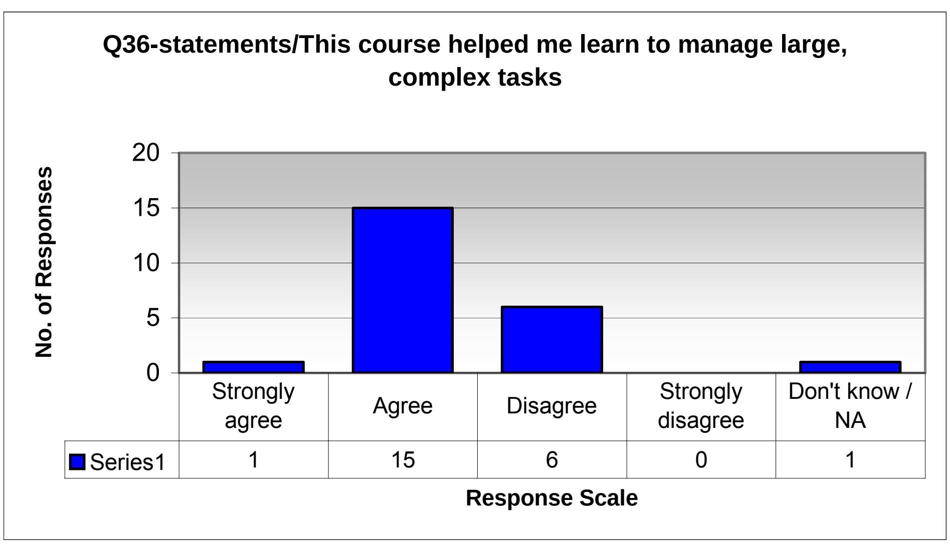
		Strongly agree	Agree	Somewhat agree	Somewhat disagree	Disagree	Strongly disagree
95.	The grades you receive generally reflect your effort on the work	❍	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

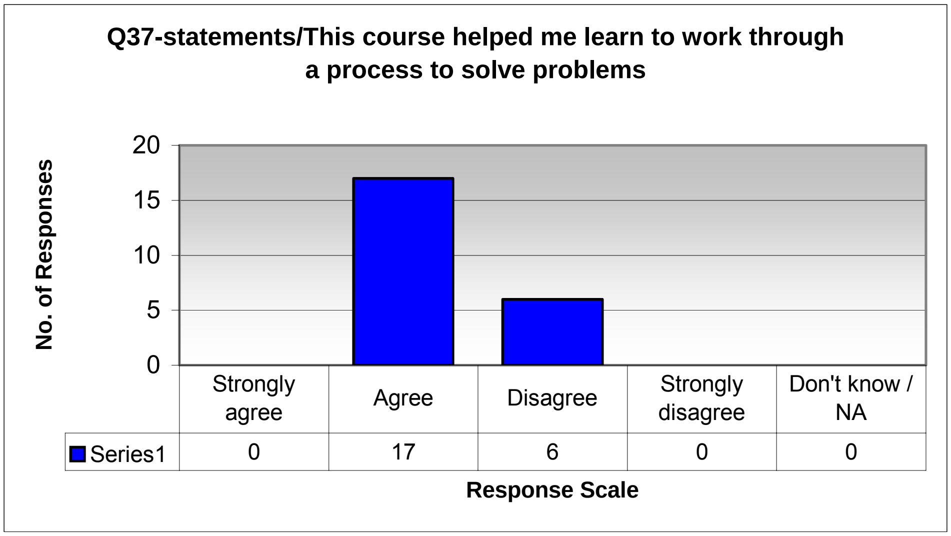
		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	Don't Know/ Not Applicable
96.	This course helped me learn to manage large, complex tasks	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

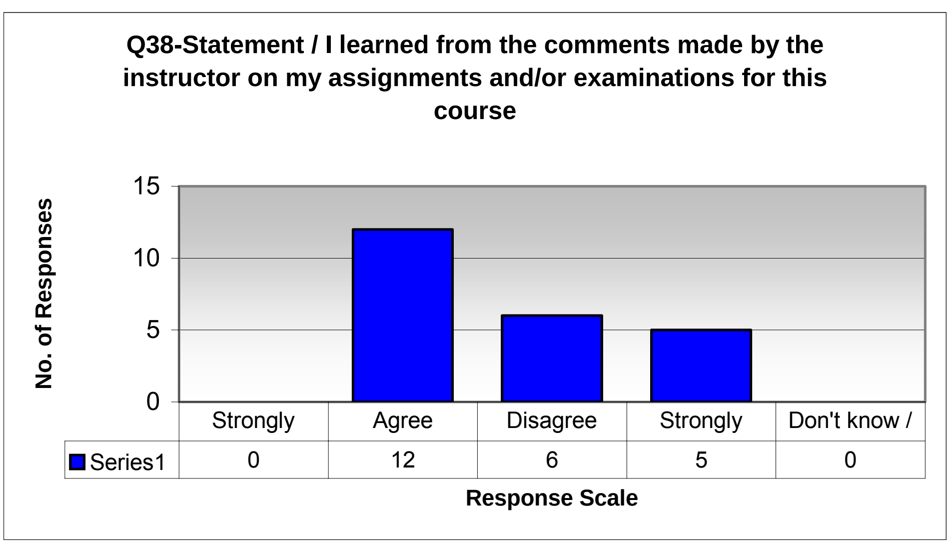
		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	Don't Know/ Not Applicable
97.	This course helped me learn to work through a process to solve problems	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

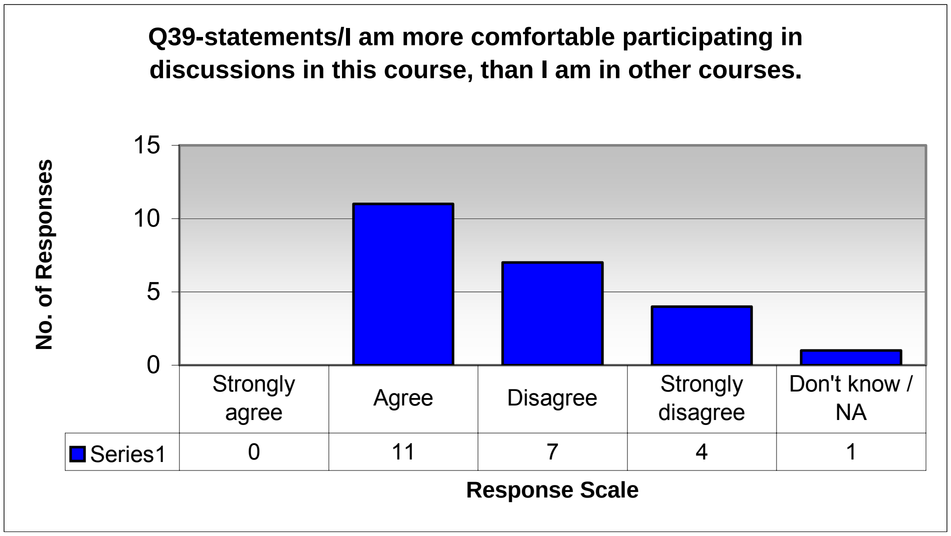
		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	Don't Know/ Not Applicable
98.	I learned from the comments made by the instructor on my assignments and/or examinations for this course	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

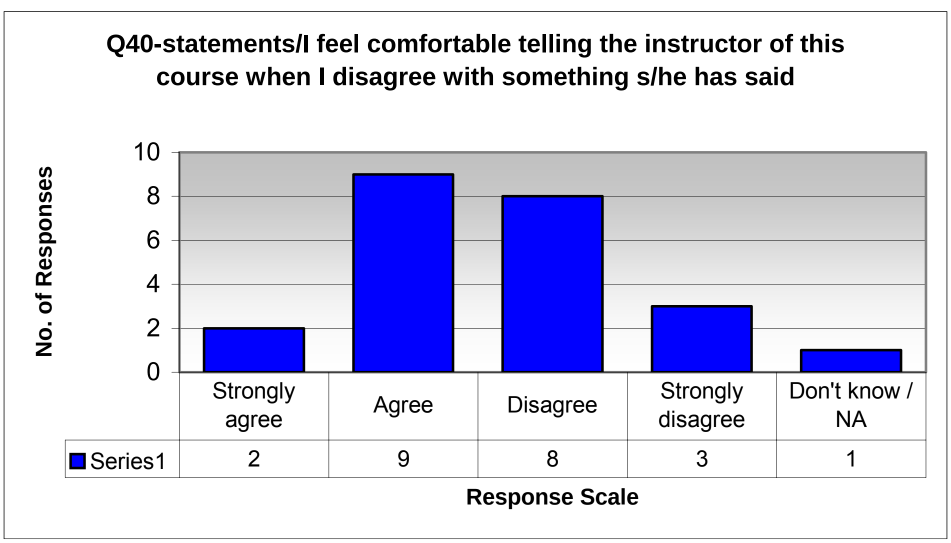
		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	Don't Know/ Not Applicable
99.	I am more comfortable participating in discussions in <u>this course</u>, than I am in other courses.	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

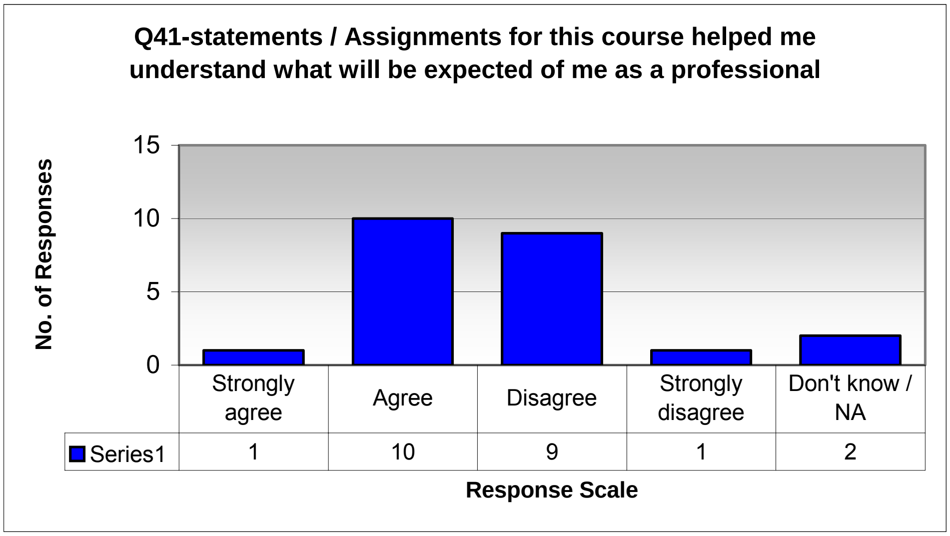
		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	Don't Know/ Not Applicable
100	I feel comfortable telling the instructor of <u>this course</u> when I disagree with something s/he has said	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

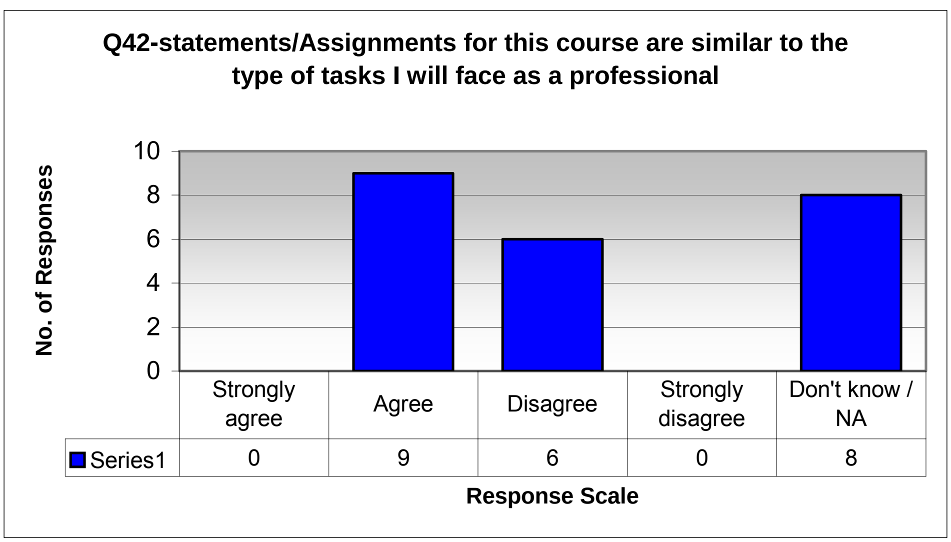
		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	Don't Know/ Not Applicable
101	Assignments for this course helped me understand what will be expected of me as a professional	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

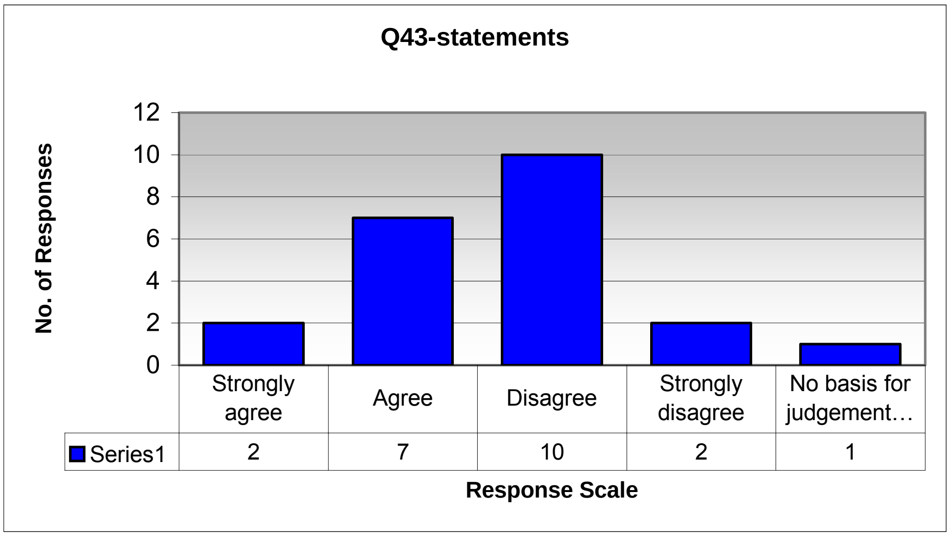
		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	Don't Know/ Not Applicable
102	Assignments for this course are similar to the type of tasks I will face as a professional	❍	❍	❍	❍	❍



To what extent do you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

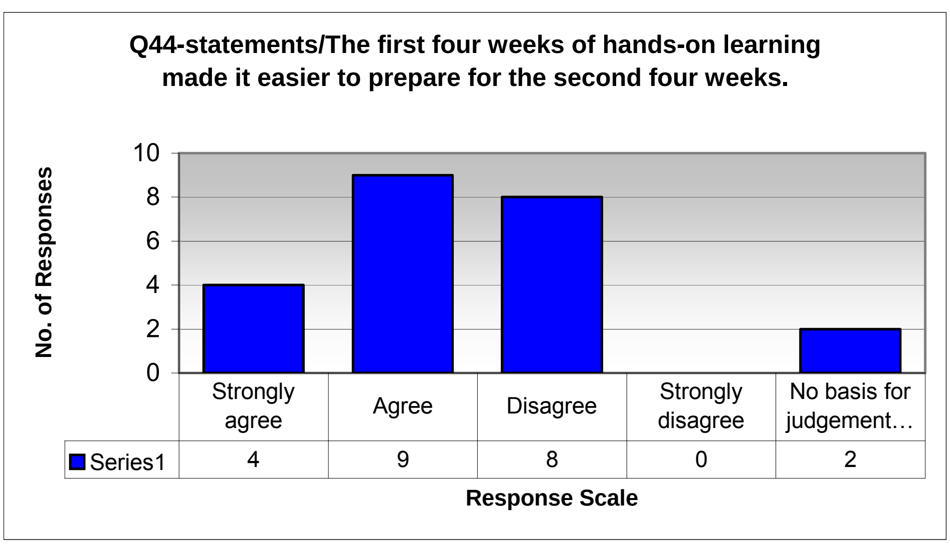
		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
103	The first four weeks of hands-on learning made it easier to prepare for the second four weeks.	❍	❍	❍	❍	❍



To what extent do you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

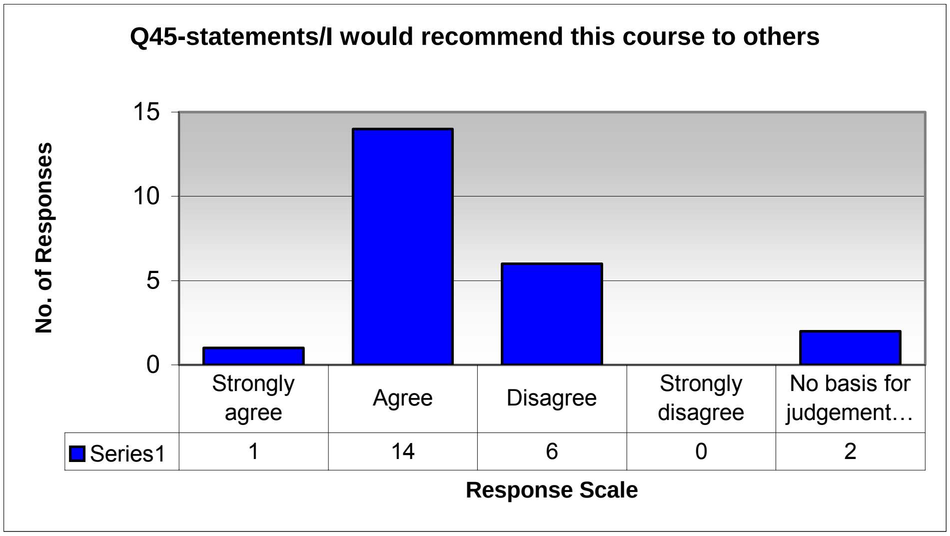
		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
104	The hands-on technique used in this course is overrated	❍	❍	❍	❍	❍



To what extent do you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

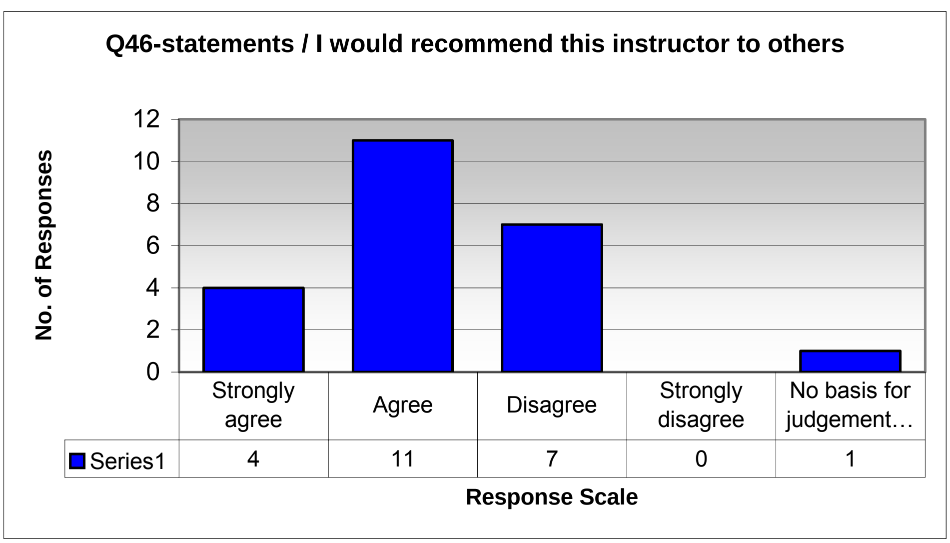
		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
105	I would recommend this course to others	❍	❍	❍	❍	❍



To what extent do you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
106	I would recommend this instructor to others	❍	❍	❍	❍	❍

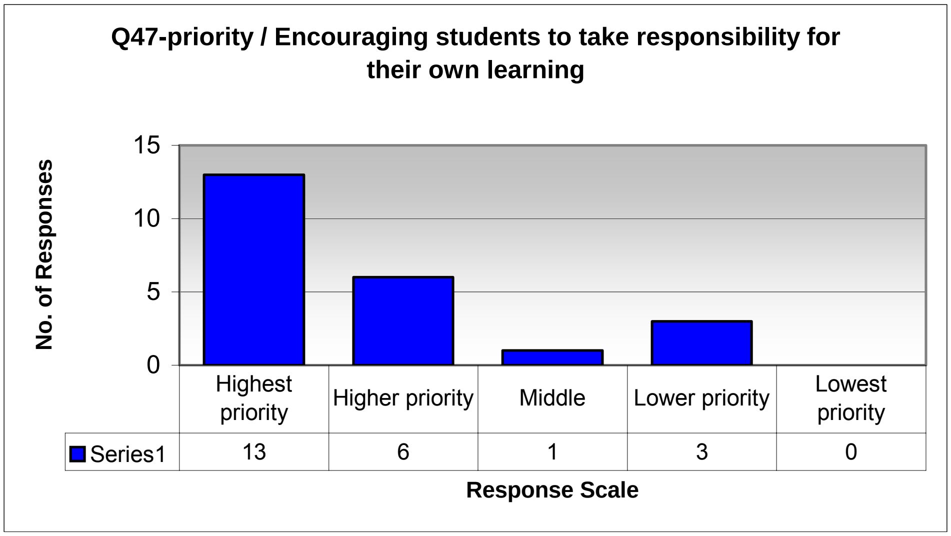


In your opinion, to what extent were each of the following given **priority** in this course:

Please rate each of the following from 1 to 5 where: *1 is the lowest priority, and 5 is the highest priority*

(circle the appropriate number, select only one response)

107	Encouraging students to take responsibility for their own learning	1	2	3	4	5

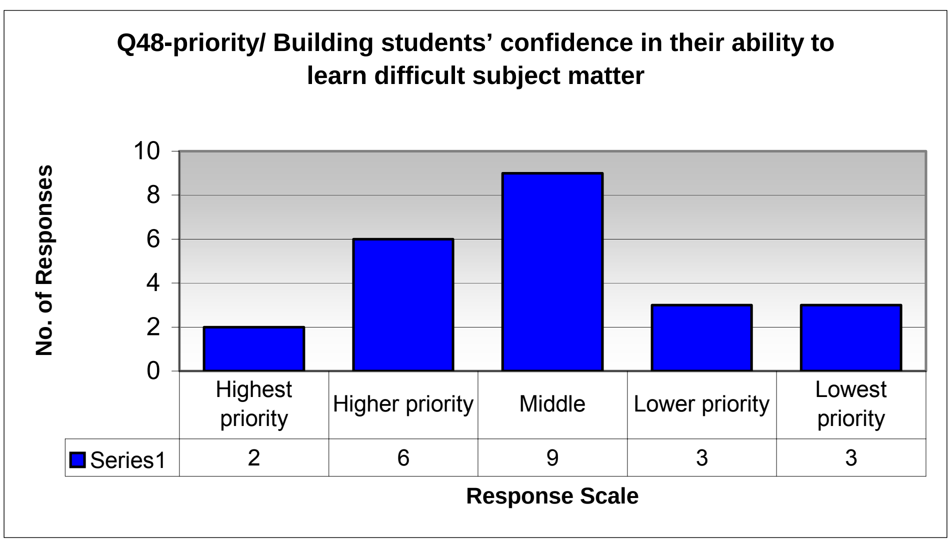


In your opinion, to what extent were each of the following given **priority** in this course:

Please rate each of the following from 1 to 5 where: *1 is the lowest priority, and 5 is the highest priority*

(circle the appropriate number, select only one response)

108	Building students' confidence in their ability to learn difficult subject matter	1	2	3	4	5

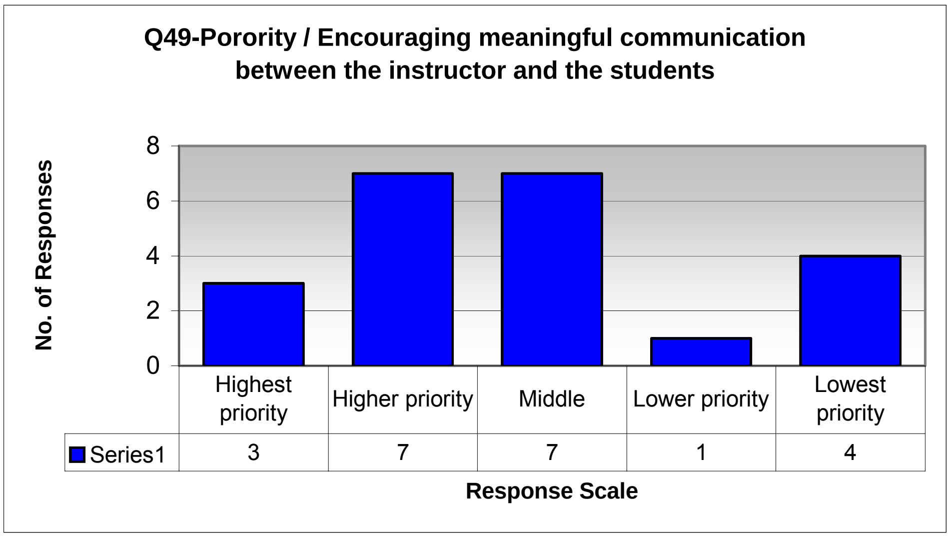


In your opinion, to what extent were each of the following given **priority** in this course:

Please rate each of the following from 1 to 5 where: *1 is the lowest priority, and 5 is the highest priority*

(circle the appropriate number, select only one response)

109	Encouraging meaningful communication between the instructor and the students	1	2	3	4	5

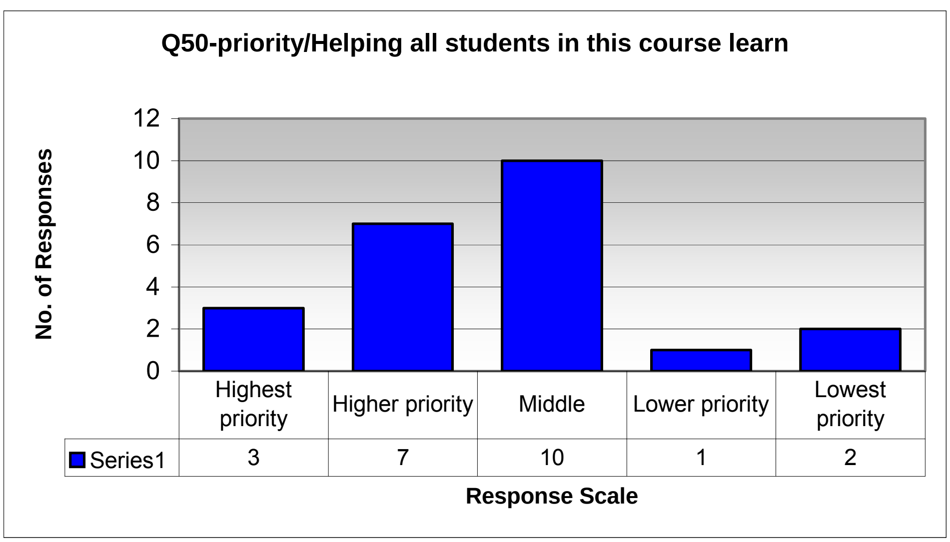


In your opinion, to what extent were each of the following given **priority** in this course:

Please rate each of the following from 1 to 5 where: *1 is the lowest priority, and 5 is the highest priority*

(circle the appropriate number, select only one response)

110	Helping all students in this course learn	1	2	3	4	5

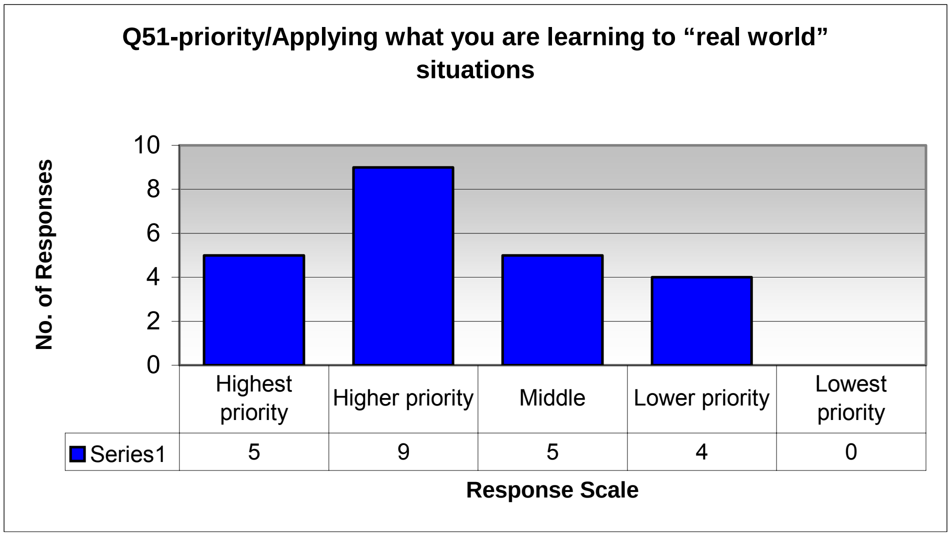


In your opinion, to what extent were each of the following given **priority** in this course:

Please rate each of the following from 1 to 5 where: *1 is the lowest priority, and 5 is the highest priority*

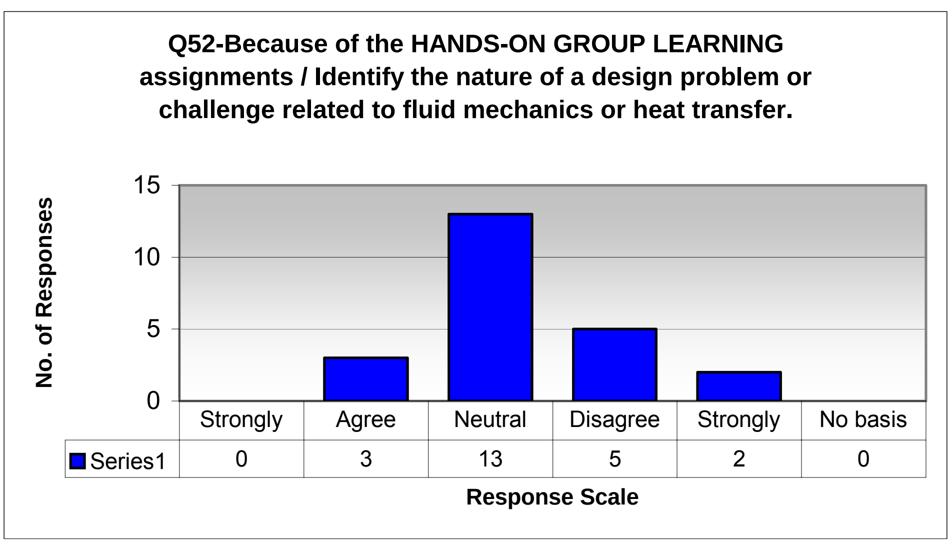
(circle the appropriate number, select only one response)

111	Applying what you are learning to "real world" situations	1	2	3	4	5

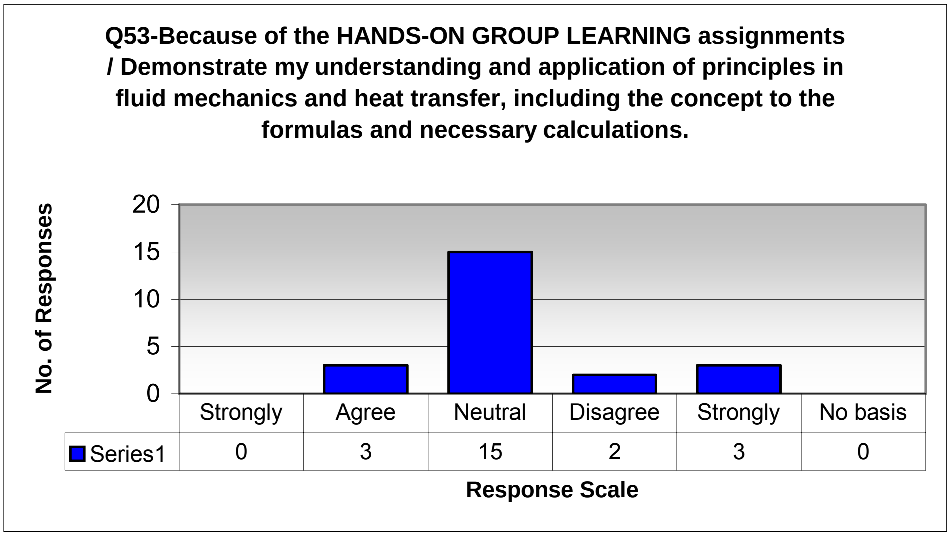


Because of the **HANDS-ON GROUP LEARNING** assignments used in this course I am better able now than at the beginning of the course to:

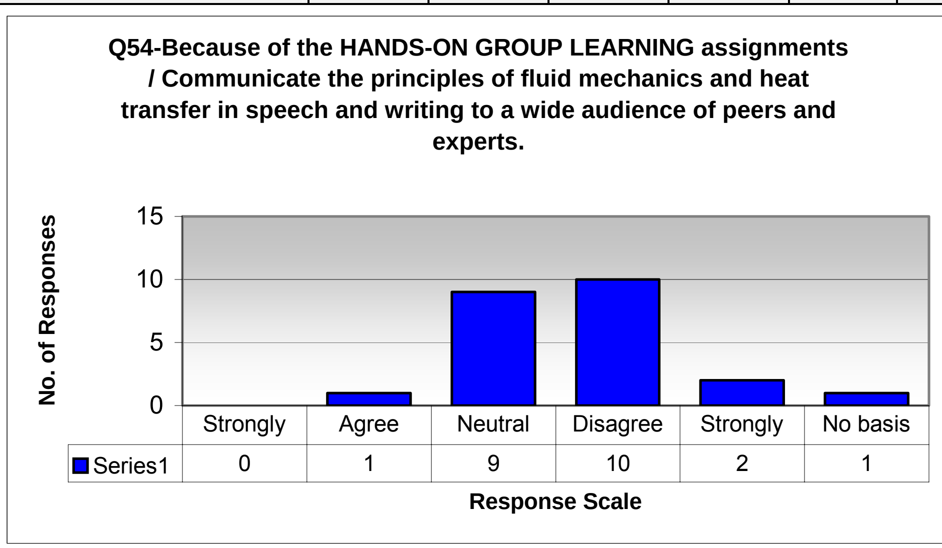
		Strongly agree	Agree	Neutral	Disagree	Strongly disagree	No Basis for Judgment/Not Applicable
112	Identify the nature of a design problem or challenge related to fluid mechanics or heat transfer.	❍	❍	❍	❍	❍	❍



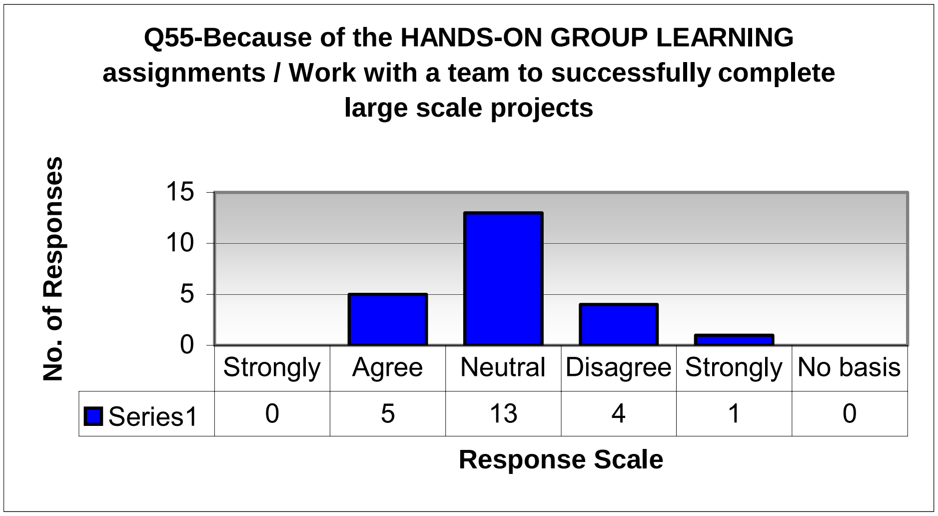
Because of the **HANDS-ON GROUP LEARNING** assignments used in this course I am better able now than at the beginning of the course to:		Strongly agree	Agree	Neutral	Disagree	Strongly disagree	No Basis for Judgment/Not Applicable
113	Demonstrate my understanding and application of principles in fluid mechanics and heat transfer, including the concept to the formulas and necessary calculations.	❍	❍	❍	❍	❍	❍



Because of the **HANDS-ON GROUP LEARNING** assignments used in this course I am better able now than at the beginning of the course to:		Strongly agree	Agree	Neutral	Disagree	Strongly disagree	No Basis for Judgment/Not Applicable
114	Communicate the principles of fluid mechanics and heat transfer in speech and writing to a wide audience of peers and experts.	❍	❍	❍	❍	❍	❍

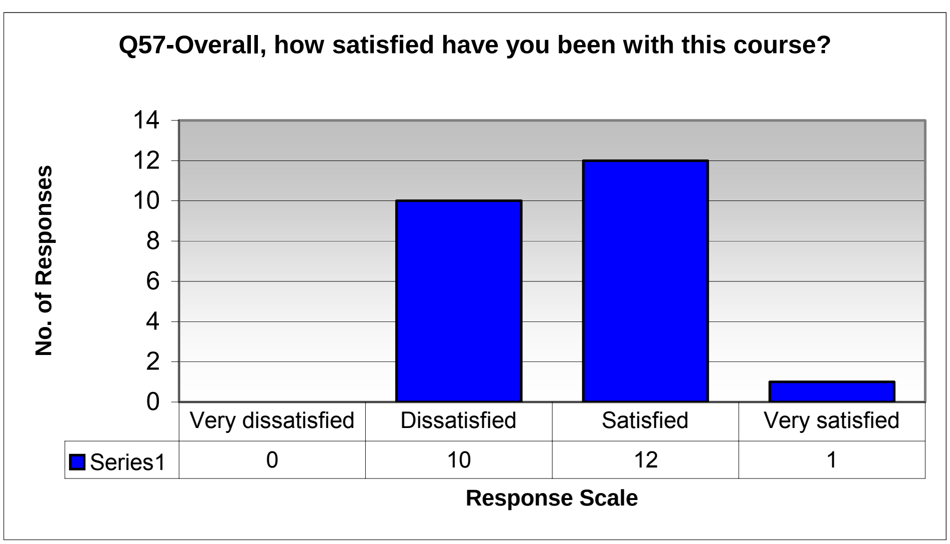


Because of the **HANDS-ON GROUP LEARNING** assignments used in this course I am better able now than at the beginning of the course to:							
		Strongly agree	Agree	Neutral	Disagree	Strongly disagree	No Basis for Judgment/Not Applicable
115	Work with a team to successfully complete large scale projects	❍	❍	❍	❍	❍	❍



57. Overall, how satisfied have you been with this course?

- ❍ very dissatisfied
- ❍ dissatisfied
- ❍ satisfied
- ❍ very satisfied

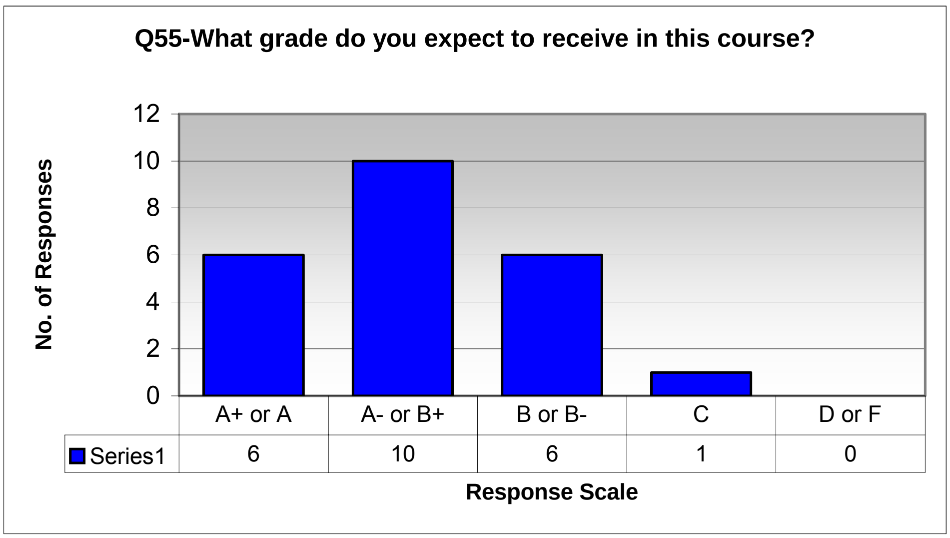


54. What additional comments do you want to say about Chemical Engineering 332? (please specify)

---

55. What grade do you expect to receive in this course? (mark the appropriate circle, select only one)

❍ A+ or A ❍ A- or B+ ❍ B or B- ❍ C ❍ D or F



Chemical Engineering 332

Question 54. What additional comments do you want to say about Dhemical Engineering 332? (please specify)

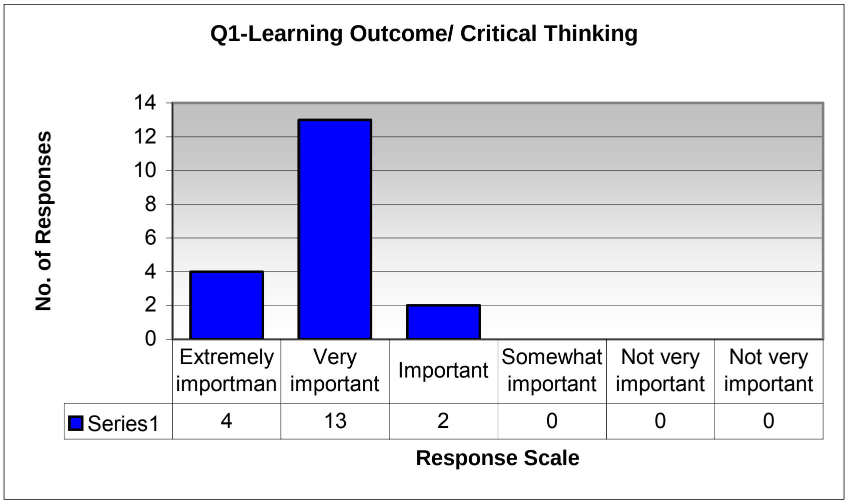
This course should be hands on. I think that the second project is one project too much, but it is valuable if everyone cares the same amt about getting it done. I think working with others has helped this experience to be positive and beneficial. There are too many surveys and 390(?) shouldn't be attached to the course.
The class needed more lecture. If there could be one to two sessions of hands-on learning and then one lecture to clarify the things learned and expand(?) on hands-on learning After ...when a student learns a subject from a … or other relevant materials, misunderstandings can occur. I thought the whole reason I paid tuition was to have a professor there to clarify misunderstandings.
I did not think there was enough lecture for how much time we spent in the lab. For all other labs I have ever taken there is usually at least 1 hour of lecture for every hour spent in the lab. It makes the students understand their goals better and reach them faster.
No response
I believe that there was no balance in this class. There was way too much hands-on and not enough lecture to back it up. I felt in the dark much of the semester and felt a strong lack of guidance due to cancelled office hours and misdirection. I felt as though the professor did not really know what was happening and had a very weak understanding of the material.
It needs more lecturing. The group learning is a good idea if it was supplemented with some teaching from the instructor. Without lecturing, like this class, I felt like I was struggling and it felt like I was spending way too much time. Also I wasn't sure all the time if I was approaching and working out problems correctly.
It needed more lecture and less hands-on. It also could have been …
BVW was stretched so thin that you could see the whiteboard through him. This class always depends on the prof.
Too demanding for only 2 credits
In this course, the fluids section was taught much better than the heat transfer section. I understand fluids very well but I am still rather clueless about most situations in heat transfer, mostly because of the way this section was taught. The concept of having group projects is great and I got a lot out of that, but having the groups lecture the class was extremely ineffective.
The major problem I have is that we didn't have enough lectures. A few lectures are needed to help set a basic understanding and to ensure that basic ideas are learned by all. The professor needs to be more open to individual questions. I would go ask a question and my question wasn't received because I wasn't with my group. Also, we spend a lot of time just standing around in the lab. Yes, the lab was useful, but 1 or 2 class periods was sufficient everytime after that was a waste of time and could've been better used as lecture time.
I think there should be at least SOME lecture from Bernie. The class was too large to have this group learning process work in both a classroom & lab. During the lab there was not enough of Van Wie(?).

A little more lecture on heat transfer may have been nice.
I feel that there needed to be more lectures so that at least the material was introduced before we were put in the lab to learn the material on our own. Sometimes, when group members are not doing will in the course in the beginning they will give up and not pull their weight on group projects.
I personally felt there was too much time spent in the hands-on environment with nothing to do and no background information to work from. Not enough lecture time before the lab to really make the hands on beneficial, as most time was spent off task. Only so much can be learned from watching water flow through a pipe. Office hours were cancelled to often, making homework very discouraging. Tough to have groups, when a member assumes they will fail the course so they refuse to do quality work, or even work at all on a group assignment. Very hard on the other members to pull their weight.
No response
I like the way the first part of the semester (fluids portion) was organized compared to the second part. The fluids half began with two or three lectures as a general orientation to basic fluids concepts before we were put in the lab. For the heat transfer portion, we were directly put into the lab w/o receiving the basic concepts in a lecture.
No response
There was not enough lecturing in the 2nd half of this course. I felt that I could have learned a lot more if there had been lecturing. We spent too much time working on our specific project, w/out enough guidance by professor Van Wie.
No response.
I would like to see the instructor giving more directions to students.
Need lectures at least once every 1/2 weeks
I though it was frustrating to learn new topics in lab but in the long run. I think it helped our understanding. When students help other students, I think it's very helpful since they're on the same mindset. Handouts the groups made were very useful and easy to follow.

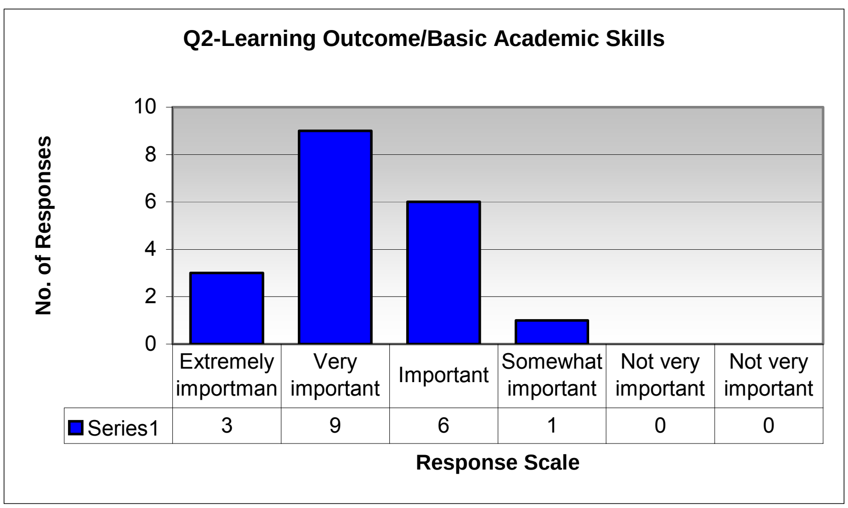
APPENDIX 2-C
SURVEY GIVEN IN 2002 TO CHE 334

Chemical Engineering 334 Spring 2002 Survey

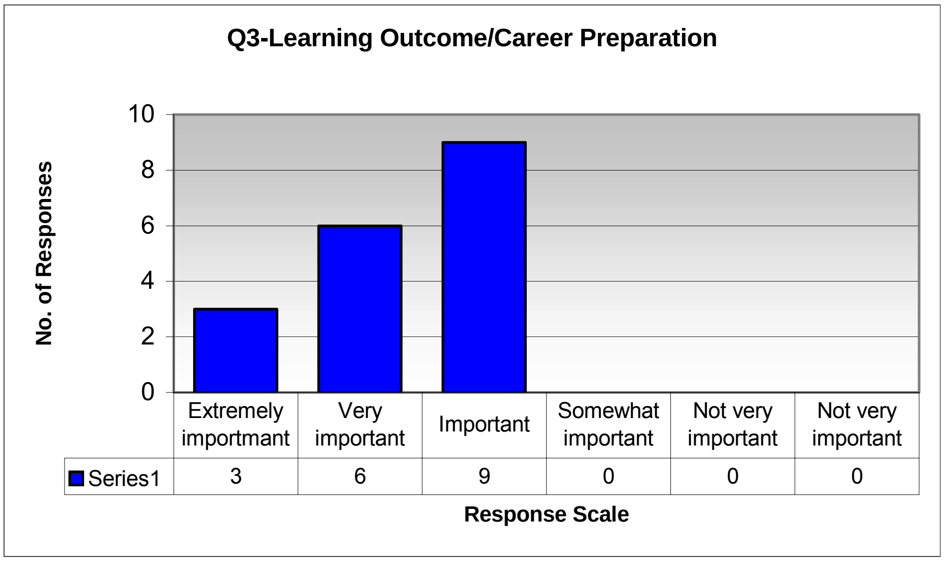
Please indicate the priority you place on the following learning outcomes in this course. (mark the appropriate circle, select only one response per question)		6 Extremely important	5 Very important	4 Important	3 Somewhat important	2 Not very important	1 - Not important at all
116	critical thinking skills	❍	❍	❍	❍	❍	❍



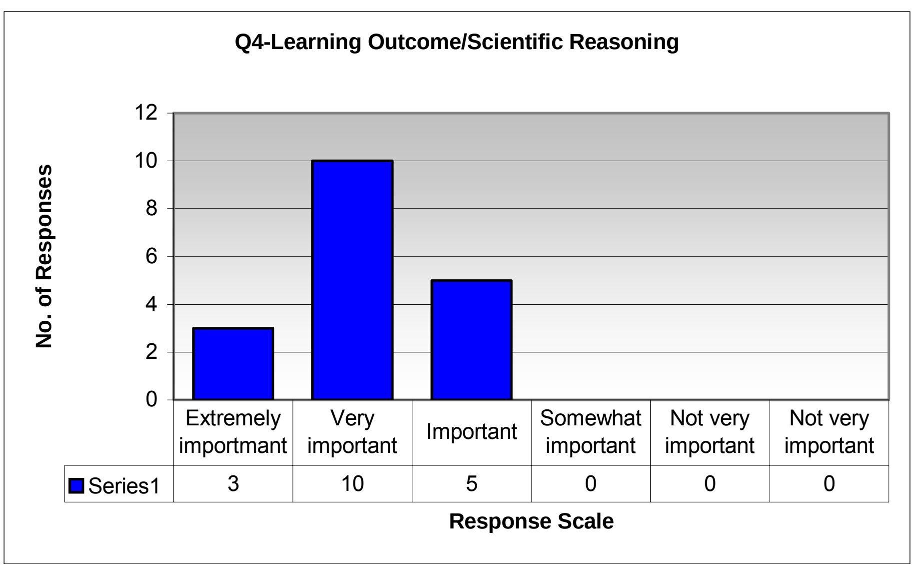
Please indicate the priority you place on the following learning outcomes in this course. (mark the appropriate circle, select only one response per question)		6 Extremely important	5 Very important	4 Important	3 Somewhat important	2 Not very important	1 - Not important at all
117	basic academic skills	❍	❍	❍	❍	❍	❍



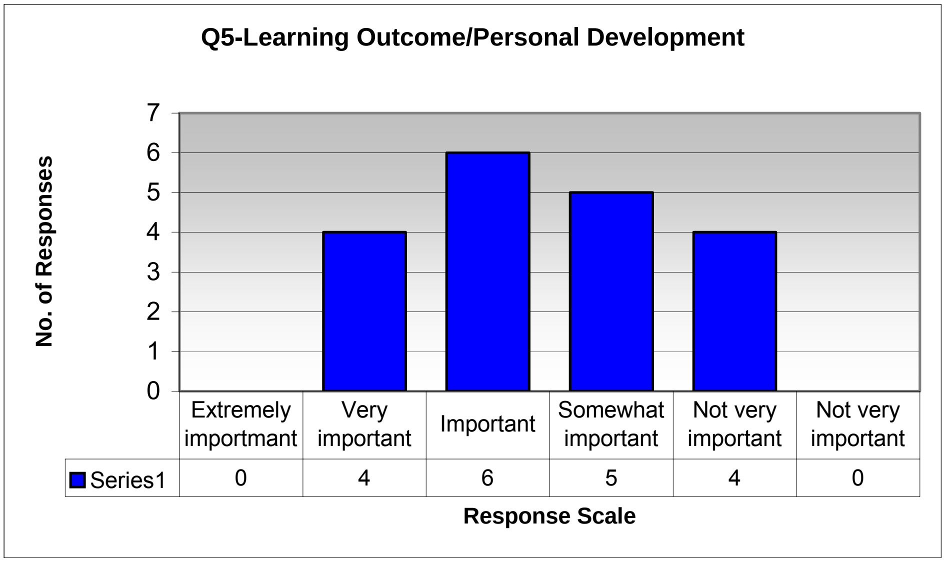
Please indicate the priority you place on the following learning outcomes in this course.						
(mark the appropriate circle, select only one response per question)						
	6 Extremely important	5 Very important	4 Important	3 Somewhat important	2 Not very important	1 - Not important at all
118 career preparation or advancement	❍	❍	❍	❍	❍	❍



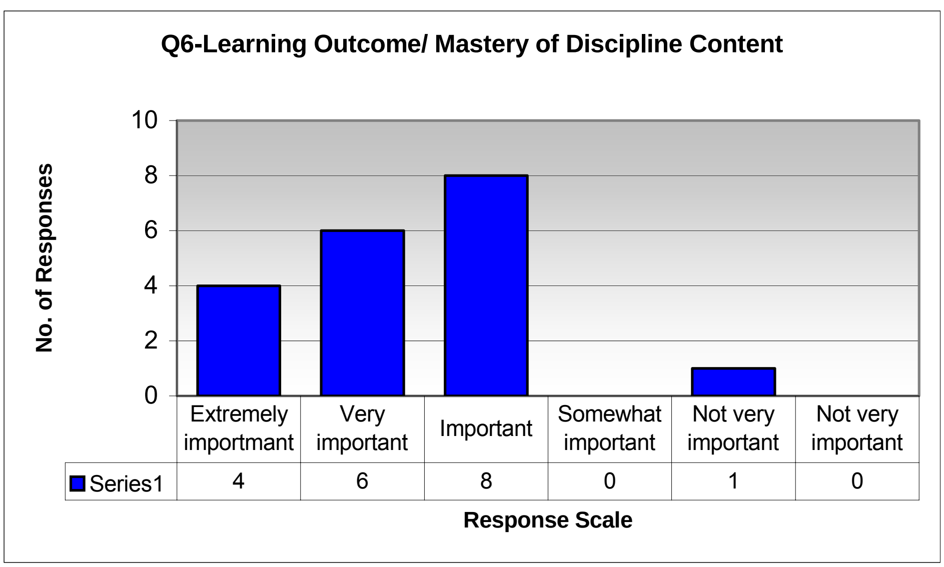
Please indicate the priority you place on the following learning outcomes in this course.						
(mark the appropriate circle, select only one response per question)						
	6 Extremely important	5 Very important	4 Important	3 Somewhat important	2 Not very important	1 - Not important at all
119 scientific reasoning	❍	❍	❍	❍	❍	❍



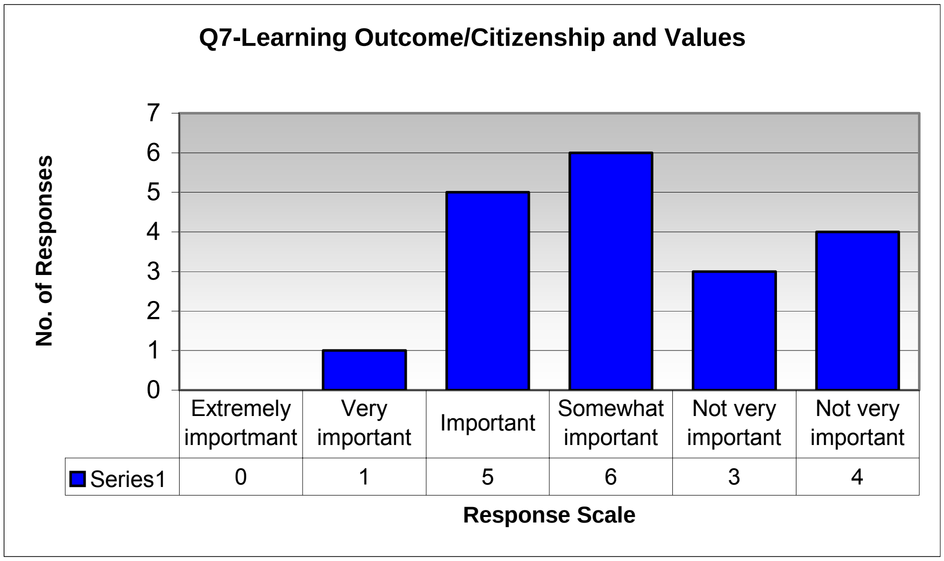
Please indicate the priority you place on the following learning outcomes in this course.							
(mark the appropriate circle, select only one response per question)							
		6 Extremely important	5 Very important	4 Important	3 Somewhat important	2 Not very important	1 - Not important at all
120	personal development	❍	❍	❍	❍	❍	❍



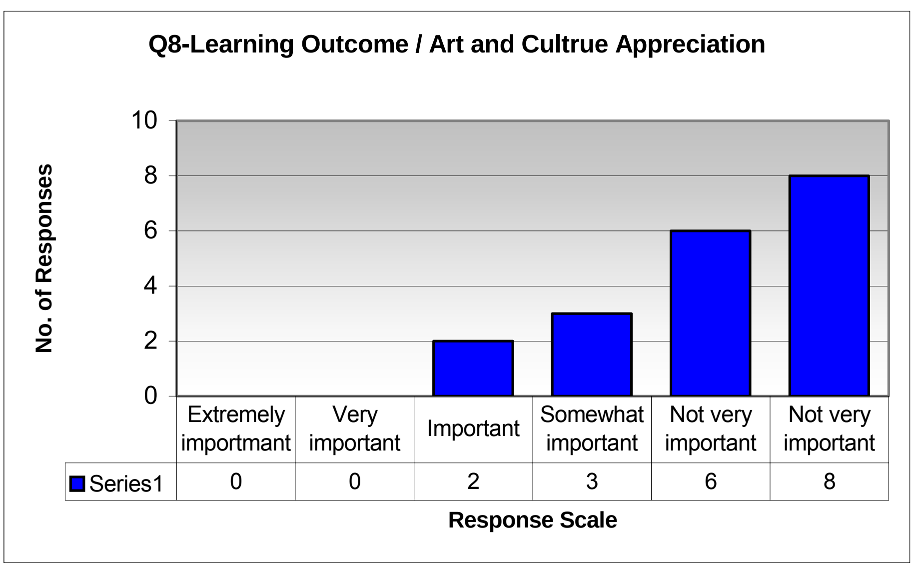
Please indicate the priority you place on the following learning outcomes in this course.							
(mark the appropriate circle, select only one response per question)							
		6 Extremely important	5 Very important	4 Important	3 Somewhat important	2 Not very important	1 - Not important at all
121	mastery of discipline content	❍	❍	❍	❍	❍	❍



Please indicate the priority you place on the following learning outcomes in this course.							
(mark the appropriate circle, select only one response per question)							
		6 Extremely important	5 Very important	4 Important	3 Somewhat important	2 Not very important	1 - Not important at all
122	citizenship and values	❍	❍	❍	❍	❍	❍



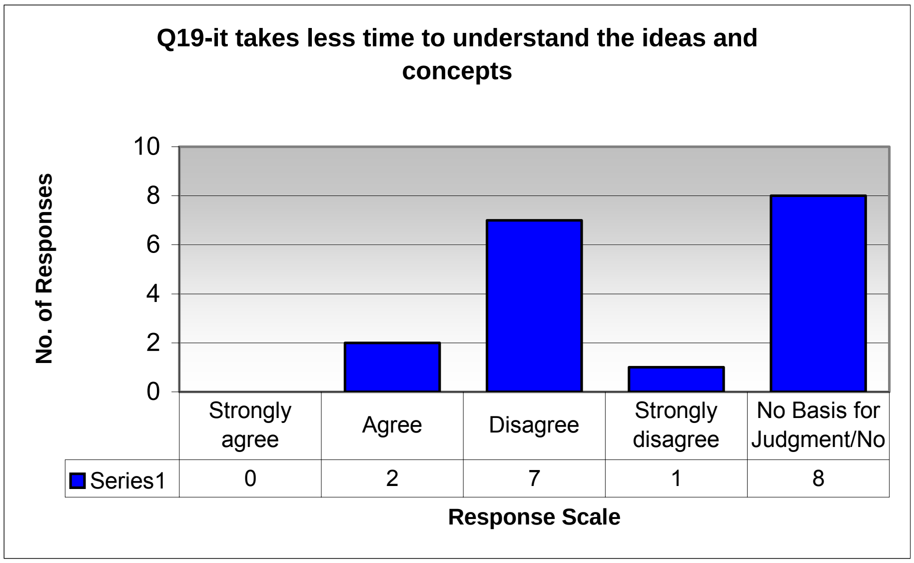
Please indicate the priority you place on the following learning outcomes in this course.							
(mark the appropriate circle, select only one response per question)							
		6 Extremely important	5 Very important	4 Important	3 Somewhat important	2 Not very important	1 - Not important at all
123	art and culture appreciation	❍	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

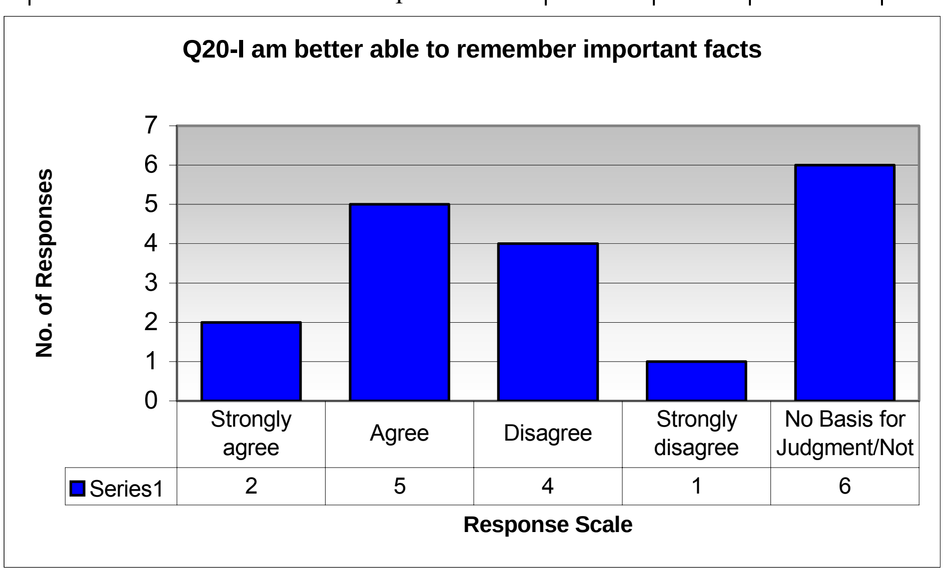
Because of the way this course uses Groups and Hands-on Learning...		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
19	it takes less time to understand the ideas and concepts taught in this course	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

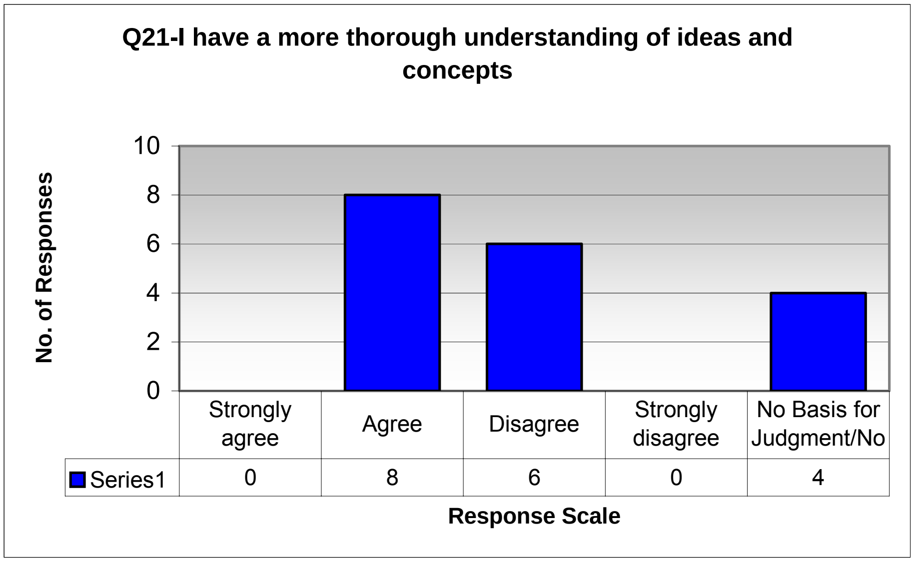
Because of the way this course uses Groups and Hands-on Learning...		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
20	I am better able to remember important facts	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

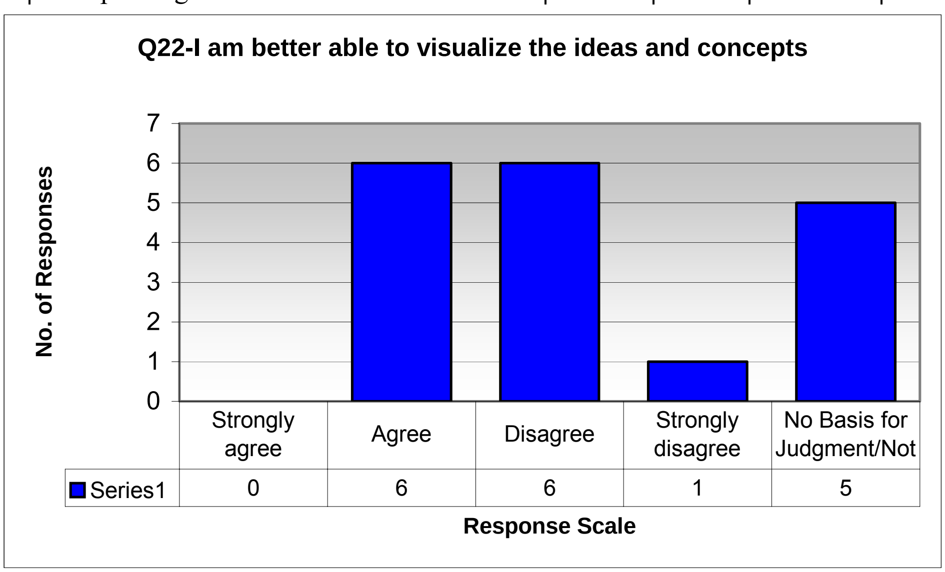
Because of the way this course uses Groups and Hands-on Learning...		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
21	I have a more thorough understanding of the ideas and concepts taught in this course	❍	❍	❍	❍	❍



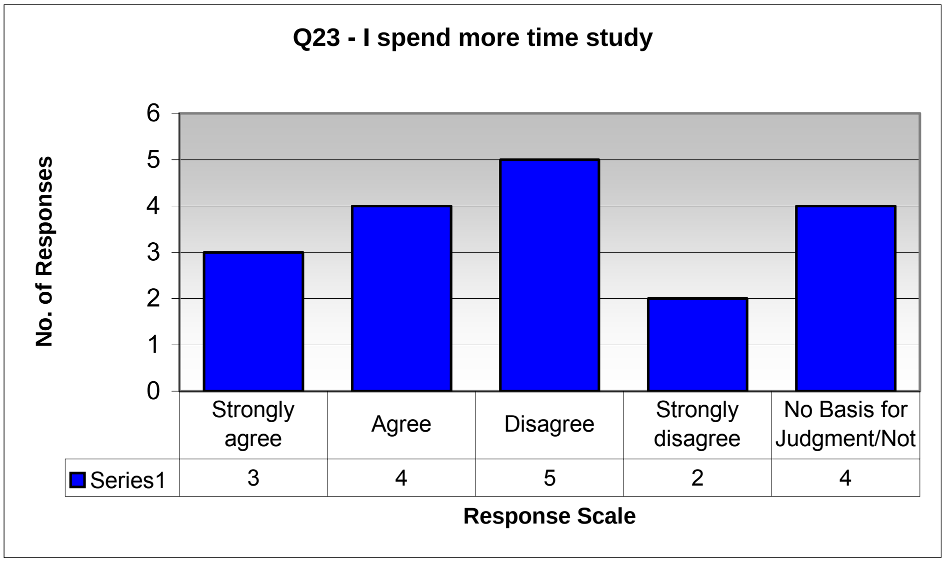
Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

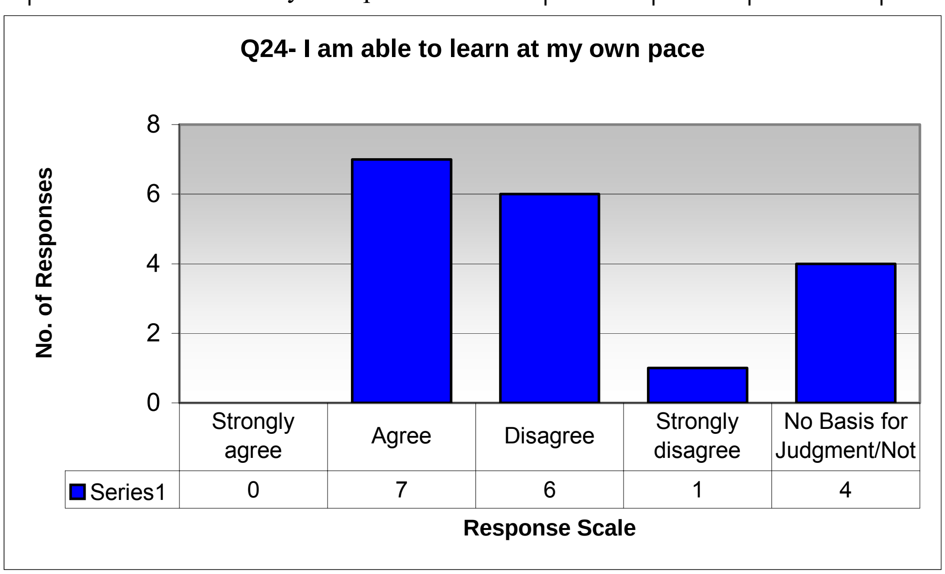
Because of the way this course uses Groups and Hands-on Learning...		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
22	I am better able to visualize the ideas and concepts taught in this course	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:						
						(mark the appropriate circle, select only one response per question)
Because of the way this course uses Groups and Hands-on Learning...		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
23	I spend more time studying	❍	❍	❍	❍	❍



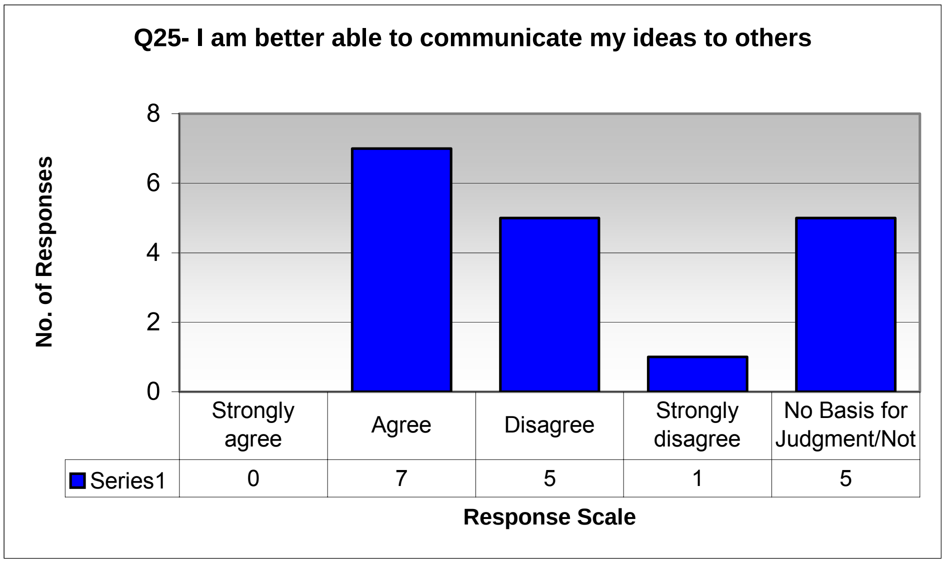
Indicate how strongly you **agree** or **disagree** with each of the following statements:						
						(mark the appropriate circle, select only one response per question)
Because of the way this course uses Groups and Hands-on Learning...		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
24	I am able to learn at my own pace	❍	❍	❍	❍	❍



Indicate how strongly you agree or disagree with each of the following statements:

(mark the appropriate circle, select only one response per question)

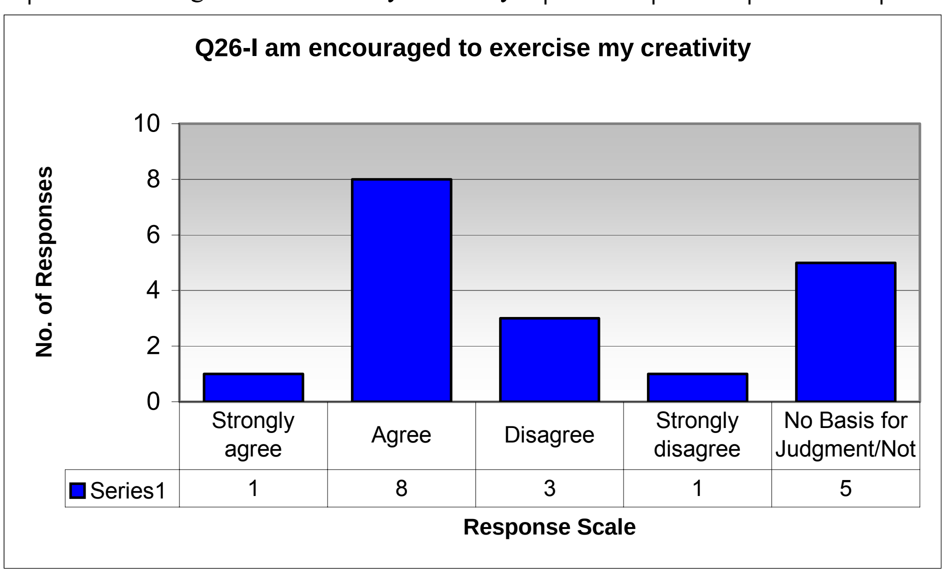
Because of the way this course uses Groups and Hands-on Learning...		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
25	I am better able to communicate my ideas to others	❍	❍	❍	❍	❍



Indicate how strongly you agree or disagree with each of the following statements:

(mark the appropriate circle, select only one response per question)

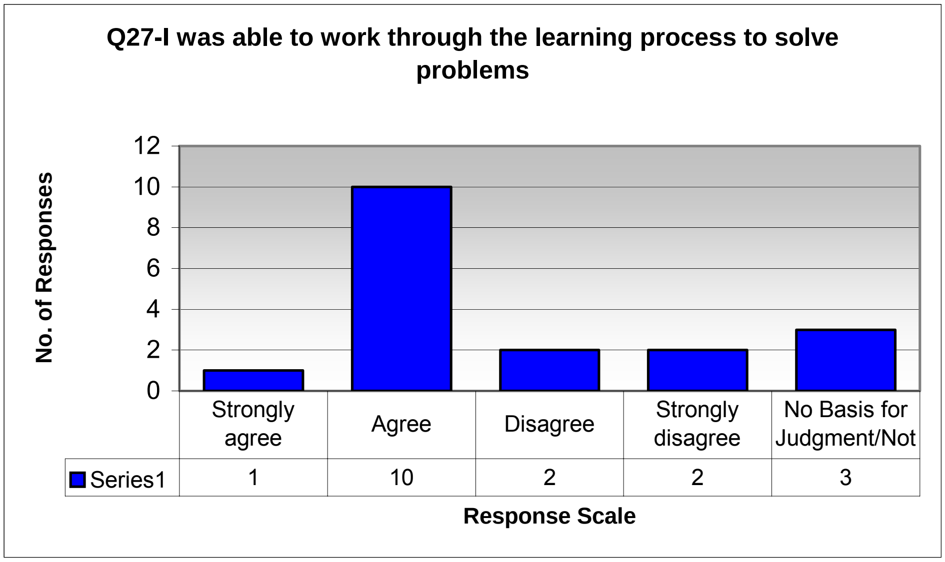
Because of the way this course uses Groups and Hands-on Learning...		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
26	I was encouraged to exercise my creativity	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

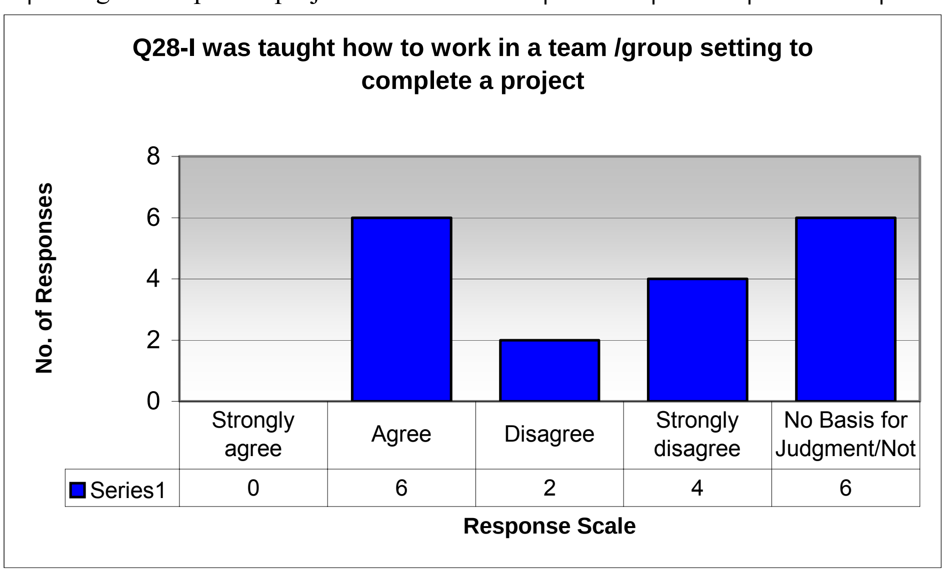
Because of the way this course uses Groups and **Hands-on Learning...**		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
27	I was able to work through the learning process to solve problems	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

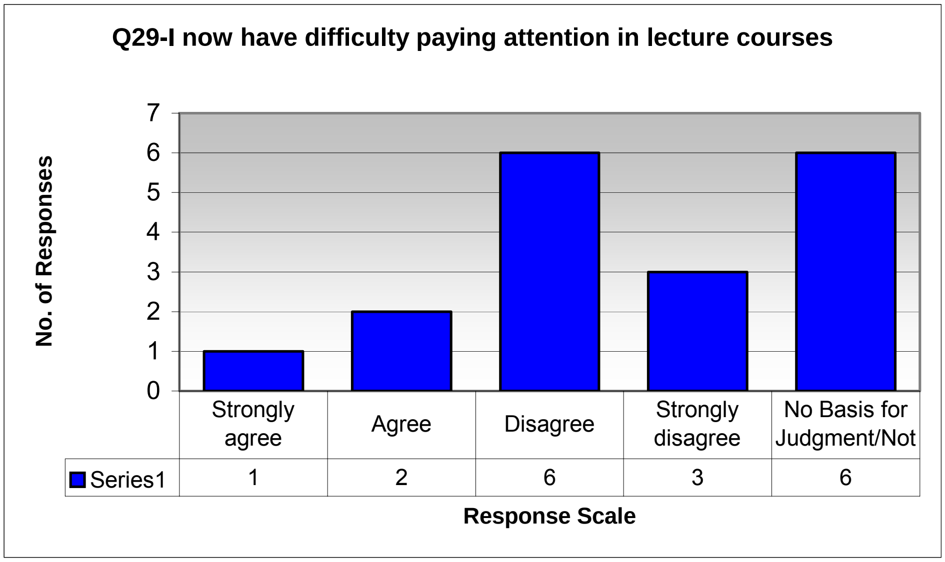
Because of the way this course uses Groups and **Hands-on Learning...**		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
28	I was taught how to work in a team/group setting to complete a project	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

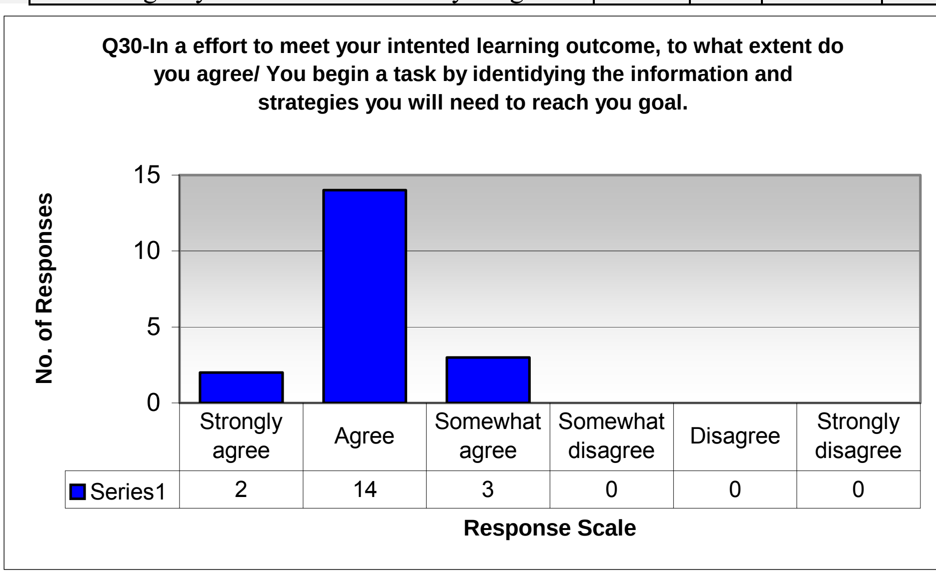
Because of the way this course uses Groups and Hands-on Learning...		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
29	I now have difficulty paying attention in lecture courses	❍	❍	❍	❍	❍



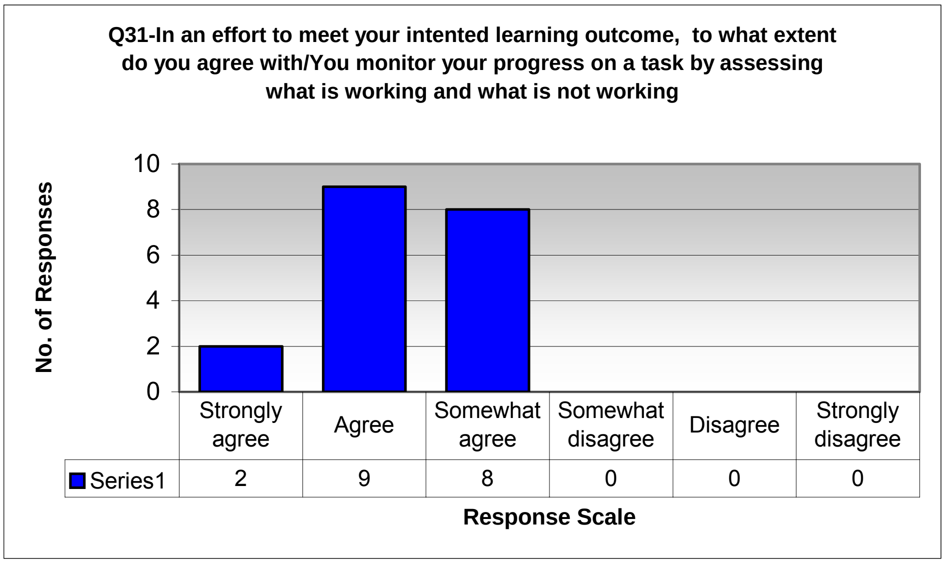
In an effort to meet your intended learning outcome, to what extent do you agree with the following?

(mark the appropriate circle, select only one response per question)

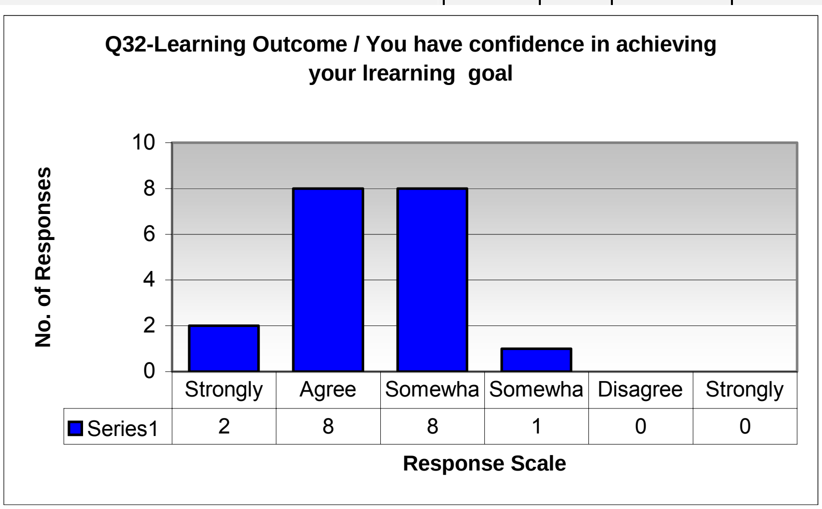
		Strongly agree	Agree	Somewhat agree	Somewhat disagree	Disagree	Strongly disagree
30	You begin a task by identifying the information and strategies you will need to reach your goal.	❍	❍	❍	❍	❍	❍



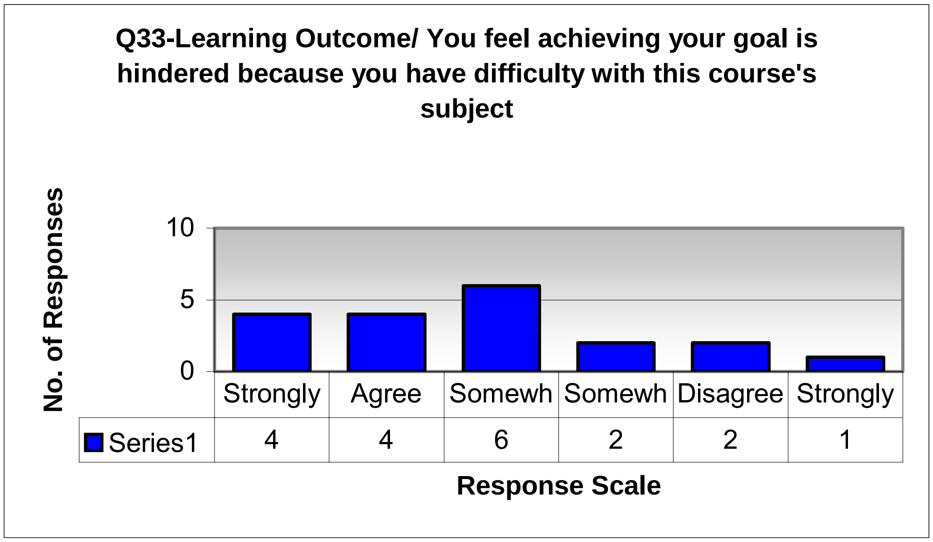
In an effort to meet your intended learning outcome, to what extent do you agree with the following?							
(mark the appropriate circle, select only one response per question)							
		Strongly agree	Agree	Somewhat agree	Somewhat disagree	Disagree	Strongly disagree
31	You monitor your progress on a task by assessing what is working and what is not working.	❍	❍	❍	❍	❍	❍



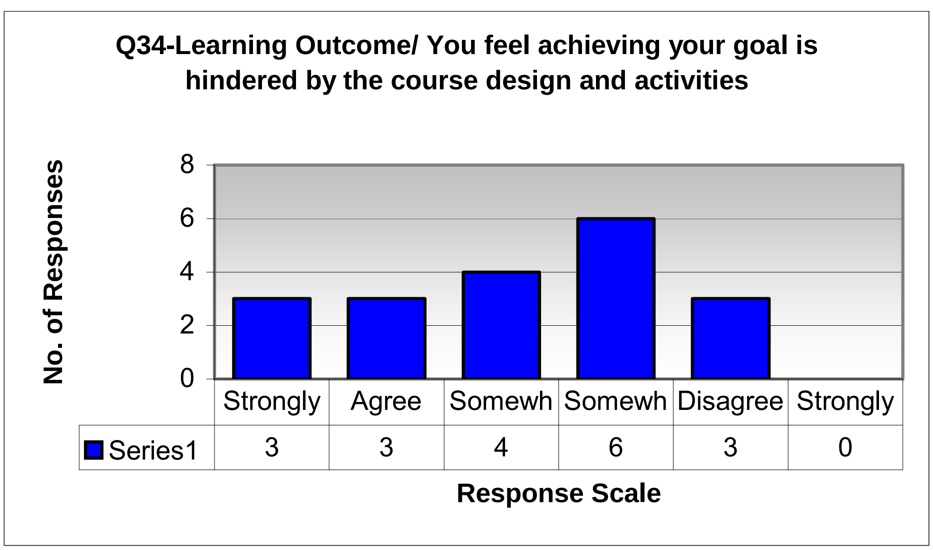
In an effort to meet your intended learning outcome, to what extent do you agree with the following?							
(mark the appropriate circle, select only one response per question)							
		Strongly agree	Agree	Somewhat agree	Somewhat disagree	Disagree	Strongly disagree
32	You have confidence in achieving your learning goal.	❍	❍	❍	❍	❍	❍



In an effort to meet your intended learning outcome, to what extent do you agree with the following?							
		(mark the appropriate circle, select only one response per question)					
		Strongly agree	Agree	Somewhat agree	Somewhat disagree	Disagree	Strongly disagree
33	You feel achieving your goal is hindered because you have difficulty with this course's subject.	❍	❍	❍	❍	❍	❍



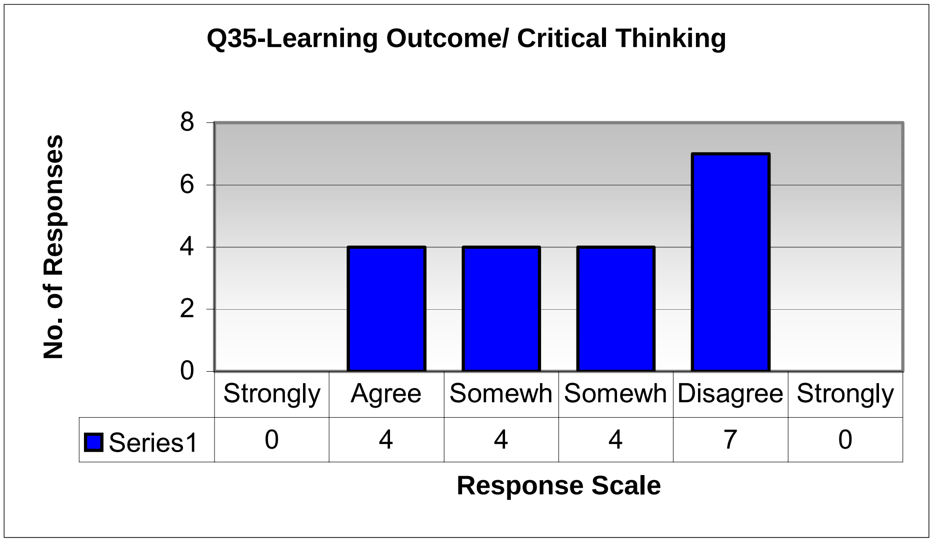
In an effort to meet your intended learning outcome, to what extent do you agree with the following?							
		(mark the appropriate circle, select only one response per question)					
		Strongly agree	Agree	Somewhat agree	Somewhat disagree	Disagree	Strongly disagree
34	You feel achieving your learning goal is hindered by the course design and activities.	❍	❍	❍	❍	❍	❍



In an effort to meet your intended learning outcome, to what extent do you agree with the following?

(mark the appropriate circle, select only one response per question)

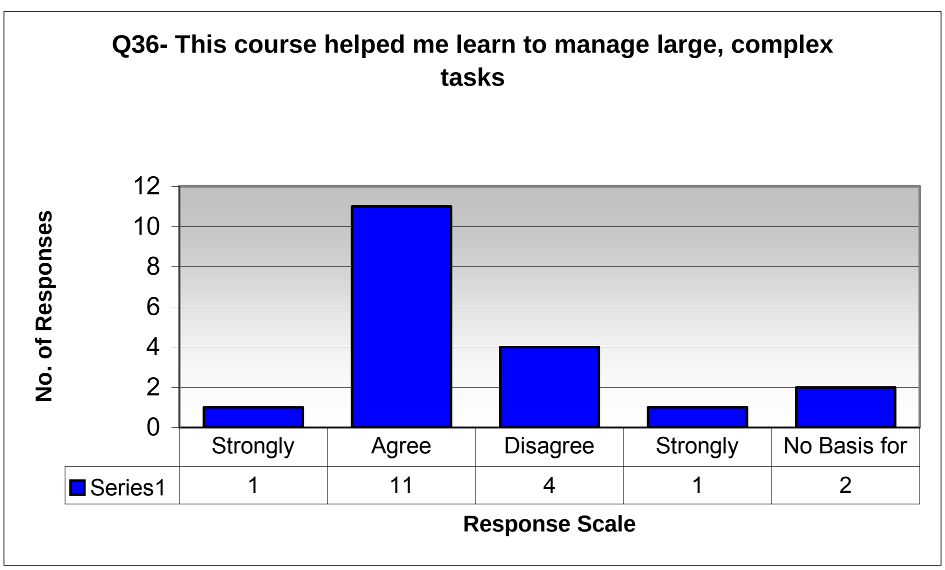
		Strongly agree	Agree	Somewhat agree	Somewhat disagree	Disagree	Strongly disagree
35	The grades you receive generally reflect your effort on the work	❍	❍	❍	❍	❍	❍



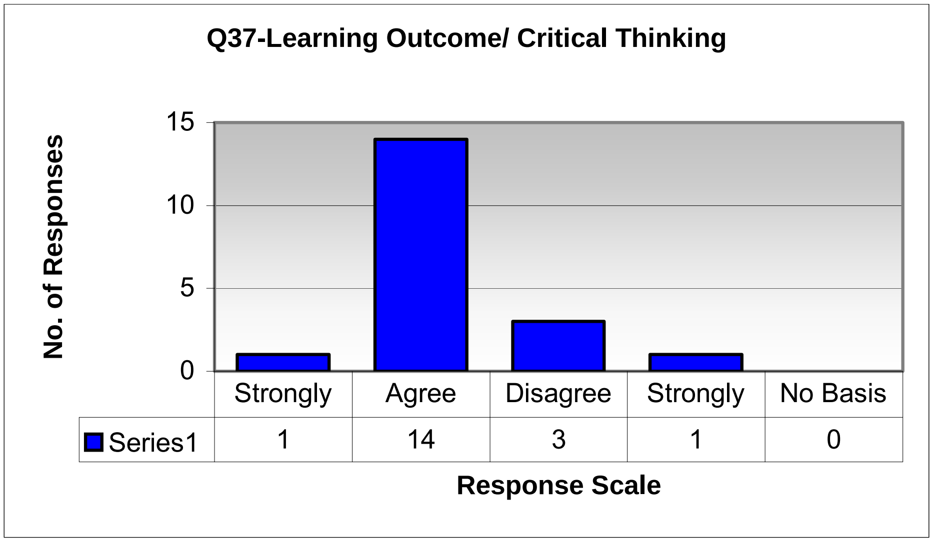
Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

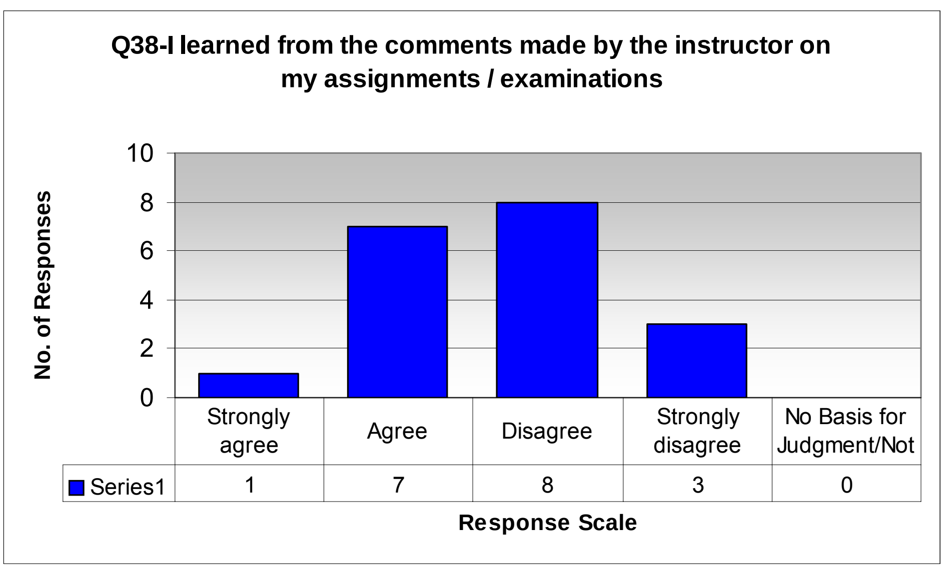
		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	Don't Know/ Not Applicable
36	This course helped me learn to manage large, complex tasks	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements: (mark the appropriate circle, select only one response per question)		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	Don't Know/ Not Applicable
37	This course helped me learn to work through a process to solve problems	❍	❍	❍	❍	❍



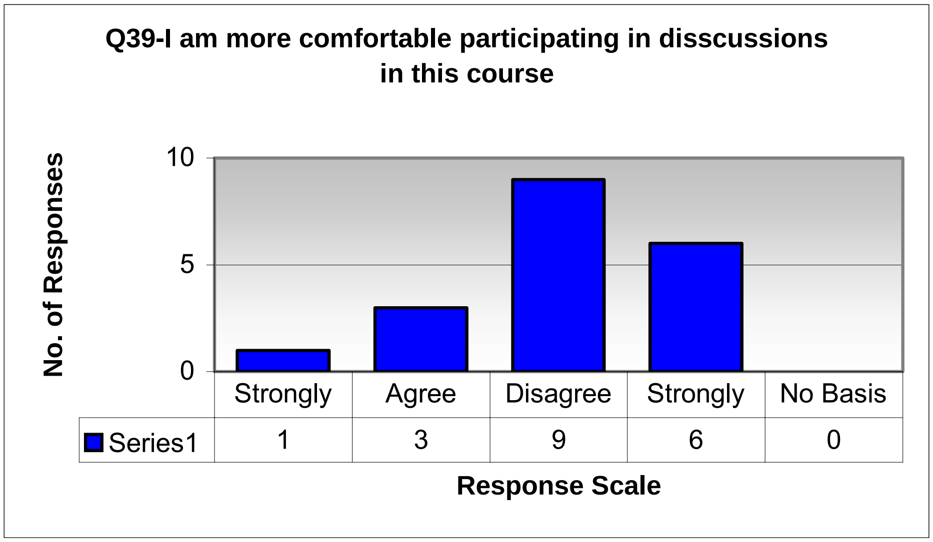
Indicate how strongly you **agree** or **disagree** with each of the following statements: (mark the appropriate circle, select only one response per question)		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	Don't Know/ Not Applicable
38	I learned from the comments made by the instructor on my assignments and/or examinations for this course	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

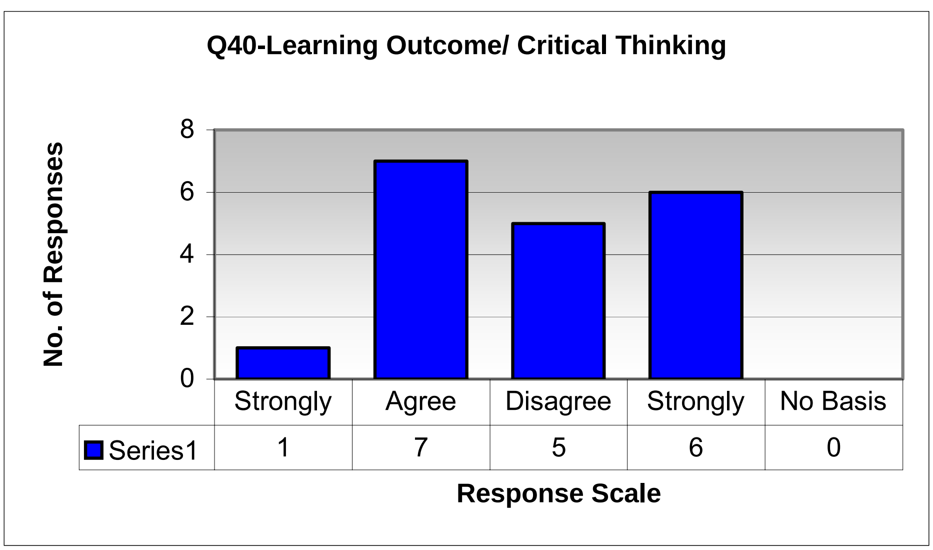
		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	Don't Know/ Not Applicable
39	I am more comfortable participating in discussions in <u>this course</u>, than I am in other courses.	❍	❍	❍	❍	❍



Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

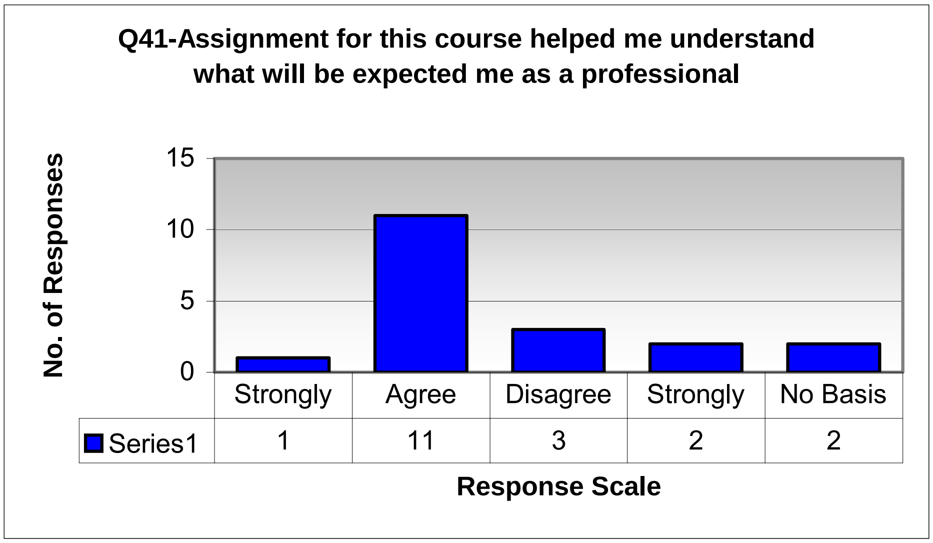
		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	Don't Know/ Not Applicable
40	I feel comfortable telling the instructor of <u>this course</u> when I disagree with something s/he has said	❍	❍	❍	❍	❍



Indicate how strongly you agree or disagree with each of the following statements:

(mark the appropriate circle, select only one response per question)

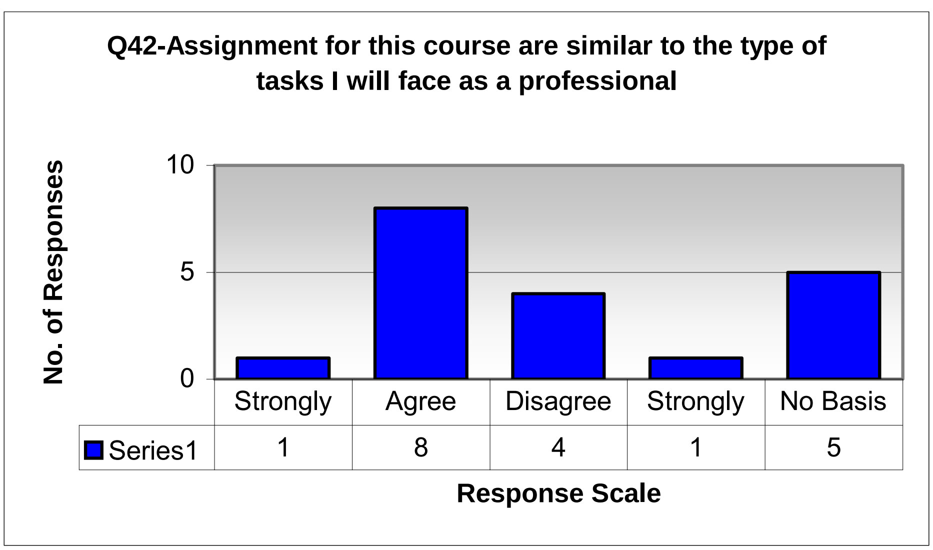
		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	Don't Know/ Not Applicable
41	Assignments for this course helped me understand what will be expected of me as a professional	❍	❍	❍	❍	❍



Indicate how strongly you agree or disagree with each of the following statements:

(mark the appropriate circle, select only one response per question)

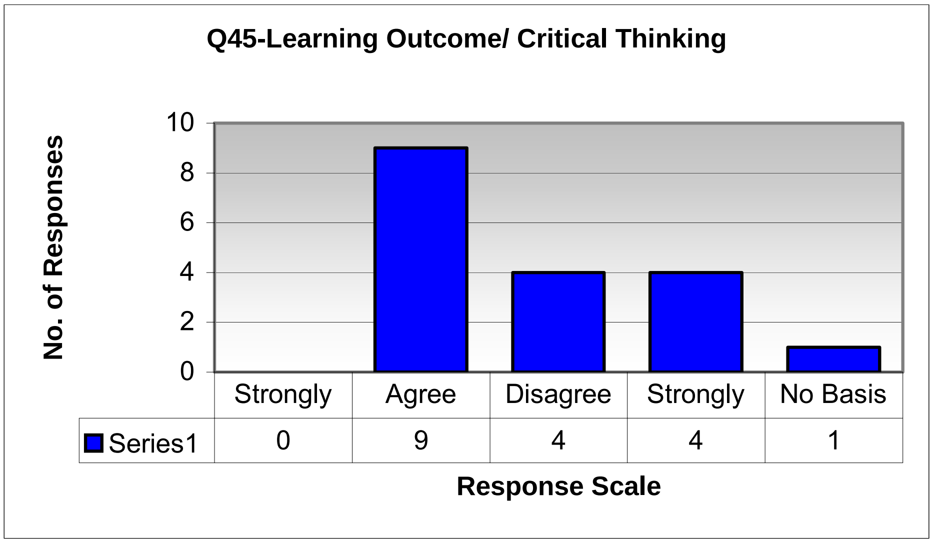
		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	Don't Know/ Not Applicable
42	Assignments for this course are similar to the type of tasks I will face as a professional	❍	❍	❍	❍	❍



To what extent do you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

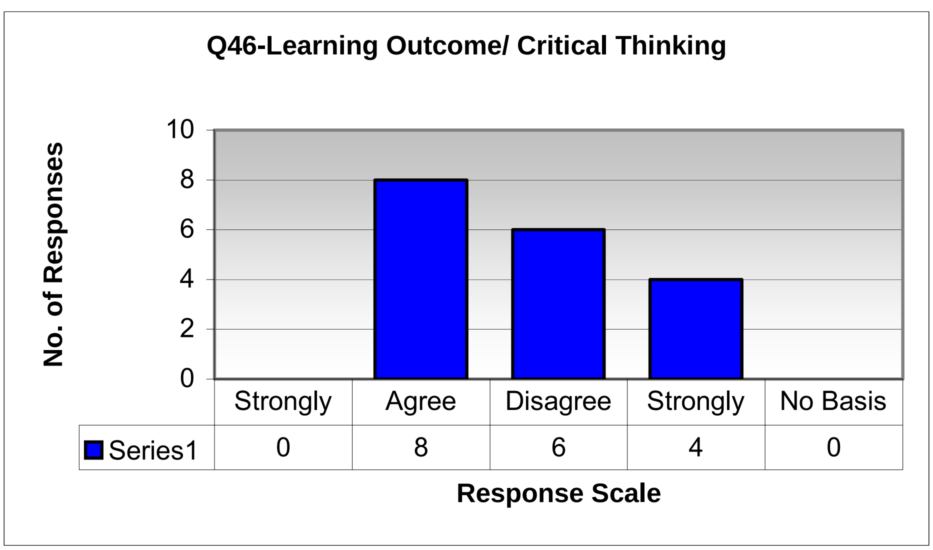
		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
45	I would recommend this course to others	❍	❍	❍	❍	❍



To what extent do you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

		Strongly **Agree**	**Agree**	**Disagree**	Strongly **Disagree**	No Basis for Judgment/ Not Applicable
46	I would recommend this instructor to others	❍	❍	❍	❍	❍

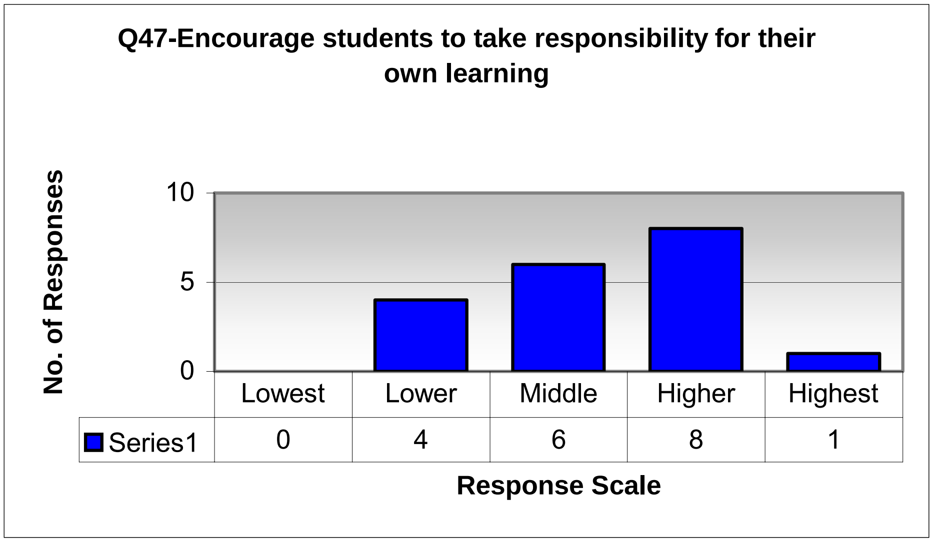


In your opinion, to what extent were each of the following given **priority** in this course:

Please rate each of the following from 1 to 5 where: *1 is the lowest priority, and 5 is the highest priority*

(circle the appropriate number, select only one response)

47	Encouraging students to take responsibility for their own learning	1	2	3	4	5

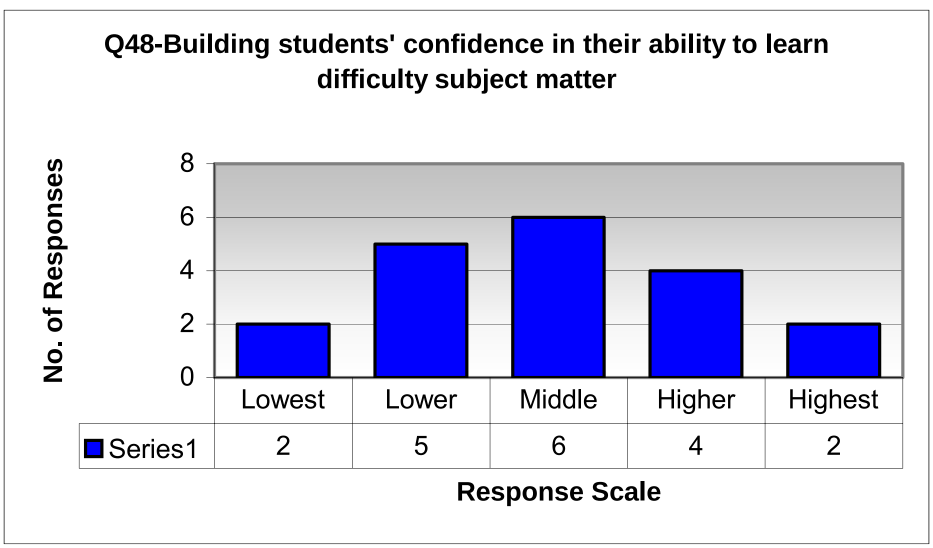


In your opinion, to what extent were each of the following given **priority** in this course:

Please rate each of the following from 1 to 5 where: *1 is the lowest priority, and 5 is the highest priority*

(circle the appropriate number, select only one response)

48	Building students' confidence in their ability to learn difficult subject matter	1	2	3	4	5

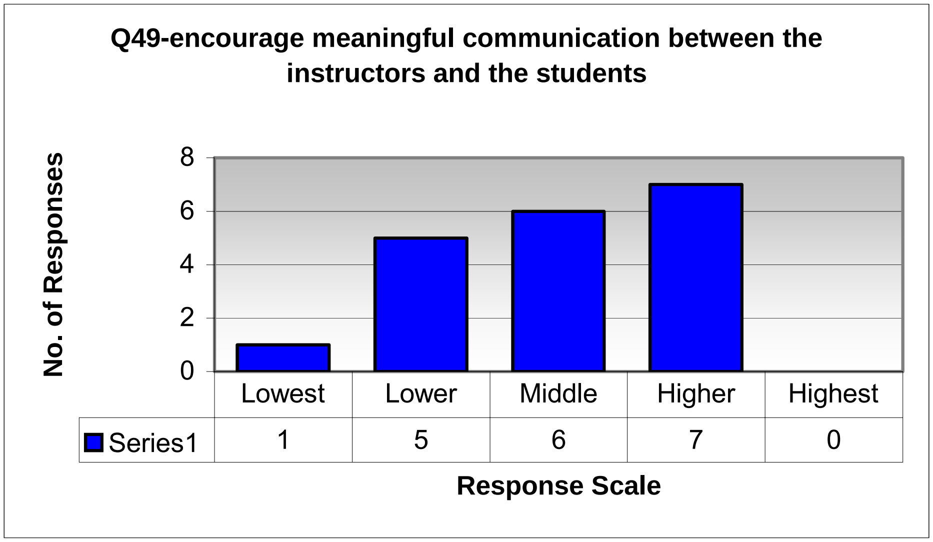


In your opinion, to what extent were each of the following given **priority** in this course:

Please rate each of the following from 1 to 5 where: *1 is the lowest priority, and 5 is the highest priority*

(circle the appropriate number, select only one response)

49	Encouraging meaningful communication between the instructor and the students	1	2	3	4	5

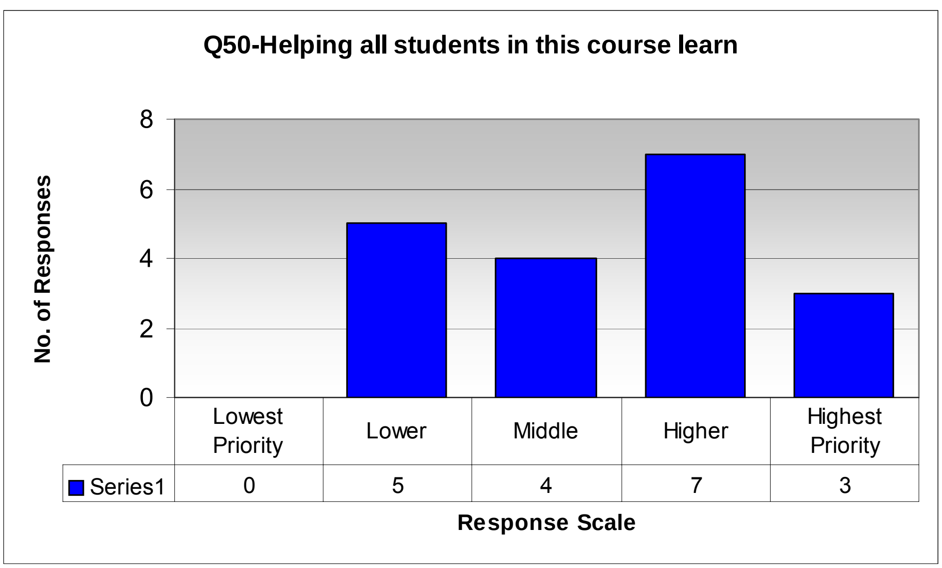


In your opinion, to what extent were each of the following given **priority** in this course:

Please rate each of the following from 1 to 5 where: *1 is the lowest priority, and 5 is the highest priority*

(circle the appropriate number, select only one response)

50	Helping <u>all</u> students in this course learn	1	2	3	4	5

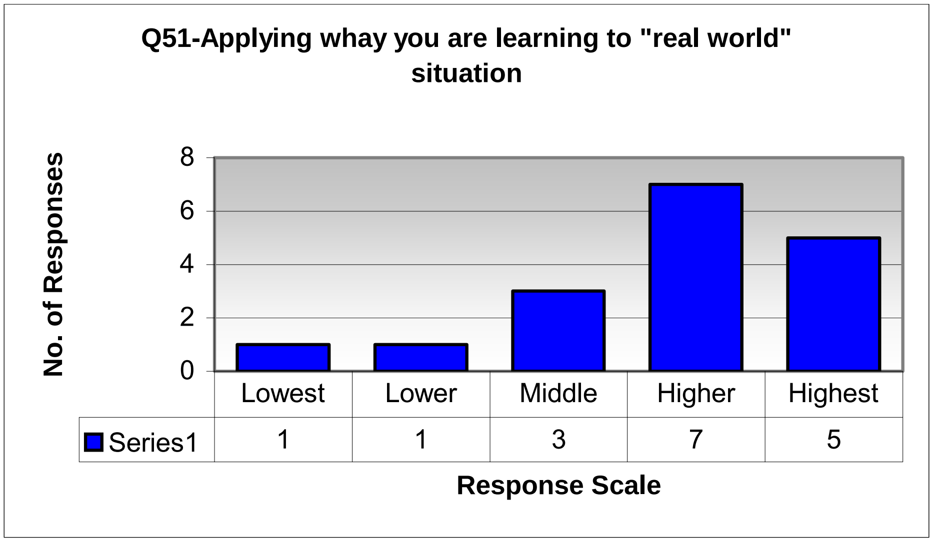


In your opinion, to what extent were each of the following given **priority** in this course:

Please rate each of the following from 1 to 5 where: *1 is the lowest priority, and 5 is the highest priority*

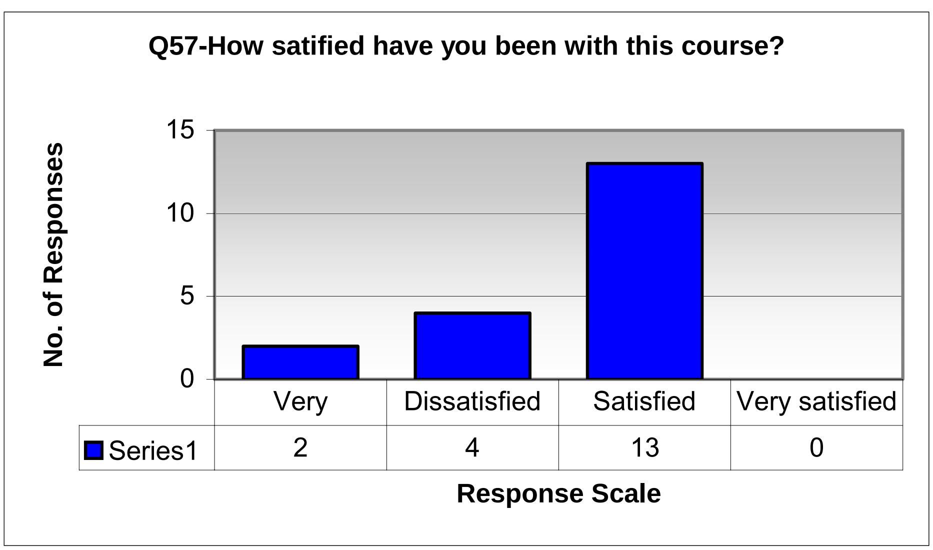
(circle the appropriate number, select only one response)

51	Applying what you are learning to "real world" situations	1	2	3	4	5



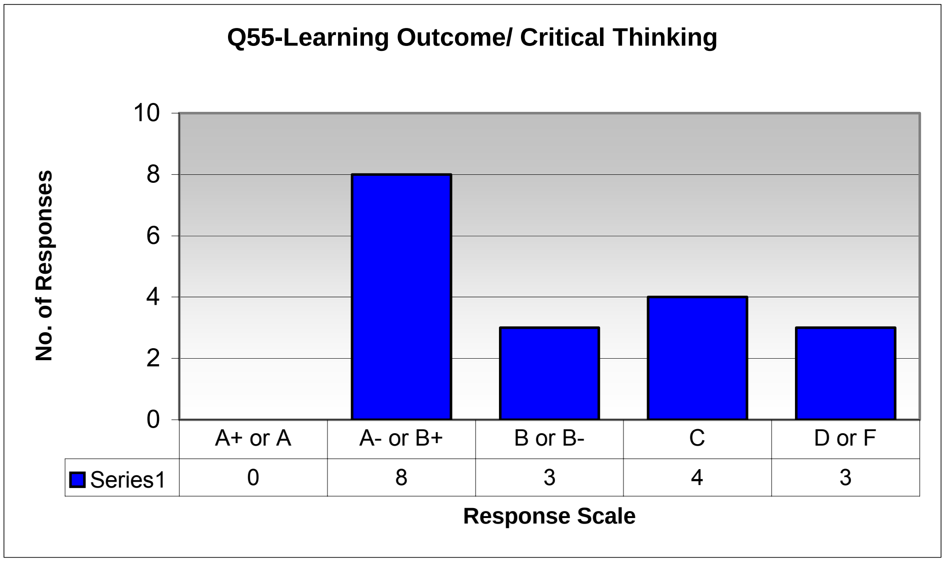
57. Overall, how satisfied have you been with this course?

- ❍ very dissatisfied
- ❍ dissatisfied
- ❍ satisfied
- ❍ very satisfied



55. What grade do you expect to receive in <u>this course</u>? (mark the appropriate circle, select only one)

❍ A+ or A ❍ A- or B+ ❍ B or B- ❍ C ❍ D or F



APPENDIX 2-D

INTERVIEW SESSION WITH THE CLASS, DR. THOMSON, AND TOM HENDERSON

Summary of Student Feedback, ChE 332: May 3, 2002

Guidelines There was almost universal feedback that insufficient guidelines were not given. Students complained about spending large periods of time on a project and then finding out they were doing the wrong thing and then having to go back and redo the project. Other comments along these lines were: "I never knew if I was on the right track", "….Even after struggling on my own for a time, I still wasn't able to get any help from the instructor", "… Pain can be a good way to learn, but when that's all there is, it's just pain", "…I felt like I was thrown in the pool and told to swim or drown", "….there is not enough balance in the course, it is too focused on individual learning, very inefficient".

Time Requirements A number of students said they spent just as much time on 332 as they did on ChE 334 and ChE 301 combined. Others stated that they felt that they had neglected their other ChE courses as a result and so, didn't learn as much as they should have.

Projects The consensus was that the first project was focused and built on what they had already learned. However, everyone complained about the second project. They felt that learning heat transfer from one narrow project (the fluidized bed was mentioned often) resulted in their not really learning heat transfer. More than a few expressed some concern that they now do not know or understand heat transfer and are worried that they might have been "short changed".

Groups There was universal consensus that the group activities were very beneficial, particularly having to teach their fellow group members. They also felt that the arguing within the groups helped them to understand the material (fluids) better.

Summary The work load was way too high. There is not enough balance between self learning and instructor assisted learning. Group interactions are good and hands on learning was also effective, it was just way too extreme. Heat transfer was "crammed" into the last few weeks of the course in the form of a project and homework (which most students "blew off", because of lack of time) and the students feel that they have not learned it.

To: Prof. Van Wie and Prof. Thomson

From: Tom Henderson; *tom@wsu.edu*, 335-6451

Date: 5/23/2002

Re: Notes taken from interview with Chemical Engineering 334 students

Notes from In-class Interview with ChemE 334 Students

These notes were taken Friday 5/3/2002, the last class session before finals week. Prof. Bill Thomson led the discussion session with the class; Prof. Van Wie was not present.

Tom Henderson took these notes by hand during the discussion session; 17 of 24 students were present.

Before I get to the interview notes I wanted to jot down a few of my impressions listening to the students. Several of the students complained that there "weren't enough lectures", that Dr. Van Wie didn't tell them "THE answer" or "we wasted time in lab when we could have been listening to lectures." These are classic responses of students who have been conditioned to listening to lectures for many years and are resistant to change (almost any change) in the classroom. Reading these notes you can tell that this class must have been a great learning experience for the students, despite their complaints. Comments like "going down the wrong road and then realizing it was very helpful" or "I really appreciate doing things in lab, we can't doze off in the lab", or "I would really like to see hands on in all of the classes."

We have many resources that substantiate the effectiveness of active learning and/or cooperative learning techniques in the classroom, please let us know if you would like some cites for your grant application.

You have probably heard of Richard M. Felder of NCSU who is the Hoechst Celanese Professor Emeritus of Chemical Engineering. He has many articles about his experience using active learning and cooperative learning groups in his classes, many of which were Chemical Engineering classes. I have just scanned several and they seem very good with a lot of practical information; two links to his work on the WWW are at:

http://www.che.ncsu.edu/faculty_staff/rmf_pub.html and

http://www2.ncsu.edu/unity/lockers/users/f/felder/public/Cooperative_Learning.html

Dr. Brown, Carrie Myers and I are available to meet with you and discuss any further help we might provide with the grant application or with the design of future classes. Please let us know if you would like any further information or revisions to these notes or any of the other information we have sent.

Interview Notes

Comments by each student are bulleted. Prof. Thomson's remarks are noted. My (Tom Henderson's) comments are in parenthesis.

- Could have used more guidelines

  clearer expectations

  questions more related to material (frustrated that instructor wouldn't give more guidance)

  we spent so much time discussing things "we didn't learn"

  talking to Dr. Van Wie didn't help, he "didn't give us the answer"

  in the end the instructor should say "this is the way it is"

  for example: the radiator had air flow and water flow we asked "should we look at convection?" and Dr. Van Wie said "What do you think?". Our group didn't include it BUT then we found out we should have

- I liked the first project much better than the second project
- We feel like we don't know the subject (Dr. Thomson then said something like "but you do", I think he was referring to oral exams conducted of ChemE 334 students)

- We spent a lot of time in the lab wasting time (especially heat transfer) we could have used that time in lab listening to lectures. (Dr. Thomson then said "would better equipment help?") student then responded "Yes, but we need more lectures."

- In the fluids section of the class we did get lecture, in heat transfer we just got "tossed into the pool." But I learned this long term, especially compared to "separations."
- On the up side I liked the group "office meeting" in the lab, i.e., Dr. Van Wie with just the group (jigsaw group)
- Our groups found our group meeting frustrating. We made corrections but then found out a member of our group was right all along!
- Dr. Van Wie wouldn't talk to a student during office hours without the group.

Dr. Thomson then said "It looked to me like Bernie (Dr. Van Wie) spent a lot of time....

- For a 2 credit course this took a lot of time. Spent a week in the computer lab just to get things done.
- It was less work in kinetics than this class.
- No matter how much time we spent we had more to do

Dr. Thomson "It seems that most of the negative comments are on the heat transfer section of the class."

- The first project was much less demanding that the 2nd project, I just wanted to put a bullet hole through the radiator.
- After watching seniors do their projects, I'm glad to have this experience.
- My having to lecture the class as part of the 2nd project was really stressful (each group had an entire class period to present their project)
- Going down the wrong road and then realizing it was very helpful.
- Heat transfer "went wrong" because each group had a project, I would like to work on more heat transfer projects (the note taker assumed more smaller projects?)

- Everything cam due about the same time, last week I had 3 finals, the PChem poster session and fluid labs.
- If you get a grant please get a few more computers for the labs. (another student then said) And get each student a license for MathCAD to take home. The bookie has an older version of MathCAD for $150 and the upgrade was $270.

Dr. Thomson then said "Is hands on experience a better way to learn things?"

- I would really like to see hands on in all of the classes
- OK to a point but you have to teach (lecture?) to teach a course
- Doing stuff in groups helps me concentrate on the course
- I really appreciate doing things in lab, we can't doze off in the lab
- The course has a lot of potential it just needs more guidance / lecture. "Just go figure it out" is a little bit unnerving.
- The jigsaw group was a really good idea!
- I liked the way Van Wie taught thermal, I am frustrated with the labs
- I want "bumpers" so I can't through a gutter ball
- I can say in my interviews that I've had experience working in teams.

Tom Henderson - Assessment Coordinator

Center for Teaching, Learning, and Technology

Washington State University

Box 644550

Pullman, Washington 99164-4550

(Tel): 509-335-6451 (Fax): 509-335-1362 Email: *tom@wsu.edu*

APPENDIX 1-E

LEARNING STYLES SURVEY RESULTS

Dear Prof. Van Wie:

Here are the results of your class's learning style survey and the charts for the analysis results.

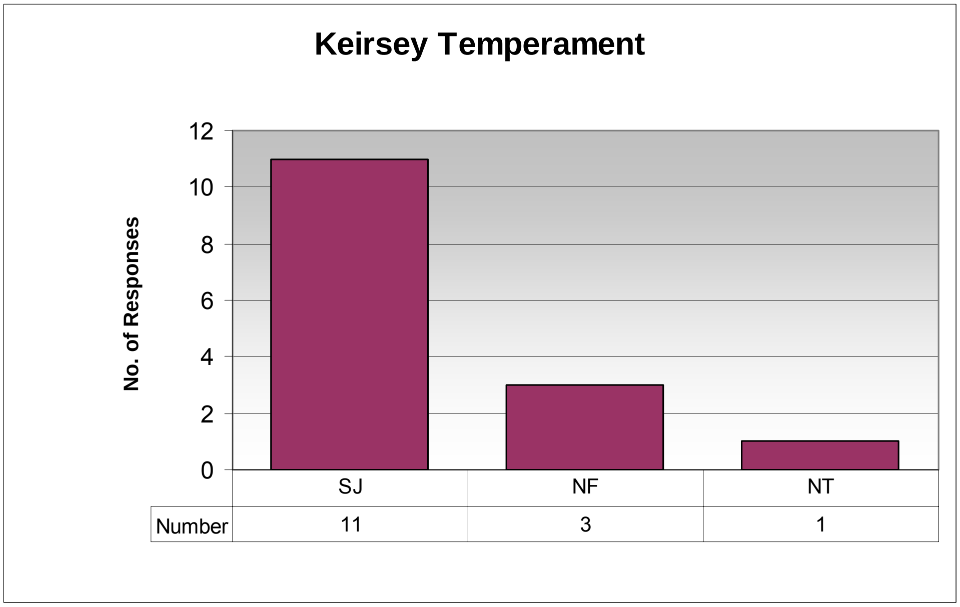
As you can see, most of your students fell into the "SJ" category.

We also did some research about Keirsey Temperament and the personal type definition. These materials are attached at end of this report. You can see a summary of SJ on page 5 of this report.

Learning Style Survey Data

Name	ACT/REF	SEN/INT	VIS/VRB	SEQ/GLO	Keirsey Temperament
	5	11	7	7	SJ
	3	1	1	3	SJ
	5	5	5	1	NT
	9	11	3	7	SJ
	1	3	9	9	NF
	5	9	1	7	SJ
	1	1	7	3	SJ
	9	11	11	7	SJ
	1	1	5	1	SJ
	9	7	5	5	NF
	5	11	1	1	NF
	3	5	1	7	SJ
	1	5	5	5	SJ
	5	1	5	5	SJ
	3	3	9	9	SJ
	1	1	1	3	

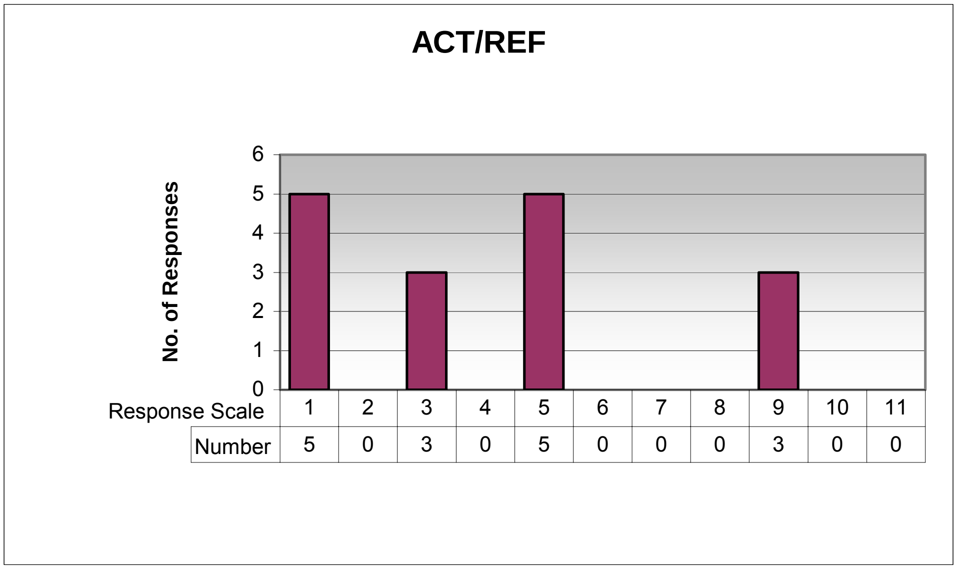
As you can see, a majority of your students fall in Keirsey's SJ category.

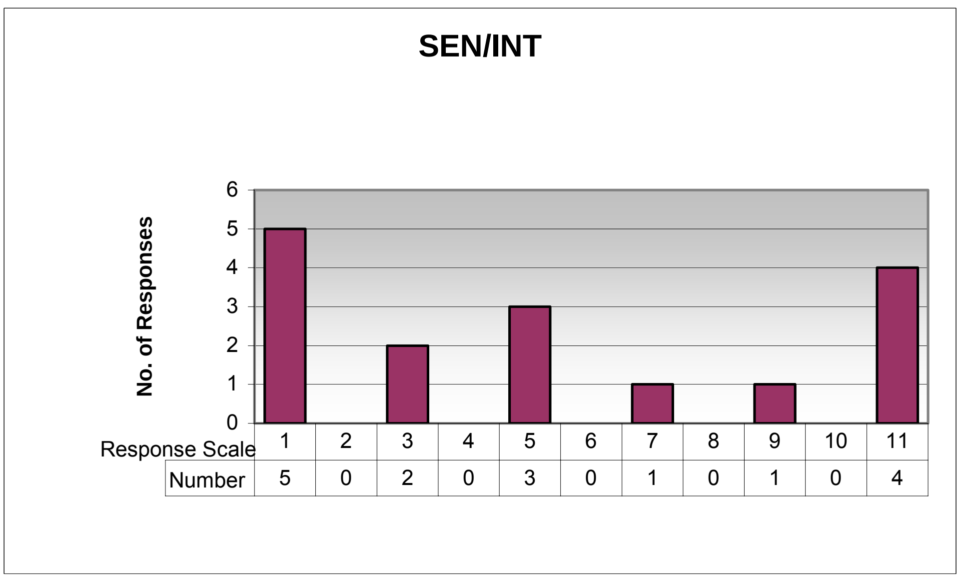


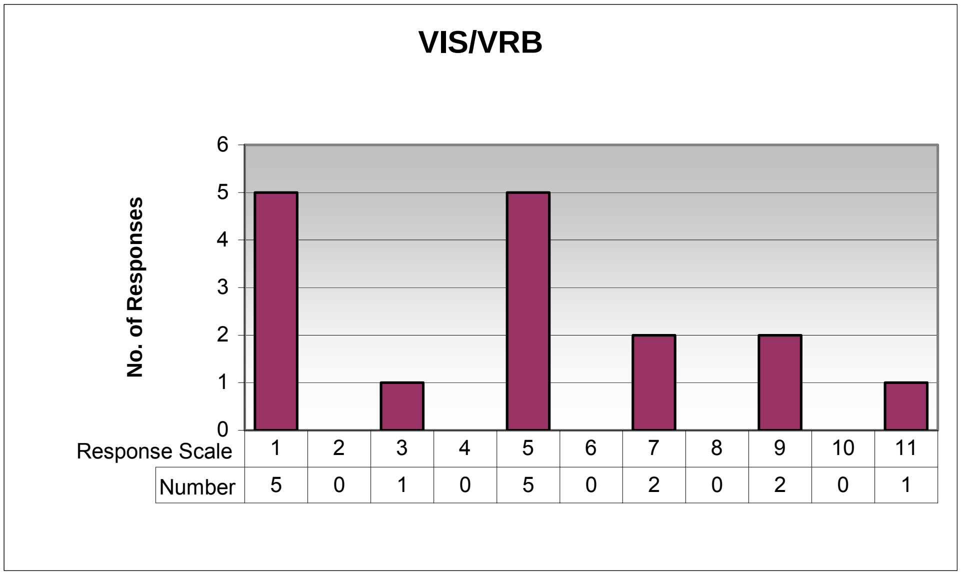
Analysis Summary

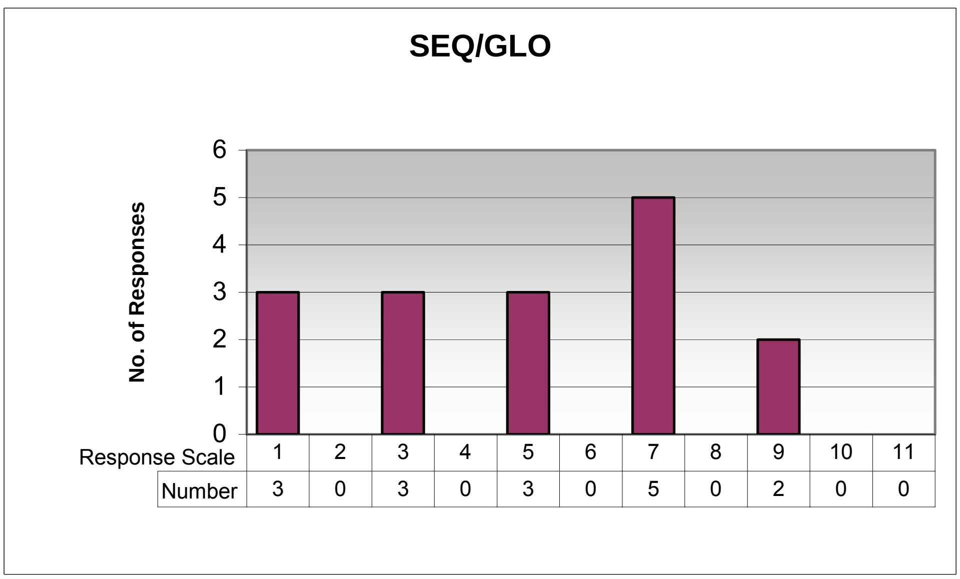
Extent	ACT/REF Number	SEN/INT Number	VIS/VRB Number	SEQ/GLO Number	Keirsey Temperament	Number
1	5	5	5	3	SJ	11
2	0	0	0	0	NF	3
3	3	2	1	3	NT	1
4	0	0	0	0		
5	5	3	5	3		
6	0	0	0	0		
7	0	1	2	5		
8	0	0	0	0		
9	3	1	2	2		
10	0	0	0	0		
11	0	4	1	0		

The charts below summarize the above table.






VIS/VRB
No. of Responses
6
5
4
3
2
1
0
Response Scale
Number
1 2 3 4 5 6 7 8 9 10 11
5 0 1 0 5 0 2 0 2 0 1


SEQ/GLO
No. of Responses
6
5
4
3
2
1
0
Response Scale
Number
1 2 3 4 5 6 7 8 9 10 11
3 0 3 0 3 0 5 0 2 0 0

Temperament

Excerpted from Please Understand Me II, by David Keirsey

Temperament versus character?

Crossing paths with Isabel Myers got me in the habit of typewatching way back in 1956. Myers completed her book The Myers-Briggs Type Indicator in 1958 and published it in 1962, though Educational Testing Service had been using her questionnaire, the MBTI, for some years doing personality research in numerous colleges and high schools around the country, and this is where I first encountered her work

I soon found it convenient and useful to partition Myers's sixteen types into four groups, which she herself suggested in saying that all four of what she referred to as the "NFs" were alike in many ways and that all four of the "NTs" were alike in many ways -- although what she called the "STs" seemed to me to have very little in common, just as the "SFs" had little in common. However, four earlier contributors, Adickes, Spranger, Kretschmer, and Fromm, each having written of four types of character, helped me to see that Myers's four "SJs" were very much alike, as were her four "SPs." Bingo! Typewatching from then on was a lot easier, the four groups -- SPs, SJs, NFs, and NTs -- being light years apart in their attitudes and actions. This, then, is what Myers had to say about the four groups:

The SPs

Myers had SPs probing around their immediate surroundings in order to detect and exploit any favorable options that came within reach. Having the freedom to act on the spur of the moment, whenever or wherever an opportunity arises, is very important to SPs. No chance is to be blown, no opening missed, no angle overlooked -- whatever or whoever might turn out to be exciting, pleasurable, or useful is checked out for advantage. Though they may differ in their attitude toward tough-mindedness (T) and friendliness (F) in exploring for options, and though some are socially expressive (E) and some reserved (I), all of them make sure that what they do is practical and effective in getting what they want.

Consistent with this view Myers described SPs as "adaptable," "artistic," and "athletic" -- as very much "aware of reality and never fighting it" -- as "open-minded" and ever "on the lookout for workable compromises" -- as knowing "what's going on around them" and as able "to see the needs of the moment" -- as "storing up useful facts" and having "no use for theories" -- as "easygoing," "tolerant," "unprejudiced," and "persuasive" -- as "gifted with machines and tools" -- as acting "with effortless economy" -- as "sensitive to color, line, and texture" -- as wanting "first-hand experiences" and in general "enjoying life." So SPs, as seen by Myers, are very much like one another and very much different from the other types, the SJs, NFs, and NTs.

The SJs

Myers had SJs, like SPs, observing their close surroundings with a keen eye, but for an entirely different reason, namely that of scheduling their own and others' activities so that needs are met and conduct is kept within bounds. Thus for SJs, everything should be in its proper place, everybody should be doing what they're supposed to, everybody should be getting their just deserts, every action should be closely supervised, all products thoroughly inspected, all legitimate needs promptly met, all approved ventures carefully insured. Though SJs might differ in being tough-minded (T) or friendly (F) in observing their schedules, and though they can be expressive (E) or reserved (I) in social attitude, all of them demand that ways and means of getting things done are proper and acceptable.

And so Myers described the SJs as "conservative" and "stable" -- as "consistent" and "routinized" -- as "sensible," "factual," and "unimpulsive" -- as "patient," "dependable," and "hard-working" -- as "detailed," "painstaking," "persevering," and "thorough." This too is a clear-cut pattern of action and attitude, highly unlike that of the SPs, NFs, and NTs.

The NFs

On the introspective side, Myers had NFs as friendly to the core in dreaming up how to give meaning and wholeness to people's lives. Conflict in those around them is painful for NFs, something they must deal with in a very personal way, and so they care deeply about keeping morale high in their membership groups, and about nurturing the positive self-image of their loved ones. Indeed, while they might differ from each other on how important judging schedules (J) or probing for options (P) is in acting on their friendly feelings, and while their social address can be expressive (E) or reserved (I), all NFs consider it vitally important to have everyone in their circle -- their family, friends, and colleagues -- feeling good about themselves and getting along with each other.

Thus Myers, an INFP herself, saw her fellow NFs as "humane" and "sympathetic" -- as "enthusiastic" and "religious" -- as "creative" and "intuitive" -- and as "insightful" and "subjective." Again this is a distinct picture of attitude and action, showing NFs to be very much like each other and greatly different from SPs, SJs, and NTs.

The NTs

Also on the introspective side, Myers had NTs as tough-minded in figuring out what sort of technology might be useful to solve a given problem. To this end, NTs require themselves to be persistently and consistently rational in their actions. Though they may differ in their preference for judging schedules (J) or probing for options (P) as they tackle problems, and though they can seem expressive (E) or reserved (I) around others, all NTs insist that they have a rationale for everything they do, that whatever they do and say makes sense.

So Myers described the NTs as "analytical" and "systematic" -- as "abstract," "theoretical," and "intellectual" -- as "complex," "competent" and "inventive" -- as "efficient," "exacting" and "independent" -- as "logical" and "technical" -- and as "curious," "scientific," and "research-oriented." Here again is a unique and easily recognizable configuration of character traits, the NTs a breed apart, starkly different from SPs, SJs, and NFs.

Outline of Please Understand Me II

by David Keirsey

Different Drummers

“Let us suppose that people are not all the same, and that their patterns of attitude and action are just as inborn as their body build. Could it be that different people are intelligent or creative in different ways? That they communicate in different ways? That they have different mating, parenting, and leading styles? That they desire to learn different things at school? That they will, if given the chance, excel at different sorts of work? Could it be that such popular sayings as ‘to each his own,’ ‘different strokes for different folks,’ and ‘do your own thing’ express something that can be put to good use in everyday life?”

• Temperament Theory: Lost and Found "... psychology came to be dominated by Freudian psychodynamics ...and Pavlovian conditioning. Behavior was explained as due to unconscious motives or to past conditioning, or to both. The idea of inborn differences in human action and attitude was all but abandoned."

• The Keirsey Temperament Sorter II "There is no substitute for careful and informed observation. But self examination is quite foreign to most people, and so devices like this questionnaire can be useful in getting you started asking questions about your preferred attitudes and actions."

• The 16 Type Combinations

- **Guardians**
  - Supervisor ESTJ
  - Inspector ISTJ
  - Provider ESFJ
  - Protector ISFJ
- **Artisans**
  - Promoter ESTP
  - Crafter ISTP
  - Performer ESFP
  - Composer ISFP
- **Idealists**
  - Teacher ENFJ
  - Counselor INFJ

- Champion ENFP
- Healer INFP

- **Rationals**
  - Fieldmarshal ENTJ
  - Mastermind INTJ
  - Inventor ENTP
  - Architect INTP

• What the Myers-Briggs Letters Mean "...in adopting [Jung's words] Myers put her own spin on them. So let us consider what Myers actually meant in using Jung's words in The Myers-Briggs Type Indicator.

E	=	Expressive	or	I	=	Reserved
S	=	Observant	or	N	=	Introspective
T	=	Tough-minded	or	F	=	Friendly
J	=	Scheduling	or	P	=	Probing

Artisans

• Plato's Artisans "The term 'Artisan' is the English equivalent of Plato's Greek word 'eikoniké' otherwise 'icon-maker,' 'image-maker,' or 'arti-factor'...and thus in Plato's Republic the Artisans' social function is to fashion those sensory images, ornaments, and objects that are useful in daily living."

• The Concrete Utilitarians "Artisans, whatever they are called, all have something in common: they [are] concrete in communicating messages and utilitarian in implementing goals....The communication of Artisans can be said to be concrete in that they are apt to talk mostly of what is going on at the moment and what is immediately at hand....In implementing their goals, or as they say, ‘going for it,’ Artisans are primarily interested in what works, what fits, and only secondarily in what meets with social approval.”

• The Tactical Intellect

• The Interests of Artisans

• The Orientation of Artisans “Artisans are practical about the present, optimistic about the future, cynical about the past, their preferred place is in the middle of the action, and their preferred time is now.”

• The Self-Image of Artisans

• The Values of Artisans “Artisans typically enjoy being excited, trust their impulses, yearn to have impact on others, often seek stimulation, prize generosity, and aspire to virtuosity.”

• The Social Roles Artisans Play “Playmate...Liberator parent...Negotiator leader.”

• Artisan Role Variants: ISTP, ESTP, ESFP, ISFP

Guardians

• Plato’s Guardians “The word ‘Guardian’ is the English equivalent of the Greek word ‘pistike,’ which means ‘those with trustworthy convictions.’ In Plato’s Republic the social function of Guardians was to keep watch over the activities as well as the attitudes of the people in their circle.”

• The Concrete Cooperators "Guardians, no matter what they're called, all have something in common, namely they [are] concrete in thought and speech and cooperative in implementing goals....Like their Artisan cousins, Guardians talk for the most part about the concrete particulars they observe in their material or social surroundings....Let us all cooperate with one another in pursuit of common goals, says the Guardian, for in the long run discipline and teamwork get us where we want to go."

• The Logistical Intellect

• The Interests of Guardians

• The Orientation of Guardians "Guardians are dutiful about the present, pessimistic about the future, stoical about the past, their preferred place is at the gates of social interaction and their preferred time is yesterday."

• The Self-Image of Guardians

• The Values of Guardians "Guardians are often concerned about some serious matter, trust authority, yearn to belong to groups, seek security, prize expressions of gratitude, and sooner or later aspire to be an executive."

• The Social Roles Guardians Play "Helpmate...Socializer parent...Stabilizer leader."

• Guardian Role Variants: ESFJ, ESTJ, ISTJ, ISFJ

Idealists

• Plato's Idealists "Plato was the quintessential Idealist, the inventor of a philosophy in which ideas are even more real than earth and its inhabitants. Plato's word for an idealist like himself was 'noetic' which, roughly translated, means 'intuitive thought,' that is, pure thinking done without recourse to either logical or empirical investigation. Plato saw these inspiring Idealists, and no others, as the philosopher-kings of his ideal republic, destined to serve a philosophic function in society, their job no less than to divine moral principles and the full meaning of life."

• The Abstract Cooperators "Idealists, whatever they are called, all have something in common: they [are] all abstract in communicating and cooperative in implementing goals...Idealists talk little of what they observe; they talk instead of what can only be seen with the mind's eye...Accord, concurrence, agreement, accommodation: this side of cooperation is what looms large in the consciousness of Idealists."

• The Diplomatic Intellect

• The Interests of Idealists

• The Orientation of Idealists "Idealists are altruistic about the present, credulous about the future, mystical about the past, their natural place is on the pathways to understanding and their natural time is tomorrow."

• The Self-Image of Idealists

• The Values of Idealists "How different from their opposites, the Artisans. Where Artisans value excitement (from without) Idealists value enthusiasm (from within); where Artisans value their impulses, Idealists value their intuition; where Artisans value impact on others, Idealists value romance with others. And so it goes, Idealists valuing identity over stimulation, recognition over generosity, and the sage over the virtuoso."

• The Social Roles Idealists Play "Soulmate...Harmonizer parent...Catalyst leader."

• Idealist Role Variants: ENFP, ENFJ, INFP, INFJ

Rationals

• Plato's Rationals "Plato's word for men like Einstein was 'dianoetic' which roughly translated means 'dialectical thought'—coordinate thought, parallel reasoning, ratiocination—hence he considered this type as the 'Rationals.' Plato regarded the Rationals as serving a particular function in society: to study nature and figure out ways to tame it, that is, to make the natural order confluent with the social order."

• The Abstract Utilitarians "NTs, whatever their name, have something very important in common with the Idealists and Artisans, and little in common with the Guardians. With the Idealists they share a predominantly abstract manner of communicating their messages, and with the Artisans a predominantly utilitarian manner of implementing their goals...Rationals talk little of what is observable and much of what is imaginable. They are inclined to speak more of what can be seen only with the mind's eye, conceptual things rather than perceptual things, ideas rather than objects...Rationals are utilitarian in going after what they want, which means that they consider the usefulness of their tools as more important than their social acceptability—whether they should be used, are moral, are legal, are legitimate."

• The Strategic Intellect

• The Interests of Rationals

• The Orientation of Rationals “Rationals are pragmatic about the present, skeptical about the future, relativistic about the past, their place is at intersections of interaction, and their time is the interval.”

• The Self-Image of Rationals

• The Values of Rationals “Where Guardians value being concerned, Rationals value being calm; where Guardians trust authority, Rationals trust reason; where Guardians yearn for belonging, Rationals yearn for achievement; where Guardians seek security, Rationals seek knowledge. And the contrast extends to what they prize and what they aspire to, Guardians gratitude and executive power, Rationals deference and wizardry.”

• The Social Roles Rationals Play “Mindmate...Individuator parent...Visionary leader.”

• Rational Role Variants: ENTJ, INTJ, ENTP, INTP

Temperament and Intelligence “Of course, most enterprises are multi-faceted, and therefore leaders would do well to understand that different kinds of intelligent roles are necessary for implementing different goals... Indeed, it appears that nothing has greater payoff for the effective leader than recognizing the kind and degree of intelligent operations needed for getting a variety of jobs done. The best policy for a leader of any temperament is to look for intelligence and put it to work where it is most effective.”

• Identifying Intelligence

• Tactical Intelligence

• Logistical Intelligence

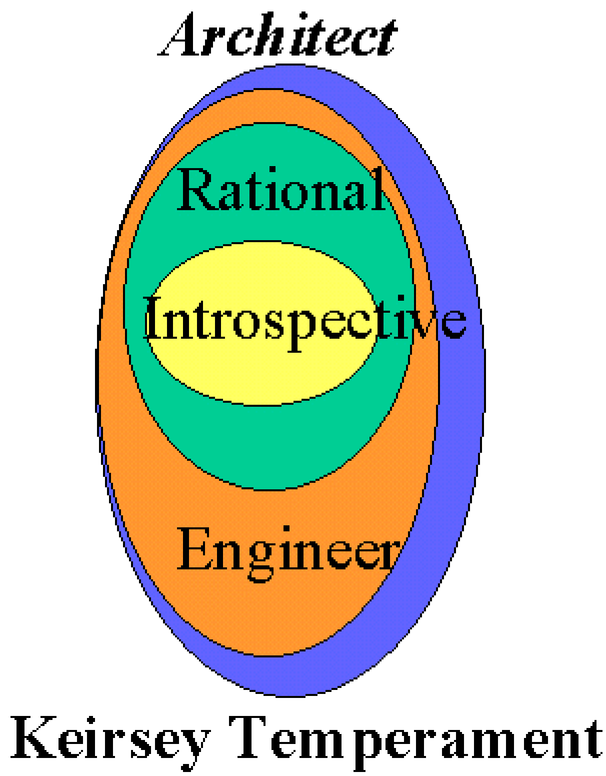
• Diplomatic Intelligence

Keirsey Temperament versus Myers-Briggs Types.

What's the difference?

Compared to the difference between astrology, or even other non-Jungian based theories or methods of classifying personality, there isn't much difference at a superficial level. However, there is some practical differences and a large theoretical difference between the two bodies of work. The essential difference is Myers used a linear four factor model to characterize "invariant" patterns of behavior of the individual throughout their lifetime, whereas Keirsey uses a systems field theory model to characterize these patterns. Lastly, the problems of intelligence and madness, that is, what are they are and how they relate to temperament, was not effectively addressed by Jung or Myers.

To illustrate graphically, the difference between the two bodies of work, one can look at the following simplifications of how the each theory represents the "temperament" and "character" of an individual, although Myers did not explicitly address the notions of temperament and character.



One of practical problems with the defining the difference of the models is a great deal of printed and web material and books have mixed the two models together: for they are similar. Keirsey gave Isabel Myers, a layman, a great deal of credit for rescuing Jung's work and having done at great job at observing people. He related her work to other work done at the early part of the 20th century in personality not related to Jung and illustrated that these ideas about personality are quite old. But many others blurred the difference between "Myers-Briggs" and "MBTI" versus the published material and work of Keirsey in Please Understand Me (published in 1978) which had a significant impact in promoting "Myers-Briggs" (MBTI published in 1962, Gifts Differing by Isabel Myers, published in 1982). In fact, most descriptions found in "Myers-Briggs" books are significantly based on Keirsey's Please Understand Me or his sixteen portraits that were circulated in the 70's. Many people give a xeroxed Myers-Briggs "test", which is in fact most likely the Keirsey Temperament Sorter. There have been numerous articles on "Myers-Briggs", which actually used Keirsey's work and instruments but attributed it to Myers-Briggs.

The bottom line of the difference between the theories comes in describing the "aspects" of personality. Keirsey has done an in-depth, systematic analysis and synthesis of aspects of personality for temperament: that included the temperaments unique interests, orientation, values, self-image, and social roles. Whereas, Myers' brilliant simplications of Jung's work facilitates the talking about four scales. For example, "Introverts" in general as a useful concept of group behavior (such as INTJ, ISFJ, INTP, ISTP), whereas Keirsey says, sorry, its more complicated than that, and if one tries to push the concept of "Introverts" too far you will make assertions that aren't true for all temperaments.

First, let's see where Isabel Myers got her "scales" (E/I, N/S, T/F, P/J); she essentially got them by her and her mother Katherine Briggs boiling down Carl Jung's writings on personality types. Where did Carl Jung get his ideas about personality? Well, he had picked a few notions from other people and some common knowledge in Germany at the time. He picked up "Extrovert" and "Introvert" from what had been around for years, a folk psychology notion that is was latinized by some German in around 1850. Most people easily recognize that there some people much more sociable than others, the parallel of "gregarious" and "shy" are related concepts. Second, Jung probably borrowed the notion of tough-minded and tender-minded for William James when discussed the mental aspects of the objective and subjective attitudes. Carl Jung also discussed all kinds aspects of "the mind", and noticed that it appeared some people were better and felt more comfortable talking about abstract concepts and others seem to be better at talking about and felt more comfortable with the concrete: having to do with real objects and real people. Lastly, Jung also talked about how "the mind" appears to make decisions, some people tending toward being judgmental and decisive and others being less judgmental and flexible.

So the first of major contributions of Jung was to contradict Freud and others, and say that no, *not* all people are governed by the same drives and that we are*not* all the same. Jung's second contribution was to pursue Kant's notion of "intuition" and discuss several aspects of "the mind" that involved what the mind does: perceive and abstract from world and note that each person can vary inheritantly in their interest in doing those two acts. Jung's third contribution was to collect a set of aspects of personality known previously and his own observations, in polar forms that seem to "cover" the space of possible "types" of people. The major contribution of Isabel Myers and Katherine Briggs was to take these contributions of Jung and made a simple linear assessment of these aspects and associate simple descriptions of those aspects so people could get a sense of what preferences they have as an individual.

The Myers-Briggs Type Indicator and Myers descriptions of personality did what no other personality instrument had done before, be able to give most people some insight into themselves and others. In fact, many people are amazed that by asking a few questions, the MBTI can "capture" the essence of a person's view of the world. People are surprised how accurate the MBTI can be.

However, when using this simple tool of assessment and a way of viewing one's personality, if one looks closely, there several problems that crop up.

First, people are more complex than just four numbers on four aspects of personality. But this is not the primarily problem with MBTI and Myers descriptions, this true of all assessments, abstractions, or "theories." A model of personality is not a personality. No matter what the descriptions of personality, they pale in comparison to the complexity of the individual. Also, the problem is not that "type" or "temperament" does not change, for the person is "changing" all the time. The difference between character and temperament (or type) of the personality help distinguish between what 'changes' and what stays the same, this is true whether one uses the

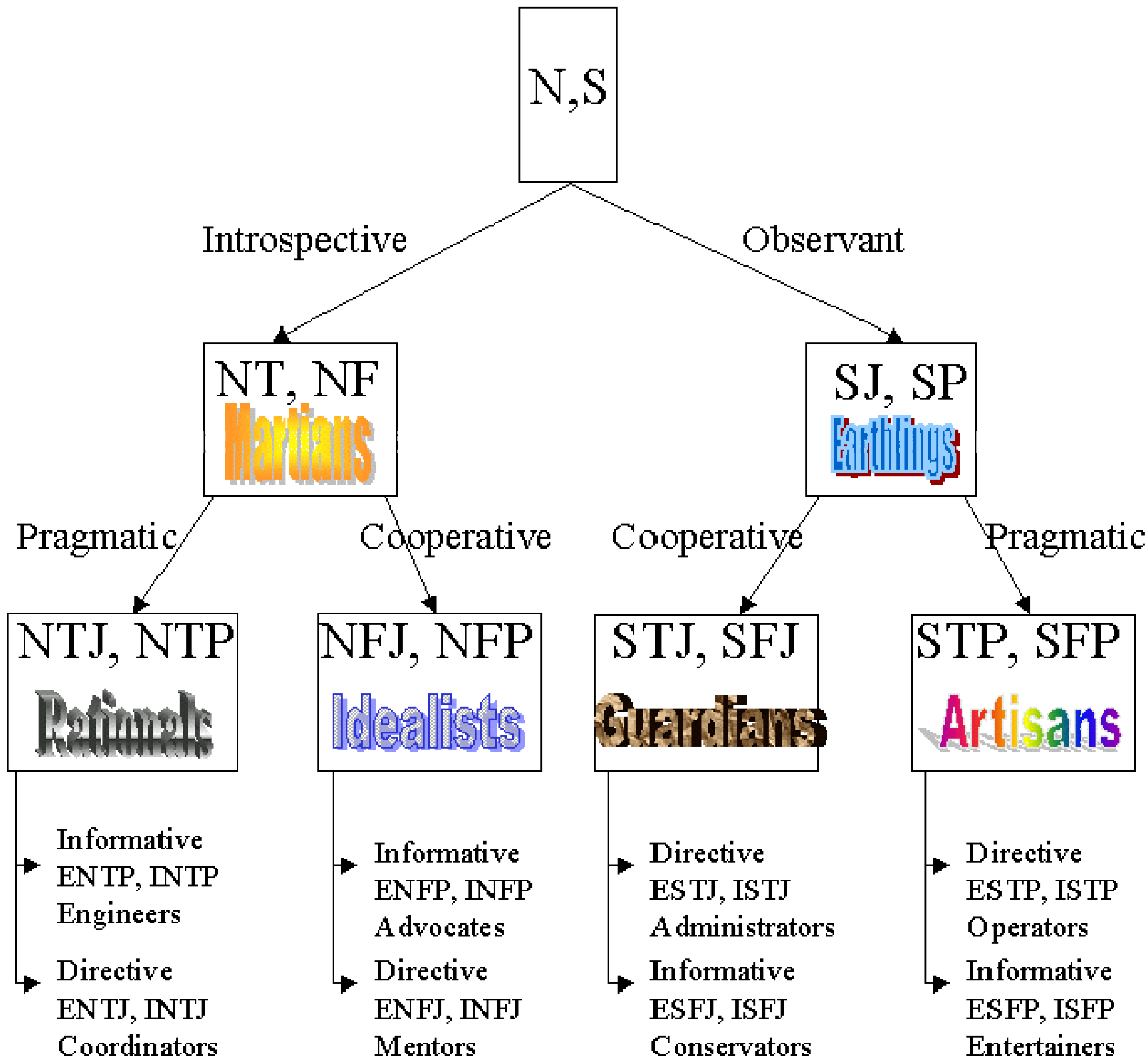
Jung-Myers notion of archetypes or function types or Keirsey's notions of character and temperament.

The primarily problem with Myer's method of description is the problem of trying to take the "personality" or more specifically what Keirsey calls "temperament" (as opposed to Myers "type") and break it into four "independent" aspects. There is great utility in thinking about them as "independent" aspects, as people who follow the line of Myers are wont to do. The "Ts" tend to be like this, the "Fs" tend to be like that. The "Es" tend to be like this, the "Is" tend to be like that. This kind of talk is fine up to a point. This is where Keirsey and Myers-Jung followers part company. The problem comes in when some "Es" are different (such as the Provider Guardian "ESFJ") other "Es" (such as Fieldmarshal Rational "ENTJ") because of temperament. The scales are not independent of each other. Of course, we are *not* talking about the myriad of other factors that complicate the analysis of personality, which includes gender, culture, etc. Those complications are another matter, irrespective of how to characterize "temperament".

Jung (hence Myers) viewed Introvert/Extrovert scale as a strong aspect, so much so that they talked about Introverted Thinkers and Extroverted Thinkers (we will let the reader speculate out what they meant by these phrases). Keirsey, on the other hand, regards Jung's N/S "scale" as the first "cut" (which of course in reality we "can't" cut the temperament into pieces). In other words, "how" one's mind primarily processes the world (through concepts or percepts) is the major determinant on how one evolves and reacts in life; not, whether one is more or less comfortable with people. As an example, Albert Einstein (INTP) is quite different from Clint Eastwood (ISTP). On other hand, if one tries to "talk about" what is "in the mind," one can start talking nonsense because we can't observe "mind".

Moreover, Myers in her descriptions mostly treat the personality aspects as independent scales. Her descriptions of the sixteen types, essentially is a concatenation of the aspects. She has a descriptive paragraph for "I," and a paragraph for "E,", a paragraph for "N," and so on. To get her descriptions, for example, an INTP, she takes her "I", "N", "T", and "P" descriptive paragraphs sticks them together and "viola" you have a full description of a person (an INTP). The problem with this Chinese menu method of personality, is that its too simplistic. Partly to fix the problem of it being too simplistic, Myers and her followers tried to work in the notion of shadow or dominant functions, however, the speculation of "what's in mind", becomes complex and confusing, and worse of all, hard to remember.

Keirsey is not concerned with "what's in mind", but what people do. What are the long-term behavior patterns: temperament. Keirsey's descriptions are not as much of a cookie cutter form as Myers-Briggs. His descriptions are more integrated. He looks at the notion of personality as whole. Thus, given that N/S is the "first" cut, the descriptions might be viewed as in a tree (or as an unfolding (emergence) of individual's temperament). As in the following, the lower level is constrained by the configuration above it.



First cut.

"Ns"   What Jung called "iNtuitive".   Keirsey liken them to "Martians."   Abstract. Introspective.

Those who look *primarily* through their *own* "minds eye."

"Ss"   What Jung calling the aspect "Sensing" Keirsey liken them to "Earthlings" Concrete.

Observant. Those who look *primarily* to the world by their "percepts", using what's out there.

Second cut of the Ns

"NTs" Myers called them "iNtuitive Thinkers"   Keirsey calls them "Rationals".

"NFs" Myers called them "iNtuitive Feeler" Keirsey calls them "Idealists".

If one is primarily viewing the world in terms of "concepts" of your own making, then clearly its important what kind of concepts are important to you. The Rationals value concepts born of their own objective (not emotional) reasoning, and the Idealists value concepts born of their own guts (emotion associated). The Rationals are pragmatic and the Idealists are credulous.

The more refined versions of Rationals include Fieldmarshals and Inventors both correlate to the Myers "Extrovert" letter in that they have something in common regarding their expressiveness towards the outside world. The problem is the E of ENTJ or an ENTP is quite different conceptually from the E as in ESFJ (Provider Guardian) even though some of the outside behavior aspects can be close.

The Fieldmarshall is not "extroverted" very much, and the Inventor is even less. Sure, both the Fieldmarshal and the Inventor can be "gregarious" or "not shy", in fact they can be sometimes overbearing. They are usually pretty friendly at parties and open to people to some extent. However, if Fieldmarshal is finding a particular person "boring" (and that can be in a few seconds) he quickly will find any excuse to exit the scene very quickly or rake the person over the coals, so to make sure that person realizes he is not considered worthy. So the Fieldmarshal is an "extrovert" with a purpose, usually that purpose is very narrow, such that the common notion of "extrovert" is not well suited for the Fieldmarshal. Same is true with the Inventor. The Inventor often appears like an Artisan, always interested in having an "interesting" time. Only the difference is the Inventor is "looking" for new experiences, new ideas, or some way to promote his ideas, so those who don't help in this endeavor are quickly cast off. That is the Inventor is an "extrovert" with an interest (outer-directed might be a better term), and that specific interest often being so narrow that the term "extrovert" is misleading.

The other obvious difference between Myers and Keirsey is the classification and characterization of the concrete types. Isabel concentrated on the sixteen types, not making a major distinction between Ns and Ss in certain type groupings (such as the Thinking Types and Feeling Types). On the other hand, Keirsey finds the distinction as being major.

Second cut of the Ss

(Myers or Jung never thought of using different criteria for different parts of the tree, because they didn't view it as a tree)

"SPs" Keirsey calls them "Artisans"

"SJs" Keirsey calls them "Guardians"

If one is primarily viewing the world in terms of "percepts" (nature supplied or environment supplied) then the issue of what to do with those percepts based on experience is crucial. Hence you can either take it in based on experience and experienced judgment or just take it in with no judgment and just react to it based on experience or what looks good at the time.

The problem with both Keirsey and Myers characterizing of personality for a particular individual is both the complexity of the individual and the myriad of circumstances that effects the individual: its hard to apply general descriptions to some specific examples. General descriptions, are just that, and other important aspects that can confuse the issue of "temperament" is the areas of intelligence (smartness and goodness) and madness (badness and stupidity), which are two subjects that will be addressed in Keirsey's forthcoming books: Temperament and Talent, and Dark Escape.

APPENDIX 3

2004 DATA AND MATERIALS

APPENDIX 3-A

STUDENT COMMENTS ON END-OF-SEMESTER COURSE EVALUATION

1. Do you have any suggestions for improving the course in any way? Do you have any suggestions for the instructor?
I have more comments than will fit on this. If you are interested, ask. I really enjoyed the course. The first day of classes this was my least favorite; however it quickly became my favorite! Liked how it was challenging and a fun class. One you look forward to going to. Dislikes: You need more office hours or at least to show up to the ones you have. (I know your busy and its not always possible.)
Put together teams by the members schedule outside of class
Less emphasis on turning in such a huge bulk of paperwork, more time to work w/ the modules & actually see how they work
Make 3 credits and have 1 lecture and 2 lab per week. Also get another TA so that there is 1 TA/Teacher per group.
It would be nice if there were as many TA's as there were groups. Because sometimes the group were left waiting for like 15 minutes without being helped.
A lecture might be needed once every other week just to set the students on the right track when they are left alone for class periods.
Maybe for one of the modules, the class could actually measure all of the variables and solve a related problem. Also, please keep better office hours; i.e. be present when needed, during office hour time, virtually all of the time.
I think the way the instructor trying to teach the students is excellent, but this "cooperative learning" idea looks not to be my style of study. Kinda hard to follow.
Make handouts more readable. Your writing is terrible.
Use the modules to do problems. We couldn't use them for quiz material and afterwards we

were so pressed for time the only thing I saw working was the white board.
Most of the kinks were worked out over the course of the semester. This class would be much better if it were supplemented by a lecture course.
2. What is your opinion concerning the overall quality of instruction in this course? How did it compare with others in the department, the college, and the university?
Good instruction
I like hand on but a little more instruction in the beginning would be nice. Overall it's a good course that helps us become better engineers.
Good course. The range of information learned was more narrow than other courses, but we went much more in depth in 332.
It was good. CL was much more enjoyable than lecture courses. CL seemed more demanding on the student however, but that also may have had a lot to do with the difficult nature of the course material.
This course is kinda different from the other courses I took so far. If I compare it with other courses, this class is pretty much teaching the students the practical one rather than the theoretical ones.
It felt like I was part of some great human experiment.
Dr. Van Wei is a talented and enthusiastic instructor. I have a lot of respect for him. He has always been fair to me.
3. Additional comments or response to questions prepared specifically for this course by the instructor.
I liked it.
Meet twice a week in lab and once a week in lecture and make it a 3 credit class.
Too much outside time was needed. Should be worth more than two credits.
Try to teach this course in the "middle of active and passive" learning. I think this class is too "active".
Sepuyatku

APPENDIX 3-B

NOTES FROM OMBUDSPERSON MEETINGS

AND STUDENT VIDEO INTERVIEWS

2/11/05 Evaluation

1)

- pretty hands on – actually doing helps
- more set in stone when you figure out
- don't have to sit in lecture for 1h
- more fun
- rotating thru modules – 1 due every 1/2 week
- SGs learning nice
  - ↳ helps you ask Qs
  - ↳ learn material better, especially if people in Jigsaw have it right.
- individual HWs helps
- handing out HW helps
- workload not bad (not more rigorous)
- more fundamental theory side being learned by TA
  - ↳ answering Brad, Mike's Qs

2) Problems

- 1/2 h figuring out Deq.
- 15 min late
- some not as serious about class
- guy dropped class & Billy took over – perfectly fine
- Billy – figured out how to teach as he went
- language barrier – asked Q he didn't know the answer to.
- wrong is getting on wrong track – persists for years — Can't read
- grade – answer off – not good enough } – some modules didn't get so, it would take more time
  - right process wrong answer –
  - HG frustrating schedule wise

3) What could we do differently if anything

- any reasonable way to know we actually have the concept
  - ↳ Jigsaw group turn in module writeup 1st
- everybody works it out
- have a set of handouts
- I say – Might want to get together before you teach it
- Do writeup of module w/ blanks
- JITT – have Jigsaw turn in 2 D before doing module.
- Jigsaw group turn in assignment early.
- meeting w/ everyone
- assignment to ~~groups~~ HGs by Jigsaw person

interviews

- 10 wks = zero ??
- Syllabus overwelming — make series of handouts
- good students (trad) not necessarily as good w/ concepts
- mixing people up worked well - met more people in class
  - less distractions (outside class intrests)
- Some people unwilling to work in groups
- more willing to get help from other students
- take responsibility for own learning
- hard to find time for groups to meet
- groups held missing members accountable
- need more structure / support for groups (2 out of 4 in 1 group non-part.)
- Syllabus doesn't quite reflect course
- module problems need work
- accountability for teaching modules
  teaching modules approached as lectures

need consequences

group ability sometimes overestimated

- better prepared by being able to work w/ new people

autorating?? or Felders grade adj.

group assessment

group roles

student interviews - Fake interview
- more work (toomuch work ~5credits worth)
- 'top' students 'carrying' group
- hard to get groups to show up to meeting
- threatening phonecalls
- very fun for 8am, not boring
- learning happened outside of class
- learn better out of text??
- stick w/ groups you already know
- non english speaker a problem
- hard to talk w/ Bernie not receptive no office hrs
- toomuch confidence in group
- problems from being only girl - became secretary
- incompatible groups
- had to drop a class??

APPENDIX 3 - C

INDEPENDENT FACULTY INTERVIEWS

William J Thomson:

I interviewed 4 students to determine their grasp of fundamental concepts related to the design of piping systems and shell and tube heat exchangers. Each interview was only 15 minutes and this was really too short a time to be able to get a good assessment.

Based on these 4 students, I have the following observations:

All students were familiar with the individual terms in the mechanical energy balance and what they represented. Three of the four were familiar with the tradeoff between pipe cost and pumping costs as a function of pipe size. All students were familiar with pressure losses for fittings and valves but only two students were able to say how skin friction losses were related to the definition of the friction factor and its dependence on Reynolds number. All the students were aware of the existence of trade-off in the design of a shell and tube heat exchanger but only two could identify the details of the trade-off. Two of the students were not able to identify the mechanism of heat transfer in the fluids and three were not able to describe how these heat transfer coefficients were calculated. When asked which dimensionless parameter would be most important in turbulent convection, only one identified the Reynolds number, while the other three attempted to write a generalized correlation equation dealing with Grashoff and Graetz numbers. It was obvious that they were trying to remember equations as opposed to concentrating on which parameters were related to the mechanism of heat transfer. Not too surprising, all the students were weak on the use of similarity methods for data correlation.

Based on only 4 students and only 15 minute interviews, it is not really possible to draw any meaningful conclusions as to the degree to which the students have grasped the fundamentals. However, based on my experience, I am reasonably confident that the students have as good a grasp as students taught in the traditional manner.

J.J. Scheldorf

All had some trouble with what was in the mechanical energy balance. Also, having figured out the mechanical energy balance, they were willing to use it (unmodified) on the heat exchanger.

I also saw some tendency to go back to homework problems and try to adapt the homework solution to explain this system.

Lots of confusion about how to change h <heat transfer coefficient>. They wanted to change diameter, material of which pipe was made, friction factor, etc.

Trouble starting at tank and working thru system and identifying causes of Δp. They tended to get these if the specific locations were pointed out, but didn't pick them out themselves.

One student wanted our of lecture and 2 hours lab per week. Another wanted more "hands on."

I didn't feel I had enough time to do justice to the list of questions. By and large they seemed to be able to "dig out" the answers given some guidance (time consuming).

Was fun.

J^2 S

To: B.J. Van Wie

From: K.C. Liddell

Date: April 30, 2004

Subject: Assessment of ChE 332 students

To help you assess the knowledge students gained in ChE 332, I met with four students individually for about 15 minutes each and asked all of them the same two questions:

(1) A puzzler. Previously, I had watered both my raspberry patch and flowerpots using a regular (nonpermeable) hose, and a ⅜ in soaker (permeable) hose on the end of the regular hose. This worked fine – flowrates were reasonable. After the ⅜ in hose sprang leaks, I replaced it with a ⅝ in soaker hose; all other conditions were identical. The flow rate to the raspberries was noticeably reduced with the ⅝ in hose, and there was no flow to the flowerpots at all. The ground is level between the faucet and the raspberries; the flowerpots are on the porch, which is approximately 2 ft higher. Explain what is going on, give me a recommendation what to do, and explain what equation(s) and data you would need to carry out calculations to back up your analysis.

(2) Explain what factors would be important in deciding the feasibility of using a fluidized bed to heat a gas stream to a desired temperature. For the same solid volume, would you be better off with a tall, small-diameter bed, or a short, large-diameter bed? What tradeoffs are involved?

One student suggested that I put tape around a portion of the ⅝ in hose, but wasn't able to explain why that would help. He thought that question should be answered using an analogy to heat transfer. He also was not able to identify any tradeoffs in operating a fluidized bed.

Another student quickly realized that in the fluidized bed, the gas residence time would need to be long enough for the heat transfer to occur, favoring a tall bed, but the pressure drop would need to be kept low, favoring a short bed. He also recognized that in the hose question, the flow rate could be estimated using a Bernoulli equation and thought that friction inside the hose may be important.

The other two students both recognized that the pressure drop is the problem with the larger hose and that its surface area is larger than that of the smaller hose. One of them also thought skin friction would be significant. Both had some trouble grasping the importance of pressure drop in the fluidized bed.

My overall impression is that the first student described above has only a weak physical intuition about fluids and heat transfer. The other three appear to understand the basics fairly well but may have some trouble with new situations.

After each student had had a chance to answer the two technical questions, I asked each of them for general comments or suggestions about the class. Three of the four thought that more frequent and longer lectures would be helpful to give them a sense of direction and cover aspects of the theory involved. One thought that the hands-on modules would be more helpful if they were used to obtain data to compare to theoretical equations. Another suggested that groups should be assigned on the basis of students' schedules.

To: Paul Golter
From: Richard Zollars
Subject: Interview of ChE 332 Students

I interviewed Barb Cramer, Erik Willis, Dan Rieck, and Brian Wilhelm about their experiences in the ChE 332 class this semester. In most cases the questions asked of each of the students were the same. These were:

1. What modules did they teach to their groups?
2. How well did their group function?
3. Explain how you would size the pump in the process diagram.
4. How do you determine the friction factor for determining skin friction?
5. What flow meter would you recommend? Why? Explain the relationship between the flow rate through the meter and the other properties of the flow.
6. If you knew the flow rates of both streams through the heat exchanger and three of the temperatures how would you go about sizing the heat exchanger? How would this procedure change if you knew the size of the heat exchanger?

7. How would the performance of the heat exchanger change if you used a few large diameter tubes versus many small diameter tubes?

In all cases the students showed a good grasp of the concepts. While some of the students were not as competent as others there was no consistent shortcoming in their understanding. As might be expected the people who had to teach a topic were more competent in answering the questions about that topic than were students who taught other topics. I would assess the general competence of this group of students as being on par with students taught via conventional techniques.

I did discover three items of interest. First concerned the groups. It seemed that the groups may have been only marginally productive. Among the four students I interviewed ant least one of the groups had a group member who apparently did not participate on a regular bases. In fact the students commented that they left his name off of the last project because of his lack of participation. In another case it appeared that the group was actually two teams of two, with some interaction between the two teams. I asked whether having a non-participating team member hindered the group's learning of the topics that the non-participating member was supposed to teach. The students indicated that they received enough guidance so that the remaining group members could learn the material on their own.

A second item does indicate another strength of group work. Brian Wilhelm commented that he had had a hard time connecting with this class because he had entered the chemical engineering program with the prior year's class. After the group work in the ChE 332 class he now has connected with this class and finds it easy to interact with other class members when he needs help.

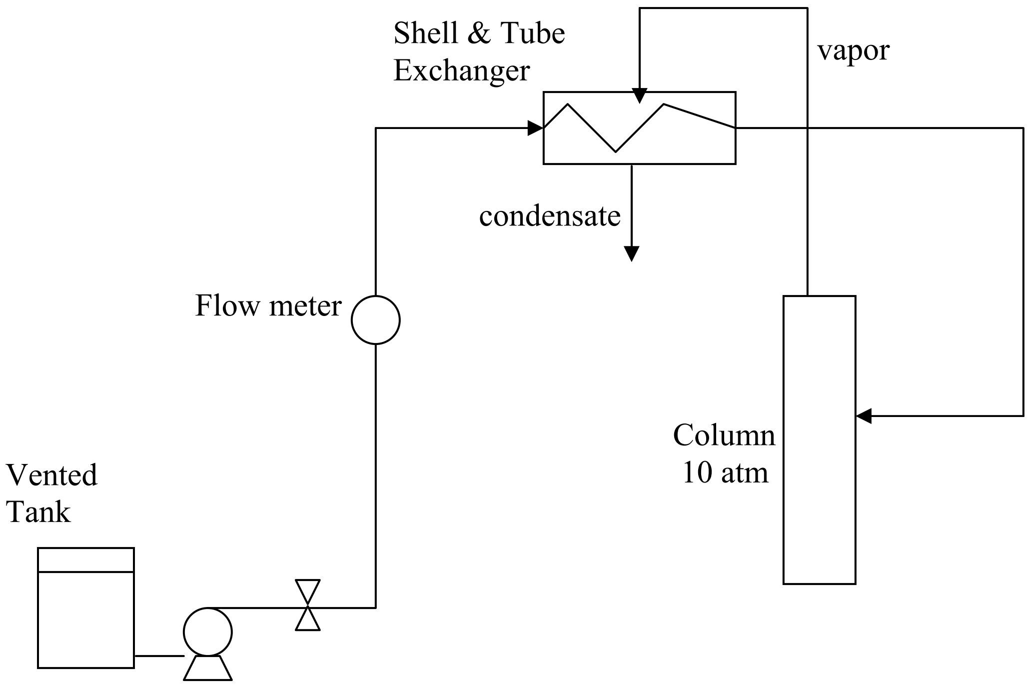
Finally, I found that the students had only be introduced to formulas for determining friction factors, e.g. $f = \frac{16}{N_{\mathrm{Re}}}$. None of the students I interviewed were even aware of the friction factor plots that are available in any text or reference. I would suggest that this should be added to this class in the future.

The following are the basic subjects that we need you to probe for:

1. Fluid Mechanics
    a. Basic Concepts of mechanical energy balances
    b. Impact of laminar vs. turbulent flow (e.g. impact on pressure drop)
    c. Flow measurement
    d. Parameters needed to design a piping system and size a pump
2. Heat Transfer
    a. Modes of heat transfer
    b. Impact of laminar vs. turbulent flow (e.g. on heat transfer coefficient)
    c. Parameters needed to size a heat exchangers
    d. Exchanger optimization (pressure drop vs. surface area)

The diagram on the next page is a good starting point for this. For your convenience we provide the following sample questions. If you would prefer, free to draw on your experience to come up with your own. The course syllabus is also provided.

- How would you determine the pressure drop between <*any two points in the diagram*>?
- How would the type of heat exchanger used influence the pressure drop, give specific examples.
- What information do you need in order to size the pump, be specific?
- Where, in the system drawn, would you expect to see each mode of heat transfer?
- What would you need to do in order to size a heat exchanger for this system?
- What are the trade offs in sizing a heat exchanger?


Shell & Tube
Exchanger
vapor
condensate
Flow meter
Column
10 atm
Vented
Tank

APPENDIX 3-D

CTLT FOCUS GROUP

June 14, 2004

To: Bernie Van Wie

From: Rebecca Dueben

Re: Focus Groups

CTLT personnel conducted a focus group with 12 students in four different groups from the spring Chemical Engineering course. The following highlights emerged.

On Course Design

- All of the students who answered the question had initial misgivings about the activities and timeline laid out by the syllabus, and several didn't anticipate that they would like group work. Most felt that there was a general improvement in the course throughout the semester.
- Many students commented that they liked this class better than a "traditional" class. They felt that the hands-on work was more fun and engaging than lecture. Many felt they learned more in the group work.
- Several students mentioned that one or more extra TA's were needed, and that it was hard to find them outside of class for help.

On the Field and Subject of Chemical Engineering

- The majority of students felt that they had learned valuable content and skills in the course.

- Several students learned that group work is valuable to their success in later jobs, while one student learned that group work is not for everyone since some people work better individually.
- Several students mentioned that they learned how to “figure out” equations and to be open to each student’s unique way of finding the answer.
- Many students felt that they learned important course content, including fluid movement, heat transfer, field measurements, and appropriate use of equipment.

Student Changes as Learners

- Several students did not understand one of the questions (How did this course change your practice as a learner, if at all?).
- Several students felt that they benefited from the social contact in group work.
- Several students noted that they had more responsibility than in other classes and that they relied less on the professor. Many noted positive changes such as extending their study groups to other classes, spending more time on task, and finding general helpfulness in group work. A few students noted no change in their study habits and a couple of other students mentioned the awkwardness of group learning.

Conclusions

- The results of this study are consistent with similar studies on student-centered instruction.
- Students’ initial discomfort with the class can be attributed to the course design being an anomaly to students.

- Benefits are real, but are neither immediate nor automatic.
- Initial student resistance tends to be strong, and can persist beyond the student's first semester in such a course.

June 17, 2004

To: Bernie Van Wie

From: Rebecca Dueben

Re: Focus Groups

CTLT personnel conducted observations of the Chemical Engineering 332 class in spring 2004. There were approximately 12 students in four different groups. Observations were conducted on two different dates. The study was limited by the challenges encountered norming raters on the use of the criteria in the Guide to Rating Critical Engagement as well as by variance between facilitators. Nonetheless, two aspects emerged from the assessment of facilitator's comments and student interaction the merit attention.

Faciliators' Contributions

- On the first observation, the raters gave an average score of 4.2 out of a possible 6; on the second visit, an average score of 3.5 was yielded.
- On the first visit, most of the observers' comments on this visit for the "nature of facilitators' contributions" noted that the interaction was student-led. On the second visit,

most observers said that the conversation was primarily between the facilitator and students, that there was little student-to-student conversation.

- During the 2nd observation, one observer noted that though the facilitator "felt comfortable allowing students to struggle over key concepts," he did "not encourage full participation of all group members."

On Student Interaction

- On the first observation, most observers noted that students were relying on each other to problem-solve. On the second observation, most observers said that the conversation was primarily between the facilitator and students, that there was little student-to-student conversation.
- For the student interaction, most observers noted that students were relying on each other to problem-solve. One observer noted that "*all* students participated and demonstrated a willingness to listen and consider other viewpoints." Another said that "All students in this group were highly engaged."
- Another observer saw that students kept conversation going between themselves, but eventually "start[ed] looking to facilitator for answers."

Conclusions

- Because the import of the activity-based nature of this class is novel and rarely reinforced in the university, students tend to revert to familiar authority-dependent models of interaction. Their initial discomfort (emerging clearly in the focus groups), resulted, as observers noted, in pressures on all participants—*students and facilitators*—to gravitate toward traditional teacher/facilitator centric models of the teaching/learning exchange.. That even as student interaction diminished slightly through the term of the course, relative to the full tradition of lectures, student interaction, observers agreed, remained extensive and robust.

- Reinforcement both from the university in general as well as the individual facilitators within the class in future efforts will only enhance an impressive effort.

Chemical Engineering Critical Engagement Study
Focus Group Results
by L. Girardeau

Introduction

Engineers are being required to use more team building and communication skills, and "[m]any engineers [have] noted that their education was too theoretical and that they would have liked more practical insight and assignments" (Cofer, 2002). Many studies have shown that SCI (student-centered instruction) increases learning gains and student engagement in comparison with teacher-centered instructional methods. Student-centered instruction is characterized by active learning, in which students solve problems, formulate and answer questions, and discuss or brainstorm during class. It also involves cooperative leaning, in which students work on problems and projects in teams to increase interdependence while retaining individual accountability. Mastery, retention, understanding, critical thinking, and engagement have all been found to increase with student-centered instruction (Felder & Brent, 1996).

Student-centered instruction involving both active and cooperative learning was implemented in an undergraduate chemical engineering course at Washington State University. Near the end of the semester, student employees at the Center for Teaching, Learning, & Technology facilitated student focus groups to analyze student perceptions of their engagement and learning throughout the course.

Methodology

Although this study yields some interesting results, there are some limitations to the data due to methodology issues. First, the same questions were not asked in all of the groups. In one group, slight variations in the way that some questions were worded may have been interpreted differently by the students. In another group, one of the questions on the planned list was omitted, and new questions were added. In groups where all of the planned questions were asked, some students did not understand some question and discussed a slightly different topic. Clarification and probing for understanding were not employed. The recording of data also presented some problems. Notes were not always detailed enough to capture the meaning of responses. Numerical data was not kept on how many students commented, how many agreed or disagreed with these comments, and whether some comments came from the same student.

Although it is to be expected that data is not completely reliable without recording and transcribing the focus groups, we created a more meaningful data set by analyzing only those student responses relating specifically to the planned focus group questions. In cases where not all of the 13 participating students were asked a certain question, the smaller sample size is noted. Since the number of students responding to each question was not provided, results are expressed in qualitative terms.

Results

Question 1: How did you initially respond to the way the course was planned in the syllabus? This question was asked in order to determine a baseline for the attitudes that students bring to their first day of class, and their preconceived notions about different instruction techniques such as group collaboration. One facilitator worded the question slightly differently:

How did you respond to the way the course was set up? Therefore, some responses may pertain to attitudes about the syllabus, while others may pertain to the first few weeks of class in general.

All of the students who answered the question had initial misgivings about the activities and timeline laid out by the syllabus. Several students initially felt confused by the syllabus plans, and didn't know what to expect. Several didn't anticipate that they would like group work. A few students noted that the semester was extended longer than it should have been in the syllabus. One student anticipated a challenging course, one thought that feedback would come too late as listed in the syllabus, one noticed a lack of concrete resources, and one didn't like the syllabus plans in general.

Question 2: How has the way you respond changed as the semester progressed?

This question was meant to track the change in student attitudes as the semester progresses and students gain more experience with group work and other innovative instruction techniques. Only half of the class was asked this question, since one facilitator did not ask this question and another asked a different question about the last week of class rather than the semester as a whole (*How did you respond in the last week of class to this course?).* That data was not counted, since the last week of class contains myriad stresses related to finals and unrelated to the study focus.

Of the students who addressed the planned question, most felt that there was a general improvement in the course throughout the semester. One student particularly liked the hands-on work and felt that it was better than listening to lectures.

Question 3: How did this course change your practice as a learner, if at all?

This question was meant to elucidate possible changes in student learning habits as a result of the course. However, the term “practice as a learner” seemed unfamiliar to most students, so many answered in terms of their preferences rather than their own habits. That data was not counted.

Of those who addressed the question, several students felt that they benefited from the social contact in group work. One student mentioned that group work was helpful in general, and one noted that group work was difficult when other members did not contribute as much as others. Several students noted that they had more responsibility than in other classes and that they relied less on the professor. One said that self-teaching felt awkward. One student read the book more than usual in order to understand concepts.

Question 4: How have your learning habits changed in this class? This question is similar to Question 3, and the subtle difference in meaning may not have been clear to the students. Again, most students did not seem to understand the question, and many answered in terms of their preferences rather than their own habits. That data was not counted.

Of the students who addressed the question, one student studied with others more than before, and one noted that their study group studied together for other classes. A few of the students felt that there was no change in their learning habits. One felt that they spent more time in the computer lab, one studied the book more since there weren’t lecture notes to study, and one noted that in the class they were given more responsibility to figure out things on their own.

Question 5: What did you learn about the field of chemical engineering in this class? This question captures gains in content knowledge and attainment of learning outcomes. This question yielded the most revealing and inspiring results.

The majority of students felt that they had learned valuable content and skills in the course. Several students mentioned that they learned how to "figure out" equations and to be open to each student's unique way of finding the answer. This indicates that many students learned to consider multiple perspectives and think for themselves in this class, which are valuable aspects of critical thinking. One student noted that their learning was "in-depth." Another noted that they learned how to "discuss a problem for 5 minutes before answering the question," another valuable aspect of critical thinking and engagement. (It is unclear whether this student was being sarcastic about a rule to discuss each problem for a certain amount of time). Many students felt that they learned important course content, including fluid movement, heat transfer, field measurements, and appropriate use of equipment. One student felt that the module didn't translate to real-world situations.

Question 6: What have you learned about yourself as a learner in this class? This question was meant to capture self-reflection that may have occurred while engaging in the new class activities. Several students did not understand the question, and reflected on the class in general rather than themselves as learners. That data was not counted.

Many students learned that each student has their own learning style, although one student mentioned that they still don't know their own. (It is unclear whether the students were parroting what the instructors had told them about learning styles, or whether they learned about their own learning styles). Several students learned that group work is valuable to their success in later jobs, and one student enjoyed the social contact of group work. One student learned that group work is not for everyone, since some students learn better individually. (It is unclear whether this student was referring to their own preference). One student did not feel that they learned much about their learning habits, and another felt that the class didn't differ much from other classes.

Additional Question: General comments on the course. This question was asked by all facilitators in order to capture any opinions that were not covered by the previous questions, or that students neglected to interject at that time. Comments on the course that were peripheral to this study on critical engagement were not counted.

Many students enjoyed the group work more than traditional lectures in other classes, and felt they learned more. Some liked the jigsaw group style, since not all group members have the right info for every assignment. However, scheduling group meetings was difficult for many students. Some suggested putting groups together based on schedules. Several students mentioned that one or more extra TA's were needed, and that it was hard to find them outside of class for help. One noticed long periods where there group had nothing to do while waiting for TA's, or for other groups to complete an in-class activity. One student noted that the test style could be aligned more closely with the hands-on activity style.

Student-Asked Question: How did your learning in this class compare to classes taught in the traditional lecture style? Which did you like better? Why?

In Focus Group 4, a student actually posed this question to the other students. Because this pertains to our topic, we are including the results. However, these results pertain to only about ¼ of the class members.

Of those who were asked this question, many students commented that they liked this class better than a "traditional" class. They felt that the hands-on work was more fun and engaging than lecture. One student commented that it helped them think critically: "You can see where the equations are coming from, rather than just looking at them on a board."

Conclusions

The results of this study are not surprising, and are, in fact, in accordance with similar studies on student-centered instruction (Felder & Brent, 1996). Countless studies have shown that properly implemented student-centered instruction and cooperative learning techniques lead to increased motivation, greater retention, deeper understanding, and more positive attitudes toward the subject matter (Bonwell and Eisen 1991; Johnson Johnson and Smith 1991a,b; McKeachie 1986; Meyers and Jones 1993). However, initial student resistance tends to be strong, and can persist beyond the student's first semester in such a course.

"The enthusiasts may be in for a rude shock…While the promised benefits are real, they are neither immediate nor automatic. The students, whose teachers have been telling them everything they needed to know from the first grade on, don't necessarily appreciate having this support suddenly withdrawn. Some students view the approach as a threat or as some kind of game, and a few may become sullen or hostile when they find they have no choice about playing" (Felder & Brent, 1996).

This may explain why many students in this course had initial misgivings about the syllabus plans for group work and other innovative activities. However, as the semester progressed, many began to enjoy the collaboration with other students and instructors, and the challenge of thinking for themselves. They reported many learning gains. Others were not so quickly sold, and seemed ambivalent about the new activities, saying that the course was "just like other courses" or noting that their own "learning style" was for individual work. Although this may be true, it may also simply be "the path of least resistance" until the student gains more experience with activities other than lecture throughout their college career. Often, the same students who report that they don't like a course because it challenges them to take more responsibility also report gains in content and critical thinking skills, as well as increased engagement with peers and instructors.

The fact that many students improved their attitudes towards student-centered instruction during the same semester is encouraging, since researchers note that these attitudinal changes sometimes take experience in several courses. Additionally, some of the students' issues with the course may have been due to organizational details that can be smoothed out in later semesters. The difficulty in coordinating group work and other innovative activities can pose organizational challenges and make students feel confused about activities and expectations. Students in this study suggested some improvements that may help the activities run more smoothly the next time.

Several students noted that although group work can be engaging, the inevitability of working with unmotivated group members detracts from this experience. Understandably, students don't like to carry the load for unmotivated students or to be graded unfairly for others' failure to apply themselves. When group members give other members incorrect information during peer tutoring or presentations, some students feel that their learning is hindered. One student said that the jigsaw group format helped with this problem. TA's are needed to facilitate the groups, and most students felt that one or more additional TA's would be helpful, since they were sometimes left waiting for TA's when they had questions or had finished their activity. Scheduling is another major issue with group work. Coordinating meeting times outside of class took a considerable amount of time and effort. One student suggested forming the groups according to schedules in the first place, so that finding meeting times outside class would work well and so that more energy could be devoted to the actual work, not the scheduling.

Dr. Richard Felder of the North Carolina State Dept. of Engineering offers solutions to managing such organizational details, as well as descriptions of common student reactions to student-centered instruction in the excellent resource, "Navigating the Bumpy Road to Student-Centered Instruction." (See reference list).

REFERENCES

Bonwell, C.C., and J.A. Eison. 1991. *Active learning: Creating excitement in the classroom*. ASHE-ERIC Higher Education Report No. 1. Washington, DC: George Washington University.

Cofer, W.E. 2002. It Takes A Village to Raise an Engineer. *Washington State Magazine,* 10.

R.M. Felder and R. Brent, "Learning by Doing." *Chem. Engr. Education, 37*(4), 282-283 (Fall 2003). The philosophy and strategies of active learning.

R.M. Felder and R. Brent, "FAQs-2." *Chem. Engr. Education, 33*(4), 276-277 (Fall 1999). Responses to the questions "*Can I use active learning exercises in my classes and still cover the syllabus?*" and "*Do active learning methods work in large classes?*"

M. Felder and R. Brent, "Navigating The Bumpy Road to Student-Centered Instruction." *College Teaching, 44*(2), 43-47 (1996). The origins and patterns of student resistance to active and cooperative learning, and suggested ways to deal with the resistance. http://www.ncsu.edu/felder-public/Papers/Resist.html

Felder, R.M. 1993. Reaching the second tier: Learning and teaching styles in college science education. *J. Coll. Science Teaching*, *23*5, 286-290.

Johnson, D.W., R.T. Johnson, and K.A. Smith. 1991a. *Active learning: Cooperation in the college classroom*. Edina, MN: Interaction Book Company.

McKeachie, W. 1986. *Teaching tips*, 8th Edition. Lexington, MA: Heath & Co.

Meyers, C., and T.B. Jones. 1993. *Promoting active learning: Strategies for the college classroom*. San Francisco: Jossey Bass.

APPENDIX 3-E

FEEDBACK FROM DR. R. FELDER

North Carolina State University is a land-grant university and a constituent institution of the University of North Carolina

Chemical Engineering

NC STATE UNIVERSITY

College of Engineering
Campus Box 7905
Raleigh, NC 27695-7905
919.515.2324
919.515.3465 (fax)

June 16, 2004

Professor Bernard J. Van Wie
Department of Chemical Engineering
Washington State University
PO Box 642710
Pullman, WA 99164-2710

Dear Professor Van Wie:

I wanted to belatedly offer some comments on my observation of your innovative fluid dynamics course. I was particularly impressed by the range of pedagogies you are bringing to bear in this course, including active learning, cooperative learning, problem-based learning, and hands-on experiential learning. I am familiar with engineering implementations of each of these methods at different institutions: for example, active and cooperative learning at the University of Minnesota and many others, including my own, problem-based learning at the University of Delaware and McMaster University, and hands-on learning at Rowan University and Olin University. I have never before heard of a course that combines them all, though, other than yours. Judging from the high quality of the student presentations I observed, it seems to be working well. I look forward to following your continuing progress with this approach.

Sincerely,

Richard M. Felder

lder
Hoechst Celanese Professor Emeritus

APPENDIX 3-F

LEARNING STYLES SUMMARY

	NC State				Brain Works	
Student	Act-Ref	Sen-int	Vis-vrb	Seq-glo	Left-right	Visual Auditory
1	3	-11	-9	-5	-0.5	0.5
2	3	-3	1	-1	-1.5	-2
3	7	7	-7	-5	-1	0.5
4	3	3	3	9	-0.5	0.5
5	5	-3	-3	-5		
6	-3	-5	1	-1	-1	-0.5
7	-1	-1	-9	5	0.5	-3
8	1	3	-3	-1	0.5	-0.5
9	3	-1	-9	-7	-0.5	-0.5
10	-7	-5	-3	-5	1.5	-0.5
11	-3	1	-7	1	-0.5	1.5
12	5	1	-9	3	0	0
13	-7	-5	-5	9	1	-1
14	-1	7	-7	-5	-0.5	0.5

APPENDIX 3-G

SURVEY GIVEN IN 2004

Compared to the beginning of the semester in this class, to what extent do you currently experience the following:	Significantly More Often	More Often	Same	Less Often	Significantly Less Often	Total
Spent more time on tasks for the class	7	3	2		1	13
Discussed topics of the course outside of class	4	6	3			13
Learned in new ways		6	5	1	1	13
Shared your ideas and responded to the ideas of other students	3	5	4	1		13
Felt more isolated			4	6	3	13
Discussed ideas and concepts taught in this course with the instructor	1	5	3	3	1	13
Made use of your unique abilities and skills to aid your learning	6	3	3		1	13
Felt challenged to create your own understanding	7	2	2	1	1	13
Felt this class has prepared you to work in the field	3	4	3	1	2	13
To what extent have you experienced the following in Chem E 332 compared to lecture-based classes you've taken:	**Significantly More Often**	**More Often**	**Same**	**Less Often**	**Significantly Less Often**	**Total**
Spent more time on tasks for the class	9	3	1			13
Discussed topics of the course outside of class	9	3	1			13
Learned in new ways	2	8	3			13
Shared your ideas and responded to the ideas of other students	3	7	3			13
Felt more isolated	1	2	3	4	3	13
Discussed ideas and concepts taught in this course with the instructor	1	5	5	1	1	13
Made use of your unique abilities and skills to aid your learning	3	3	5	2		13
Felt challenged to create your own understanding	5	4	3	1		13
Felt this class has prepared you to work in the field	3	6	2	2		13

Compared to the beginning of the semester in this class, to what extent do you currently experience the following:	Significantly More Often	More Often	Same	Less Often	Significantly Less Often	Total
Spent more time on tasks for the class	54%	23%	15%	0%	8%	100%
Discussed topics of the course outside of class	31%	46%	23%	0%	0%	100%
Learned in new ways	0%	46%	38%	8%	8%	100%
Shared your ideas and responded to the ideas of other students	23%	38%	31%	8%	0%	100%
Felt more isolated	0%	0%	31%	46%	23%	100%
Discussed ideas and concepts taught in this course with the instructor	8%	38%	23%	23%	8%	100%
Made use of your unique abilities and skills to aid your learning	46%	23%	23%	0%	8%	100%
Felt challenged to create your own understanding	54%	15%	15%	8%	8%	100%
Felt this class has prepared you to work in the field	23%	31%	23%	8%	15%	100%
To what extent have you experienced the following in Chem E 332 compared to lecture-based classes you've taken:	**Significantly More Often**	**More Often**	**Same**	**Less Often**	**Significantly Less Often**	**Total**
Spent more time on tasks for the class	69%	23%	8%	0%	0%	100%
Discussed topics of the course outside of class	69%	23%	8%	0%	0%	100%
Learned in new ways	15%	62%	23%	0%	0%	100%
Shared your ideas and responded to the ideas of other students	23%	54%	23%	0%	0%	100%
Felt more isolated	8%	15%	23%	31%	23%	100%
Discussed ideas and concepts taught in this course with the instructor	8%	38%	38%	8%	8%	100%
Made use of your unique abilities and skills to aid your learning	23%	23%	38%	15%	0%	100%
Felt challenged to create your own understanding	38%	31%	23%	8%	0%	100%
Felt this class has prepared you to work in the field	23%	46%	15%	15%	0%	100%

APPENDIX 4

2005 DATA AND MATERIALS

APPENDIX 4-A

STUDENT COMMENTS ON END-OF SEMESTER COURSE EVALUATION

1. Do you have any suggestions for improving the course in any way? Do you have any suggestions for the instructor?
The method of CL worked very well. However, I don't think that this method would work effectively with other classes such as ChE 201 and 211
• The students teaching other students was only effective to only a certain degree. I remember on the first exam missing points on a topic that was not mine and didn't know much about it and the person who had that topic got the question right. • to improve students needs to be given more time to teach their topic to other students, as well as more time to prepare to teach
It would be good if lecture given by the instructor once a week
A lecture at least once for every topic will be good because some of the basic concepts were not clear to us still
The lab experience was very good. However it works better if all students do the reading and participate. A participation grade might be needed with other students grading their group members.
Don't try to pack so much homework into a week. Spread it out a little more.
• For a 2 cr. Course, there was an awful lot of mat'l to cover and I think reducing the amount would help me retain a more through understanding • Specify what is expected on the 2 major group projects - on the 1^{st} proj. it was not clear that we had to fully design each unit.
I spent way too much time on HW than most 3 credit courses I still think a lecture here and there would help learning process to ensure what you think is taught was actually learned by other group members
Do not use student based teaching for modules – it is not helpful to watch someone for an

hour who has no idea how to present important material. Felt that I could not approach instructor without entire group present. Limited ability to discuss topics outside of class. Very unhelpful group (home) little to no cross training. Each person completed small segment of projects at last minute, so there was no time for entire group to learn entire project.
Some lecture would be nice. Just to give an overview of what we are learning.
I would have liked to use the equipment for pressure drop in long pipe.
Module Problems – work through them first to see if they work and all essential info is available. Many hours were spent working on some that were unsolvable at first.
I would have this class taken prior to ChE 310. I feel as though I didn't understand the overall concepts of ChE 310, until I took this class. This class gave me the necessary understanding to take 310, however, if I was to take it after 332, it would benefit me more.
I wish there would be a lecture mixed in to the cooperative learning style.
This class includes many practical ideas and concepts. I would suggest a 3-credit hr course in which one lecture would be held a week to cultivate ideas and direct them properly. The homework load for this class and outside involvement was too much for a 2-credit class.
1. give answers to practice exams. I would work on them in a group, but sometimes nobody in the group would catch that we made and error, so we'd miss it on the exam. 2. The students teaching other students in class doesn't work very well. There was not enough time to have us become "experts" on the subjects. 3. The 2nd part of the course was too rushed, I don't feel I learned it as well. 4. Only a 2 credit class: Too much time had to be put in. Chem Eng majors are overworked – not enough time for sleep.
There needs to be a lecture along with the lab, because the group that I was in we would waste more time learning the wrong way to do things, and or never learn the right or proper way to go about solving these types of problems. A lecture to steer us in the right way would be the most beneficial thing for myself and most others that I have talked with in this class.
Learning from students interpretations of concepts is not always correct. I felt I missed some key concepts because they just weren't presented properly by peers. Other than checking solutions, there was no way to verify if a concept was correct.
2. What is your opinion concerning the overall quality of instruction in this course? How

did it compare with others in the department, the college, and the university?
The instructor was very good. But he should've spend more time and cooperate with the students more, when we were doing our hw and projects.
• We spent too much time outside of class, the amount of homework was ok it was just the length of time it took to complete them. • Overall although this class was very time consuming I liked the group work and activities I felt like I learned a lot more in this setting.
I like this class, this class prepare us for real life job comparing to other class
It takes a lot of time to do the homeworks for this class because some of the questions are unclear.
I really enjoyed this experience and feel that it gave me a much better understanding of the subject matter.
It was the same as other classes, but required much more time than even my 3 cr. Classes.
Very different, but helpful in working with groups. Had to overcome some difficulties in group. Instructor was enthusiastic and easy to talk to. Good job.
Very good instruction.
It was fine.
Group working did have its ups & downs. A lot of time getting together, however a lot more ideas. Overall, it was better than I originally thought.
I feel as though I learned a lot in this class, however, in lab, I feel that if van-we would have jumped in and given us straight advice it would have helped more. Another thing: before presenting on your subject, it would be helpful if van-we gave all the presenters handouts of what they needed to cover. Also, it benefits me to be told how to do things when I get stuck!
I didn't like being or feeling taught by my peers. I felt I was "thrown to the wolves" too much and because of this I still don't understand some concepts I feel I should know, or would know being taught by an instructor.
I like the teamwork – it helped me get to know a lot of people.
I felt that I don't have anywhere close to the amount of knowledge from the second half of the semester that I should have, because of the lack of "right" information presented as in I

studied the wrong way to do things more than the right way.
3. Additional comments or response to questions prepared specifically for this course by the instructor.
This class should be taught like this in the future. Good job Dr. Van Wie
The instructor is very good at encouraging us into doing more challenging tasks specially in our projects.
Perhaps delivering a few background lectures to give us a starting point for concepts like radiators, packed vs. fluidized beds (terminology and goals of each).
Maybe do more w. learning styles @ beginning of course. Be careful in picking people for groups – by this time most of us know who we work best w/, so maybe put more people w/ their 1st or 2nd choice.

APPENDIX 4 – B

NOTES FROM OMBUDSPERSON MEETING

Ombudsperson Meeting – Kathryn Gahrett – 2/18/05

Preceptors: Bernie Van Wie, Paul Golter, Billy Schmuck

Positives: Learning the material

Time spent on the modules is good.

Handouts + reading assignments really helped.

Debates over problems is good; discuss a lot more (worked together in thermo last semester under their own motivation)

Groupings are new – getting to know others in class better than would have – new perspectives – new blood – everyone contributing equally –

Jigsaw: adequate – played in more time to prepare issue; didn't feel like they adequately learned the packed bed and shell & tube – could be personal focus wasn't there, maybe didn't understand formulas and how they applied to things. E.g. packed bed definitions, packing volume, bed volume, void volume. Thomson didn't adequately explain the packed bed – more information the better.

Lecture – have this in Phys 205 & 206 taught by Tom Dickenson – Socratic method of teaching yourselves w/ 2h block with TA for homework help.

Constructive Criticism:

More prep time – more preparation for the project i.e. more time to get it done is needed especially with the 3-Day weekend.

Module Problems – more time to get them done – give an extra day, etc.

Significant time being spent on homework problems; 2.5 – 6 hours/week per 2 problems per week – WORDING vague in some of the problems (both Module problems & Thomson). This doesn't seem to be such a problem to the preceptors.

Reading sometimes too broad and unfocused without direction.

Home group time with modules could be greater – trouble with shell & tube and fluidized bed.

More of a take home quiz while doing the reading (Jigsaw Team makes up quiz)

ChE 332 Ombudspersons Meeting

April 8, 2005

Brian Esparza and Todd Doering

General Feedback on the class

What's going well?

- Seeing a real system, pointing to places on the real system – don't have to say it or hear it perfectly – can jus point.
- Quiz: Most benefit of the quiz is making them.
- Likes this way of learning – think better when on your feet; think more in depth.
- Now everyone works together for every class – cliques have broken down, a larger majority are working together now. Seniors could care less what person next to them is learning – very competitive, withholding information.
- Finding velocity by measuring volumetric amount – never forgot it; Paul showing the importance of the points where taking your measurements – where the measurement is taken is vital – don't even have to review it now; anything visual is really a powerful tool; laminar flow with a dye is pretty visual.

Where are there problems?

- Everyone needs to take more responsibility for the quizzes, i.e. getting them back to the module leader.
- Getting everything out to people on time for the take home quiz is a problem.
- Not all groups with a fill in.

- Still some problems with a group member showing up always.
- Woman in group – may have done better with other friends in the group. Only knew one person previously.
- Problem with motivation: in one group many don't check e-mails or show up to other classes so you can talk with them, don't answer phone.
-

How can we improve it?

- Solving quiz issues: give ahead of time, but must fill it in at the beginning of the hour. Turn in the take home at the beginning of class. Must give the module on time or the group leader misses points.
- Quiz: Cool if they could hang on to them while developing the equations and turn in at the end; Have last Jigsaw on Monday, turn in learning module by Wed. Instructor assembles package and e-mails to everyone; first module on Fri.
- Two things that were sticky – "mesh" not defined anywhere. 10 x 20 mesh – shake one screen and then shake the other and collect stuff in between; Sphericity is wrong in an example in Thomson.

How are the groups working?

Test: Majority (14 people of 22) have a take home given 10a Th, due 12 noon Friday. Everyone except for Blake said they don't care when they had the test.

How well do think people are learning?

- First project – wrote up everything for that group whereas no-one else did anything else.
- How did the group do on the module problems – fluid part, one person went to other groups, one person seemed to teach all; must have learned it because they all scored higher on the test – no clue four days before the test they didn't know anything, yet they knew it for the test. Heat Transfer Module Problems – only two people did the work on the module problems, a couple showed up two hours late. Group evaluation – grade each other. When only two people show up it's bad because you need an intermediator. ***
- Good group: show us and discuss things together. Other groups appear to be doing well (Group I works great together; Difficult to communicate with a person who's not in the same courses as the others)

Overall

General Feedback –

– being able to see a real system + being able to point – good
(don't have + communicate perfectly to talk about problem)

– everybody needs to take more accountability for group stuff. ie turning in quizez on time.

– disagree / take home quiz being better than in class. Sometimes don't get quiz until too late to do ahead. → accountability issues. (quizes need to be turned in during class, also needs accountability on getting reading/quiz out on time)

– most benifit on quizes from making them. maybe hang on to quizes during class to provide ~~question~~ discussion material (worksheets didn't work so well or were forgotten during heat x portion – due to timing of spring break?)

– more fun – its how I learn, think better when on feet anyway
– makes you think more in depth

– Everybody works together in every class – broke up the cliques
– Finding velocity w/ volumetric flow – real visual, seeing where points are – visual very good, laminar flow ect.

Groups – Scheduling

– 1 member rather shop than work (always has friend coming in, ect)
– issues w/ only 1 woman in group?? – more that she didn't know most of group ahead of time
– she does go to work w/ group w/ other women ½ time
– slow group motivation – nobody checks email, don't go to other classes, don't answer phone
– communication tough w/ people who don't have alot of the classes

How well learning

– 1st project – didnt seem like rest of group did anything, group didn't work together on fluid module probs, somehow they all scored high on on test
heat x – 2 people do all work rest of group did implication work
{ slows things down alot

– would like to see group evaluations

how to find odd definitions such as Mesh (Tyler screens)
error in Thomson on sphericity in example prob

– Final schedule – most people don't care except for Blake

2-18-5
Ombudspersons
Kathryn + ~~Brian~~ Josh ← no show

e-mail Ernie
Fluid Module prob E.

Going Well

Feel like really learning material

need more preptime + org for project on Wed. - due to 3 day wkend
w/ module probs as well. → not quite enough time to get prob. done
too much time on Hwk ~ 2.5 — 6 Hrs / 2 probs ⇒ /wk
Handouts + reading really helped on modules, but not sure what to focus on for
pre-reading - take home quiz to focus reading assign. - jigsaw group creates
→ vague wording in problem statements - both module + book problems
debate very good - we're discussing ~~arguing~~ gets other perspectives
been doing informal groups in last few classes, groupings different, getting
new perspectives, meeting rest of class — Good
Home group - contributing equally, jigsaw - too brief to say

Jigsaw - seemed adequate - took more time to prepare, not too sure ~~and~~ really understand
a couple of the modules - not sure why either personal focus or not sure
what definitions were on packed bed (volumes!) maybe could have been
resolved w/ well designed take home

Kathryne ~~Catherine~~
personally does better w/ more detail

Had similar style w/ Physics 205 + 206 w/ Dickison, so no lecture kind of fine
low lecture
Socratic style

APPENDIX 4-C

LEARNING STYLES SUMMARY

	NC State				Brain Works	
Student	Act-Ref	Sen-int	Vis-vrb	Seq-glo	Left-right	Visual Auditory
1	-1	-9	-5	-9	-1	-2
2	1	-5	3	-9		
3	-11	-5	-3	-7	1.5	-1.5
4	-1	-3	3	-7	-2	1
5	-11	3	-11	-5	-0.5	-1
6	-1	-7	5	-5	-1	0
7	-7	-7	-7	-3	-0.5	0
8	-1	-3	-7	-3	-1.5	-0.5
9	-9	-1	-7	-3	-1.5	0.5
10	-9	-7	-3	-3	-0.5	1
11	1	-3	-3	-3	-0.5	-1
12	-1	-9	-9	-1	0	0.5
13	-1	-1	-7	-1	-1	-0.5
14	-5	3	-5	-1	-1.5	-1.5
15	-7	-1	-7	1	-0.5	0.5
16	-3	3	-7	1	-0.5	-1.5
17	-5	-9	-5	1	-0.5	-3
18	5	-1	-5	1	-1	1
19	-1	1	-9	3	0	0.5
20	3	-7	1	3	-1	-0.5
21	1	9	3	7	1	-0.5

APPENDIX 4-D

SURVEY GIVEN IN 2005

Compared to the beginning of the semester in this class, to what extent do you currently experience the following:	Significantly More Often	More Often	Same	Less Often	Significantly Less Often	Total
Spent more time on tasks for the class	8	7	3	1		19
Discussed topics of the course outside of class	8	6	4	1		19
Learned in new ways	2	10	5	1	1	19
Shared your ideas and responded to the ideas of other students	7	8	3	1		19
Felt more isolated	1	2	2	8	6	19
Discussed ideas and concepts taught in this course with the instructor	1	4	9	4	1	19
Made use of your unique abilities and skills to aid your learning	2	5	11	1		19
Felt challenged to create your own understanding	4	9	6			19
Felt this class has prepared you to work in the field	5	9	2	1	2	19
To what extent have you experienced the following in Chem E 332 compared to lecture-based classes you've taken:	**Significantly More Often**	**More Often**	**Same**	**Less Often**	**Significantly Less Often**	**Total**
Spent more time on tasks for the class	11	8				19
Discussed topics of the course outside of class	8	7	3		1	19
Learned in new ways	5	8	5	1		19
Shared your ideas and responded to the ideas of other students	8	6	4		1	19
Felt more isolated	1		3	8	7	19
Discussed ideas and concepts taught in this course with the instructor	1	3	9	4	2	19
Made use of your unique abilities and skills to aid your learning	2	7	9		1	19
Felt challenged to create your own understanding	4	10	4	1		19
Felt this class has prepared you to work in the field	5	8	4	1	1	19

Compared to the beginning of the semester in this class, to what extent do you currently experience the following:	Significantly More Often	More Often	Same	Less Often	Significantly Less Often	Total
Spent more time on tasks for the class	42%	37%	16%	5%	0%	100%
Discussed topics of the course outside of class	42%	32%	21%	5%	0%	100%
Learned in new ways	11%	53%	26%	5%	5%	100%
Shared your ideas and responded to the ideas of other students	37%	42%	16%	5%	0%	100%
Felt more isolated	5%	11%	11%	42%	32%	100%
Discussed ideas and concepts taught in this course with the instructor	5%	21%	47%	21%	5%	100%
Made use of your unique abilities and skills to aid your learning	11%	26%	58%	5%	0%	100%
Felt challenged to create your own understanding	21%	47%	32%	0%	0%	100%
Felt this class has prepared you to work in the field	26%	47%	11%	5%	11%	100%
To what extent have you experienced the following in Chem E 332 compared to lecture-based classes you've taken:	**Significantly More Often**	**More Often**	**Same**	**Less Often**	**Significantly Less Often**	**Total**
Spent more time on tasks for the class	58%	42%	0%	0%	0%	100%
Discussed topics of the course outside of class	42%	37%	16%	0%	5%	100%
Learned in new ways	26%	42%	26%	5%	0%	100%
Shared your ideas and responded to the ideas of other students	42%	32%	21%	0%	5%	100%
Felt more isolated	5%	0%	16%	42%	37%	100%
Discussed ideas and concepts taught in this course with the instructor	5%	16%	47%	21%	11%	100%
Made use of your unique abilities and skills to aid your learning	11%	37%	47%	0%	5%	100%
Felt challenged to create your own understanding	21%	53%	21%	5%	0%	100%
Felt this class has prepared you to work in the field	26%	42%	21%	5%	5%	100%

APPENDIX 4 – E

CRITICAL THINKING RUBRIC

Initial Homework Problem

	Miller		VanWie		Golter		Schmuck		Average
Group 1	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Final
Identifies and Understands the Problem	3	3	4	3	3	3	3	3	3.00
Identifies and presents the STUDENT'S/Group's OWN method as it is important to the solution.	3	3	3 / 4	3	3	3	3	3	3.00
Identifies and assesses the key assumptions.	3	3	2	2	2	2	3	3	2.50
Assess the quality of the solution.	2	2	2.5/3/4	3	3	3	4	3	2.75
Average									2.81

	Miller		VanWie		Golter		Schmuck		Average
Group 2	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Final
Identifies and Understands the Problem	3	3	2	2	2	2	2	2	2.25
Identifies and presents the STUDENT'S/Group's OWN method as it is important to the solution.	3	3	3 / 4	3	3	3	2	2	2.75
Identifies and assesses the key assumptions.	2	2	1.5	2	2	2	?	1	1.75
Assess the quality of the solution.	2	2	1.5	2	2	2	2	2	2.00
Average									2.19

	Miller		VanWie		Golter		Schmuck		Average
Group 3	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Final
Identifies and Understands the Problem	3	3	2.5	3	2	2	2	2	2.50
Identifies and presents the STUDENT'S/Group's OWN method as it is important to the solution.	3	3	3	3	3.5	3	2	2	2.75
Identifies and assesses the key assumptions.	2	2	2.5	3	3	3	2	2	2.50
Assess the quality of the solution.	2	2	2	2	3	3	2	2	2.25
Average									2.50

	Miller		VanWie		Golter		Schmuck		Average
Group 4	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Final
Identifies and Understands the Problem	3	3	2.5	3			2	2	2.67
Identifies and presents the STUDENT'S/Group's OWN method as it is important to the solution.	3	3	3	3			2	2	2.67
Identifies and assesses the key assumptions.	4	3	2	3			2	2	2.67
Assess the quality of the solution.	3	3	2	2			2	2	2.33

Average									2.58

Project 1

Group 1	Miller Initial	Miller Final	VanWie Initial	VanWie Final	Golter Initial	Golter Final	Schmuck Initial	Schmuck Final	Average Final
Identifies and Understands the Problem			3	3	3	3	3	3	3.00
Identifies and presents the STUDENT'S/Group's OWN method as it is important to the solution.			3	3	3	3	3	3	3.00
Identifies and assesses the key **assumptions**.			4.25	3	4	3	2	2	2.67
Assess the quality of the solution.			4	3	2	2	3	3	2.67
									2.83
Group 2	Miller Initial	Miller Final	VanWie Initial	VanWie Final	Golter Initial	Golter Final	Schmuck Initial	Schmuck Final	Average Final
Identifies and Understands the Problem			2.75	3	3	3	3	3	3.00
Identifies and presents the STUDENT'S/Group's OWN method as it is important to the solution.			3-Jan	4	3	4	4	4	4.00
Identifies and assesses the key **assumptions**.				2	2	2	3	3	2.33
Assess the quality of the solution.			3.5	3	3	3	3	3	3.00
									3.08
Group 3	Miller Initial	Miller Final	VanWie Initial	VanWie Final	Golter Initial	Golter Final	Schmuck Initial	Schmuck Final	Average Final
Identifies and Understands the Problem			3.75	3			3	3	3.00
Identifies and presents the STUDENT'S/Group's OWN method as it is important to the solution.			4	3	3	3	3.5	3	3.00
Identifies and assesses the key **assumptions**.			4	3	3 // 4	3	2	2	2.67
Assess the quality of the solution.			3.5	3	3	3	3	3	3.00
									2.92
Group 4	Miller Initial	Miller Final	VanWie Initial	VanWie Final	Golter Initial	Golter Final	Schmuck Initial	Schmuck Final	Average Final
Identifies and Understands the Problem			2.75	3	3	3	4	3	3.00
Identifies and presents the STUDENT'S/Group's OWN method as it is important to the solution.			3	4	3	4	4	4	4.00
Identifies and assesses the key **assumptions**.			2.5	3	2	2	3	2	2.33
Assess the quality of the solution.			4	4	3	4	3	4	4.00

									3.33

Project 2

Group 1	Miller Initial	Miller Final	VanWie Initial	VanWie Final	Golter Initial	Golter Final	Schmuck Initial	Schmuck Final	Average
Identifies and Understands the Problem			3	3	3	3	3.5	3	3.00
Identifies and presents the STUDENT'S/Group's OWN method as it is important to the solution.			3	3	3	3	3.3	3	3.00
Identifies and assesses the key **assumptions**.			3	3	3	3	3	3	3.00
Assess the quality of the solution.			3	3	3	3	3.5	3	3.00
									3.00
Group 2	Miller Initial	Miller Final	VanWie Initial	VanWie Final	Golter Initial	Golter Final	Schmuck Initial	Schmuck Final	
Identifies and Understands the Problem			4	4	3	4	4	4	4.00
Identifies and presents the STUDENT'S/Group's OWN method as it is important to the solution.			4-Jan	4	3	4	4		4.00
Identifies and assesses the key **assumptions**.			3	4	3	4	4	4	4.00
Assess the quality of the solution.			3	3	3.5	3	3	3	3.00
									3.75
Group 3	Miller Initial	Miller Final	VanWie Initial	VanWie Final	Golter Initial	Golter Final	Schmuck Initial	Schmuck Final	
Identifies and Understands the Problem			3	3	2	2	3.5	3	2.67
Identifies and presents the STUDENT'S/Group's OWN method as it is important to the solution.			3	3	4	3	3	3	3.00
Identifies and assesses the key **assumptions**.			3	3	4/2	3	3	3	3.00
Assess the quality of the solution.			3	3	3	3	3	3	3.00
									2.92
Group 4	Miller Initial	Miller Final	VanWie Initial	VanWie Final	Golter Initial	Golter Final	Schmuck Initial	Schmuck Final	
Identifies and Understands the Problem			4	4	3	4	3.5	4	4.00
Identifies and presents the STUDENT'S/Group's OWN method as it is important to the solution.			4	4	3	4	4	4	4.00
Identifies and assesses the key **assumptions**.			4	3	2	2	4	3	2.67
Assess the quality of the solution.			4	3	1	2	2	2	2.33
									3.25

1) Identifies and understands the **problem**.

1	2	3	4	5	6
Cannot identify or understand the problem: “What are you asking for”	Identifies main problem: “This is what he wants us to do.”	Understands the Problem: “This is what we need to do, and this is why”	Understands the problem and its implications: “If we did X it might cause Y”	Integrates concepts from other subjects: “We need to consider X, which we learned about in Y”	Full and complete understanding of the problem and its underlying theory: “Sure I can derive that from scratch! (on the back of my napkin in this restaurant without any references)”

2) Identifies and presents the STUDENT’S/Group’s OWN **method** as it is important to the solution.

1	2	3	4	5	6
Doesn’t know how to begin the problem: “Where do I start”	Approaches the problem by modifying a textbook example: “They did it this way, so if I make these small changes it will work for me.”	Background supplies appropriate solution method: “This is how we usually solve this type of problem”	Recognizes problem may be unique: “Does the usual solution method apply?”	Can develop unique solutions from fundamental theory if needed: “If we go back to the fundamentals we can do it this other way.”	Can develop a novel method worthy of publication (in a trade or academic journal): “No ones ever tried this before but it should work really well.”

3) Identifies and assesses the key **assumptions**.

1	2	3	4	5	6
Uses equations that look like they might work:	Uses the correct equation: "We used eqn. X because that is what is used for this."	Recognizes the conditions for which an equation was developed and can modify the equation for different assumptions: "Lets add a component for turbulent flow"	Can correctly select assumptions for a system based on an analysis of the physical components: "We have open channel flow, so we can't use a no-slip condition for all surfaces."	Recognizes commonly idealized assumptions and can determine their applicability: "This is the 1% of the time when X doesn't apply."	Knows, from experience, when 20% is close enough. "3.14 is close enough for pi."

4) Assess the **quality of the solution**.

1	2	3	4	5	6
Does not care about the quality of the solution: "Well I got an answer."	Wants the "right answer": "What did you get?" "What does the answer book say?"	Questions physical validity of the solution: "Does my answer make physical sense?" "Is it realistic?"	Understands impact of physical components on the solution and how differing physical portions would impact the solution: "What if the pipe was bigger?"	Understands appropriate application and impact of errors throughout the system: "Well, are measurements are really only so good, so our solution is ……"	Can identify the impact of various fundamental theories upon the problem solution: "If we account for the compressibility it will change in this direction."

5) Comments and Observations

6) Questions Asked by this Person / Group

APPENDIX 5

ALUMNI SURVEY

Bernie Van Wie
Professor and Graduate Coordinator
Chemical Engineering Department
Washington State University
Pullman, WA 99164-2710

[DATE]

[RECIPIENT ADDRESS]

You are invited to participate in a study of cooperative learning experience in the Chemical Engineering 332 course. The purpose of this study is to collect data on the learning experience in ChE 332 and to make suggestions for future practice. Please answer the following questions as completely as possible. It should take approximately 10-20 minutes to complete this survey. Responses submitted through this mail survey will not be associated with the respondents' names. The identity of all respondents will be held in strict confidentiality.

This project has been reviewed and approved by the Washington State University Institutional Review Board. If you have any questions about the research, you may contact Bernie Van Wie by electronic mail at <bvanwie@che.wsu.edu>, or by phone at (509) 335-4103. If you have questions about your rights as a research subject, you may call the WSU Institutional Review Board at (509) 335-9661.

Your return of this survey to the address specified on the return envelope signifies your informed consent to participate in this research study. Please contact Bernie Van Wie <bvanwie@che.wsu.edu> with any questions.

Sincerely,

Bernie Van Wie

Professor and Graduate Coordinator

Chemical Engineering Department, WSU

ChE 332 Alumni Survey

EXPERIENCE IN CHEMICAL ENGINEERING 332

Listed below are several statements. Use the scale provided to indicate your best answer for each item below.

1	2	3	4	5
much better than other courses	**better than other courses**	**about the same**	**worse than other courses**	**much worse than other courses**

1. How did the hands-on cooperative learning experience in ChE 332 compare with other courses in helping you develop …

Teamwork skills:

ChE 332:	**1 2 3 4 5 N/A**

Best other ChE course (list course): ____________________

Average other ChE course: ____________________________

Comments: ____

____

____

Communication skills:

ChE 332:	**1 2 3 4 5 N/A**

Best other ChE course (list course): ____________________

Average other ChE course: ____________________________

Comments: ____

____

____

1	2	3	4	5
much better than other courses	better than other courses	about the same	worse than other courses	much worse than other courses

Conceptual understanding of fluid mechanics & heat transfer:

ChE 332: 1 2 3 4 5 N/A

Best other ChE course (list course): ____________________

Average other ChE course: ____________________________

Comments: ____

____

____

Adapting to new situations (i.e. getting up to speed on a new job):

ChE 332: 1 2 3 4 5 N/A

Best other ChE course (list course): ____________________

Average other ChE course: ____________________________

Comments: ____

____

____

Critical thinking (i.e. the ability to reason, analyze and synthesize information before judgment):

ChE 332: 1 2 3 4 5 N/A

Best other ChE course (list course): ____________________

Average other ChE course: ____________________________

Comments: ____

____

____

1	2	3	4	5
much better than other courses	better than other courses	about the same	worse than other courses	much worse than other courses

Independent learning (i.e. the ability to make responsible decisions and take action to develop one's capabilities and powers through learning):

ChE 332:	1 2 3 4 5 N/A

Best other ChE course (list course): ____________________

Average other ChE course: ____________________________

Comments: ____

____

____

Problem solving:

ChE 332:	1 2 3 4 5 N/A

Best other ChE course (list course): ____________________

Average other ChE course: ____________________________

Comments: ____

____

____

2. Looking back on the ChE 332 Hands-on Cooperative Learning experience how would you compare it to other coursework in terms of helping you prepare for industry or graduate school?

3. What suggestions would you make for professors and teaching assistants who are teaching the course now?

BACKGROUND INFORMATION

Please provide the following demographic information to help us interpret the results of the questionnaire.

4. Year ChE 332 was taken:

☐ **1999**

☐ **2000**

☐ **2001**

☐ **2002**

5. Employment History:

Year: ____________________ **Company:** __________________________________

Year: ____________________ **Company:** __________________________________

Year: ____________________ **Company:** __________________________________

THANK YOU FOR COMPLETING THIS SURVEY!

Please submit the survey using the stamped return envelope.

APPENDIX 6

MODULE PROBLEMS

Fluid Mechanics Problems

Fluid Module Problem A

After eating far too much pepperoni and jalapeño pizza, you find yourself having a troubling dream. You see water traveling at 6 mL/s through a 2-foot section of new 1-inch schedule 40 PVC pipe. This flow is causing a pressure drop of 8 cm across a 45 degree inclined manometer filled with some strange glowing green liquid. Just before you wake up, you hear Yoda's voice telling you that the density of the manometer fluid will be the answer on today's random radio question. You remember that today's prize is a round trip ticket to the Dagobah System, so you get right to work.

After spending much time with Yoda in his swamp, he tells you that you must develop two expressions for the friction loss portion of Bernoulli's equation before you can complete your Jedi training. You know from previous training that the key to solving this problem lies in the fact that the friction factor is usually dominated by an inertial portion or by a portion for viscous forces depending on the flow regime. You decide to finish your training so that you can get back to Pullman in time for midterms.

Fluid Module Problem B

Against your better judgment, you find yourself walking down a pretty sketchy alleyway somewhere in Orange County, California, when a desperate looking college student jumps out and holds you at gunpoint. He demands you to derive the following flowmeter equations or your life is forfeit. The pressure drop across the meter in every situation is 1 cm Hg, except for perhaps the pressure on you.

Starting from Bernoulli's equation

- Derive the pitot tube equation
- Derive the equation that models the venturi and orifice meters

Introduce a correction factor for the pitot tube equation for the following calibration data

– 1 mm pitot tube diameter

– 5 mL/s water

– 6 mm inner diameter

– 1 cm Hg

Find the flow rate if a venturi meter has

– ½ in pipe

– ¼ in orifice

– 1 cm Hg

– $C_v = 0.975$

Find the flow in an orifice flowmeter for

– 4 mm orifice diameter

– 1 in pipe diameter

– 1 cm Hg

– $C_o = 0.61$

Fluid Module Problem C

Simply because it's a cool thing to do, you are hanging out in the Chemical Engineering lounge when a heated argument breaks out between two of your friends. One claims that *Perry's Chemical Engineering Handbook* is the best reference, and the other avows that the Internet is the best source for finding information to solve homework problems. To prevent them from coming to blows, you propose a contest in which they use their reference of choice, and you will solve the problem in the computer lab where you have access to Perry's and the internet.

They agree to predict the pressure drop in the outer tube of a double pipe heat exchanger. You all agree to use the hydraulic radius method and to either find a friction factor vs. Reynolds number plot, or an equivalent length to account for friction and minor losses.

The heat exchanger is a ½ inch copper outer pipe and a ¼ inch copper inner pipe with two straight through T valves and 18 horizontal helical turns with a 6 cm radius. Predict the pressure drop in the outer tube for a flow of 20 mL/s and a vertical drop of 2 feet.

Fluid Module Problem D

You find yourself in a life-threatening situation in which you need to use a fluidized bed reactor to convert an explosive gas into harmless components so that its concentration stays below its lower flammability limit. You are pinned next to the reactor by a large top-secret device that you've been researching in the lab. The explosive gas concentration rises slowly, but it is late Friday afternoon, and you realize that you'll likely be trapped in lab all weekend. Most unfortunate of all is that a lit Bunsen burner and the operating manual for the fluidized bed are both out of reach. You decide to start solving the fluid aspects of the reactor in your attempt to understand how to use it. (Hint: since you are not really trapped in real life - see MS&H).

Starting from first principals, develop the Ergun equation, which is an equation modeling a packed bed as fluid flowing through many small parallel tubes of equivalent diameter.

- Explain where the empirical constants of the Ergun equation come from.
- Discuss the inertial and drag terms of your equation.
- Describe physically what happens at the point of minimum fluidization.
- Derive a relationship, with adequate explanations, to relate void fraction and bed height to superficial velocity.
- Transform your packed bed Ergun equation to one that is appropriate for a fluidized bed.

You have a 6-inch bed diameter with a maximum bed length of 33 inches filled with spherical particles that may pass through a 150-mesh screen, but not a 200-mesh screen. The particles have a density of 25.1 g/mL (erroneous value, students should realize this density is way too high and if they look up values for sand or go to the Section 2 hands on lab they will find it to be about an order of magnitude less in density so 2.5 or so would be more acceptable) and a void fraction of 0.38. The bed diameter is 3.5-inches, packed bed height is 43 cm, and the maximum available height is 33 inches. Calculate the minimum fluidizing velocity and the bed height if air is used with these particles. If you increase the velocity by 50%, what will the new bed height be?

Fluid Module Problem E

In the process of trying to reduce your energy bill, you decide to make a solar-powered heat exchanger to help warm your hot water. After heating the liquid on your roof, you run it through a small shell and tube heat exchanger so that you can get the energy into your shower water. Flipping a coin, you decide to run the water through the tube side. Unfortunately you realize that you will need a small pump in order to get the water to your heat exchanger. You have a small heat exchanger lying around in your closet. It has tow tube passes of eight tubes each. The tubes are 3/8" nominal copper ACR tubing and are 16" long. Just to make sure you don't spend a Benjamin to save a George, find out the work you water circulation pump (seventy percent efficiency) will perform due to the pressure drop caused by the heat exchanger. Since you are doing this on the back of a receipt at a hardware store (maybe you shouldn't wait to the last minute to do things) you decide to use room temperature as a rough basis for your calculations.

Alternate Shell and Tube Module Problem Developed by Dr. Van Wie for the DLM

"The Justice League" finds itself preparing in a group member's apartment for a ChE 332 desktop learning module demonstration with the shell and tube heat exchanger cartridge designed by Jonathan. Unfortunately, we are in the middle of a -20ºC Pullman cold snap. This typically happens only every few years and usually only lasts a few days, but in this case Mount Saint Helen has just erupted again (which only happens every 500 years) so that the apartment solar heating panels haven't been working and ~~Prof. Van Wie~~ Bernie, out at his poser farm, is out of firewood (which has never yet happened) so the group can't even borrow some firewood to get their fireplace going. Fortunately for us, hot water is available as the apartment water heater runs on natural gas. So the group can still work the desktop module, members can take a hot bath (individually of course) and have a round of hot chocolates. The fill-in-the-blank worksheet requires calculation of the ***shell side*** and ***tube side*** pressure drops. The group needs to make sure their answers are reasonable given that Bernie and Paul are always alert at 8:00 am in the morning and will surely catch any mistakes. The following dimensions are known for the S&T exchanger and the conditions for the water are given.

System inlet and outlet tubes connected to heat exchanger: D_{system} = 3/16 in

Heat Exchanger Tubes: D_i = 1/16 in; D_o = 1/8 in; L_{tubes} = 6 in; N_{tubes} = 10; n_{passes} = 2

Shell:

D_{shell} = 0.622 in; $N_{baffles}$ = 24; Baffle spacing = 0.25 in; Number of rows of tubes = 4

At the center of the shell we have a maximum no. of tubes of 4 with a Tube clearance = 1/32 in and Tube pitch = 0.156 in. See Thomson p. 365 Figure 12-6 (a) Top View for detail. We are using a triangular pitch.

Water:

ρ_{water} = 1 g/cm^3; μ_{water} = 0.008 Pa·sec;

m_{water} = 12 g/sec on both the tube side and shell side

Hints:

1) For the shell side Reynolds No. you need to figure out the mass velocity by taking into account the free area for fluid to flow considering the tube diameter and clearance. This is typically done at the center of the shell where you have a maximum number of tubes normal to the flow path. Drawing a picture will help.
2) Peters and Timmerhaus (the design book from which you found pressure drop calculation equations) has a sample problem in case you get really stuck.
3) In your calculations remember that another student (albeit a senior) has provided some of the numbers for you, that Prof. Van Wie just made up this problem for the first time this year (and it usually takes a couple years to get all the bugs worked out even for a professor), and that hey, this is real life where problems are ill defined and you are

budding engineers who need to learn to make reasonable assumptions when necessary. Still as far as I know everything should work for you and my Mathcad solution gives me pressure drops on the two sides ranging from 2 ft to 3.5 ft of water.

Heat Transfer Problems

Heat Transfer Module Problem A

You are the chief engineer for the annual Latah County Fair. Your current major project is the syrup heater for the pancake-eating contest. Everyone agrees that 90 °F syrup is the best temperature for quickly consumed flapjacks. The syrup enters the center of a coiled double pipe heat exchanger at the same temperature as the ambient air, 70 °F, and the hot water inlet stream is at 150 °F and flows counter-current to the syrup. This particular variety of maple syrup is a Newtonian fluid, and it needs to flows at 14.5 mL/s.

The heat exchanger is a ½ inch copper outer pipe and a ¼ inch copper inner pipe with two straight through T valves and 15 horizontal helical turns with a 5 cm radius.

- What is the heat transferred to the syrup from the water?
- What is the required flow rate of water?
- What is the heat loss due to natural convection of the outer tube?
- What is the final temperature of the heating water?

Hint $T_{film}=(T_{wall,avg}+T_{ambient\ air})*0.5$

Some fluid and thermal property data for this particular synthetic syrup:

Thermal conductivity = 0.142 W/m.^{o}C

Specific heat = 2 kJ/kg.^{o}C

Viscosity (Temperature ^{o}F): 2.0 (70); 1.5 (90); 0.95 (150) cP

Density = 0.9 g/mL

Other properties are similar to water

Hint: May need to apply content learned in ChE 211.

Heat Transfer Module Problem B

Marvin the Martian is in the process of attempting to blow up earth with his ray gun. It just so happened that Bugs was on site as part of NASA's ongoing research of the Red Planet, and stumbled across the cooling mechanism for Marvin's ray gun. He is about to disable the whole device when he realizes that the system might be under-designed and blow up on operation anyway. He quickly looks the system over and calls you to perform some calculations for him (It's a little known fact that cell phone coverage on Mars is better than in Pullman).

The cooling system is a forced air car radiator. There are 28 rectangular parallel flow channels with the cross-sectional dimensions of 2 mm wide by 40 mm deep. Each tube is 15 mm apart and connected by 192 aluminum fins spaced every 2mm for the entire height of the radiator. These fins create rectangular channels through which air is forced. Inlet fluid temperature is 150 °F and ambient air is at 70 °F. The ray gun will blow up if 1 L/s of 90 F water is not supplied.

- What is η? (Numerically and verbally. See 3-25).
- Neglecting natural convection, what airflow rate is required to save Earth? (Assume Martian air is the same as Earth's. Bugs seems to do fine after all).

Hint: Air may be the same as Earth, but what is different?

Heat Transfer Module Problem C

It is a little known fictitious fact that the fluidized bed reactor was designed to cure the food dye in pixie sticks. To prevent the dye from fading (and thus decreasing shelf life to values well below 30 years) the pixie dust is cured in a fluidized bed, which holds the dust to a constant 100 °F. The bed is 4 inches in diameter (the tube is 0.5 in acrylic) and has a maximum height of 28.5 inches. Minimum fluidization and operation fluidization values are given below. The room in which many of these reactors are operated is supposed to be kept at a constant 70 °F. However, the heating and cooling systems are very old. The union complains that the reactors cause the temperature that some of their employees have to work in to be too high. You are called in to answer a few questions to settle the dispute, and also provide some information that may be used to increase the efficiency of the reactors. Note that the air from the reactors does not vent into the room, it goes through a cleaning system, and then out the plants stack.

- What is the T_{out} of the fluid (air)?
- What is the heat loss due to natural convection through the sides of the bed (If significant it would affect $T_{o,air}$ – in which case you will not likely have an analytic solution?)

Some relevant and irrelevant information

$\varepsilon_{mf} = 0.385$ $\varepsilon = 0.430$	$\rho_s = 2.0$ g/mL	
$v_{mf} = 0.5458$ cm/s	$v_0 = 0.819$ cm/s	$D_p = 0.009$ cm
$L_{mf} = 44.2$ cm $L = 47.7$ cm	$k_{acrylic}$=0.11 BTU/ft*h*°R	

Heat Transfer Module Problem D

Many nuclear reactors are cooled by a contained water system (so that yesterday's cooling water isn't today's drinking water), which is in turn cooled by another water stream through a heat exchanger so that the major heat sink (quite likely a river) for these reactors remains uncontaminated. WSU has a little nuclear reactor on campus (so there can only be a little fallout if something goes wrong) and it likely cooled in the same manner. Some measurable data for the shell and tube heat exchanger is given below.

$T_{H,in}$ = 55 °C (Water to be cooled is tube side)	Cu Tube O.D. = 3/8”
$T_{H,out}$ = 25 °C	Cu Tube I.D. = .311”
$T_{C,in}$ = 20 °C (Cooling water is on shell side)	Tube side flow = 13215 ml/min
Baffle Window = 0.1955	Tubes per pass = 8
Tube Spacing (Center to center) = 0.625 in	Number of passes = 2
Baffle Pitch = 2.2”	Shell side I.D. = 3”
	Tube Length = 16”

- Explain the log mean temperature difference and why it is used for shell and tube problems.
- Derive G_B, G_C, and show what G_{eq} is, and give the Reynolds number in terms of G_{eq}.

Using the baffling data from above, what is:

- The heat duty?
- The flow rate of cooling liquid?
- The temperature of the cooling liquid?
- Is this reasonable?

Hint: May need to apply content learned in ChE 211.

Heat Transfer Module Problem E

A kettle reboiler (please refer to the figure in McCabe, Smith & Harriott) has been ordered. Steam is to be fed into the system at 6.7 psig and will condense as it transfers heat. Heat is transferred to liquid water initially at 212°F, which is boiled to exit the system at 0 psig, with a flowrate of 0.55 lb/min. The boiler has eight 5/8" BWG#12 copper tubes, which are 22" long. It is desired to double check some of the design calculations. Neglect heat loss due to natural convection.

- Find the inside and outside heat transfer coefficients.
- Assuming nucleate boiling, determine whether enough surface area is available for sufficient heat transfer to occur.

Hint: Surface tension will have to be searched for. One site found is www.cheresources.com.

Hint: to solve the problem you must assume a $T_{wall, inside}$ by using a $Q_{overall}$=Q_{film} analysis similar to what is shown in an earlier heat transfer section in McCabe, Smith & Harriott.