# AC 2011-1787: EXPERIENCE WITH A CROSS-DISCIPLINARY INTENSIVE, HANDS-ON PRE-TRANSPORT COURSE

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# Experience with an Intensive, Hands-on Pre-transport Course

An intensive, elective, 7-day pre-transport course was offered at The University of Oklahoma with the objective of providing sophomore engineering students with an intuitive understanding of fundamental concepts in fluid mechanics and heat transfer and preparing them for subsequent learning. The intersession offering between the fall and spring semesters immediately precedes the beginning of the regular transport sequence in chemical engineering. The interdisciplinary class was open to chemical engineering, mechanical engineering, and civil engineering majors and listed under a College of Engineering designation. The transport of momentum and heat are important to these and other branches of engineering endeavor and it is therefore imperative to establish a solid foundation for future higher learning objectives.

Course content, to be described, emphasized experiential learning through the use of video material and hands-on activities developed at Washington State University and the University of Oklahoma. Implementation of the course activities proceeded with consideration of Fink's Significant Learning taxonomy. Effectiveness of the course was assessed through the use of a concept inventory given to students at the beginning and end of the regular introductory transport course which emphasizes traditional phenomenological and mathematical approaches. Problem solving and essay type homework were also assessed to gauge whether the students were adequately primed for further learning in the sequel transport class. Students' preconceptions were gauged using a pre-test and any misconceptions were addressed in the instructional intervention. A post-test was thereafter administered to evaluate the efficacy of the intervention. Will students be motivated to learn a particular aspect (momentum or heat or both) better because they know it would be useful in a subsequent discipline-specific course? What will be the source of this motivation since extrinsic motivators (e.g. grades, recognition) are not particularly attractive? A survey was designed and administered to check whether the students perceived they were better prepared for the sequel class and how they thought the class had helped and/or will help them achieve their academic and professional goals.

## 1.0 Introduction

Despite steady growth in Science Technology Engineering and Mathematics (STEM) enrollment in the US in the last three decades, enrollment in engineering still remains inadequate to meet demand for skilled engineers [1-2]. The National Academies Of Sciences also reported a higher decline in enrollment for graduate studies in engineering [2],p 83. This seeming apathy for engineering is attributable to a lot of factors including: lack of mathematical savvy, dearth of qualified and motivated teachers, inadequate pedagogies (not engaging enough), lack of authenticity ("real-world" engineering) in the curriculum and pedagogy, faulty social and institutional support structures, lack of feeling of self efficacy and, faulty scaffolding and resultant failure during early learning stage. Remedies for this malaise should be multifaceted [3] and some have been proposed. These include the use of novel pedagogies [4-6], curriculum enhancement and faculty training in, and support of, novel pedagogy and curriculum [3]. Preparatory learning interventions have various advantages: 1) students have preconceptions which may be misconceptions and may defy dislodgement or unlearning [7]. This may interfere with further learning especially in a fast-paced regular class. Thus a slower-paced class in which common misconceptions in the subject matter are exposed by intentionally creating conflict between exposed misconceptions and an observed phenomenon which the student cannot explain is needed, 2) slower students may need more exposure to the material to enable them participate better in the main class. 3) students who feel they have no prior knowledge of the material and need to come up to speed before class starts will benefit in no small measure, and 4) students who are high achievers may feel the need to confirm their knowledge and also learn a few more concepts or skills. Whatever the motive of the participating students, the major objective of a prequel is to cognitively and affectively prime the student for higher (Bloom's taxonomy [8]) and more in-depth learning.

From the curriculum enhancement perspective, the authors believe that augmentation of traditional curricula with prequels for courses that students have found to be rather challenging will go a long way to prepare students for more classroom learning. Curriculum augmentation using a pre-instructional e-learning strategy has been successfully implemented in a materials science and engineering class [3] and it is believed that the augmentation concept can be extended to other classes and other augmentation tools.

Fluid mechanics and heat transfer (FMHT) concepts have been found to constitute some challenge to engineering students [9-11] and therefore FMHT represents a good candidate for curriculum augmentation. We report a study of a 7-day FMHT prequel class carried out at the University of Oklahoma (OU) over the Christmas break. This prequel class titled "ENGR 1510 Intensive Hands-on, Interactive Fluid Flow & Heat Transport" was focused on developing students' intuition using videos, hands-on activities, lectures and discussions. It was made open to all engineering majors because a lot of engineering classes contain elements of FMHT, and the grading policy adopted was a pass/fail (S/U) with course participation taking 50% of the weighting and the remaining 50% equally distributed between the class exercises and final examination.

Given the context of this class, the researchers deemed it fit to ask questions in the form: Can the learning in this class be deemed significant enough to prepare the students' cognitively and affectively for more learning? Also, given the pass/fail grading policy for this class and the holiday mood, can we discount extrinsic motivation (e.g. motivation from grade) as the sole driver for academic success in this study? To answer these questions, we start by articulating the theoretical underpinnings of this study and attempt to operationalize the constructs to reflect the context of the work.

## 2.0 Theoretical Considerations

A lot of research in engineering education have been largely exploratory (as contrasted with cause-effect and mechanistic type research) and bereft of theoretical considerations [12]. No matter the type of research questions, the community of engineering educators continues to emphasize the need for grounding research in theoretical frameworks as a vital ingredient for enhancing quality in scholarly work [13-16]. In line with this thought, the authors outline the most important theoretical considerations relevant to the research questions in this work below.

### 2.1 *Fink's significant learning taxonomy*

Fink proposed a non-hierarchical, relational and interactive taxonomy [17] that he believed could succeed the popular Bloom's taxonomy [18]. He posits that designers of learning experiences would do well to inculcate the elements of significant learning into their lessons. The elements that he identified are enumerated below:

1) *Foundational knowledge*: This refers to the fundamental concepts in the knowledge domain of interest that aids other kinds of learning. For instance, the learner needs to know fundamental fluid dynamics phenomena like Newton's laws of motion, viscous and inertial forces, mechanical energy balance, laminar and turbulent flows, and so on to be better able to analyze flow systems.
2) *Application*: This allows putting into use some of the foundational and other types of knowledge solve new intellectual, physical or social problems. An instance of this would be when the learner applies the modified Bernoulli equation in specifying the pump power that would move a fluid through a specified piping network.
3) *Integration*: This type of learning occurs when the learner is able to make cross-domain connections of knowledge. For instance, in the design of heat exchangers, connections have to be made between fluid flow characteristics and the form and magnitude of heat transport.
4) *Human dimension*: This type of learning enables students to learn about themselves and others. It informs the learner about the human significance of what he/she is learning.
5) *Caring*: This provides the motivation or energy for the learner to engage more vigorously in learning. Without this caring dimension, classroom attendance is reduced to rote. When learners care very much about something, this becomes a driving force for learning all they can about it.
6) *Learning how to learn*: This happens when students learn about how learning is constructed in general or in a particular domain. This helps speed the progression from novice to expert by fostering independence. One way this can be achieved is through a cognitive apprenticeship model [19].

### 2.2 *Motivational theories*

Achievement motivation theories in education attempt to explain actions in terms of a student's beliefs, values and goals. Achievement motivation can be defined as "the motive related to performance on tasks involving standards of excellence" [12]. As a learner-centered framework, the theories (individually and/or collectively) posit that the learners motivation is influenced by three factors: his belief about the value of the task, his belief about his ability to successfully complete the task, and his impression about who is the primary determinant of the outcome [15]. The value of the task is influenced by general or individual interest, its inherent challenge, the value attached to it by peers, its relationship to long range goals of the learner and the immediate pay off. The self confidence of the learner is influenced by his record of success at same or similar task, possession of all or most of the skills required for task completion, persuasion by peer or someone else that success is possible, seeing peers succeed at the same task and the perceived difficulty of the task. The learner's perception of the primary determinant of the outcome is influenced by the perceived situation of control (internal or external), flexibility of the outcome (can the outcome change under different circumstances). A consideration of the factors aforementioned led to the development of the motivational theories. The ones most relevant to this work are discussed below.

*Self-efficacy theory*

This theory is based on the premise that the decision to engage in an activity is based on the learner's perceived competence with regard to that activity [15]. Competence beliefs are developed through four main sources: learner's experiences attempting a task, observations of peers doing the same or similar tasks, performance feedback from peers or superiors and feelings (such as dread or elation) experienced while doing the task [12]. The authors believe that the wording of the announcement for this class engendered some feeling of self-efficacy in the students. For instance the statement about the prerequisites is quoted below:

**"**Prerequisites**:** There are no prerequisites for this course. However, it is recommended that students have completed PHYS 2514 General Physics for Science and Engineering Majors, MATH 1823, MATH 2423 Calculus and Analytical Geometry I & II."

The students who registered for this class may have attempted or passed the recommended courses and so this could have created that self-belief that they can also be successful in this course.

### *Self-determination theory*

This theory asserts the importance of needs for competence (desire for mastery), autonomy (desire to be in control) and relatedness (desire to fit into a supportive community) [12, 15]. The wording of the announcement for this class implied some degree of self determination. For instance the information on the grading policy implied that students were responsible for their learning and subsequent grade. The exact wording of the grading policy is reproduced below:

> "Course Grading: This course will be S/U graded. Class Exercises-25%, Exam-25%, Course participation-50%.Course Participation includes attendance, group demonstrations, and active learning exercises, presentations, discussion, etc. Final grades will be determined using the above formula to determine an overall score for each student at the end of the semester."

Also, we believe that the information about hands-on and interactive activities suggests a supportive community.

### *Expectancy-value theory*

The expectancy part of this theory refers to the learner's choice to engage based on task-specific competency beliefs while the value part refers to the subjective importance placed on a successful completion of the task [15]. It is expected that the learners in this case will find the class useful and also have feelings of self-competency because of the importance of FMHT to engineering practice and of course because they have had some exposure to the recommended courses.

### *Achievement goal orientation theory*

This is a relatively new theory which asserts that the way the learner thinks about what he or she wants to accomplish (goal orientation) will determine their degree of motivation and task engagement [15]. Four possible orientations have been identified in this theory, and are listed below in order of desirability:

1) Mastery orientation: In this orientation, the learner is willing to try anything that will help them learn whatever it is he or she is working on. Such a learner will be more likely to ask questions copiously in class and study more than required. The learner’s focus here is not just the grade (an extrinsic reward) but some higher goal (for instance curiosity or a desire to expand the frontiers of knowledge, an intrinsic reason).

2) Performance Approach orientation: In this orientation, the focus is not on learning for its own sake, but learning in order to get some immediate outcome, like a high grade or being the best in the group. Although this is still a powerful motivator, it is directed toward the wrong thing if the learners become too focused on the end recognition and not what they have learned in the process. Such a learner most likely forgets about what was learnt after the end outcome has been achieved and thus transfer of knowledge to different contexts is hindered.

3) Performance Avoidance orientation – sometimes learners are being very cautious during learning in order to avoid making any mistakes that might make them appear incompetent. A learner with this orientation will usually avoid asking clarifying questions likely due to an ego problem. This is generally considered a bad orientation to adopt. One way to mitigate this approach is to adopt a safe class atmosphere where learners are not discouraged from making mistakes in the learning process but are rather encouraged to view mistakes as part of the learning construction process.

4) Work Avoidance orientation: In this orientation, the learner seeks to do the barest minimum work to justify the immediate payoff (balancing payoff with effort). A learner, who has adopted this approach, will be unlikely to put in much effort for rigorous learning in, for instance, a 1credit, Satisfactory/Unsatisfactory grading class.

## 3.0 Materials and methods

This section details the learning materials and procedures followed in this study.

### *3.1 Materials*

This subsection describes the materials that were used in this study.

*The Desktop Learning Modules (DLMs)*: This consists of desk size plug-in cartridges of miniaturized industrial equipment plugged into a base unit that has pumps, tanks and electronic accessories (see figure 1). The DLM, designed and built at WSU on an NSF grant [20-21], represents a convenience for quick in-class experiments and demonstrations.

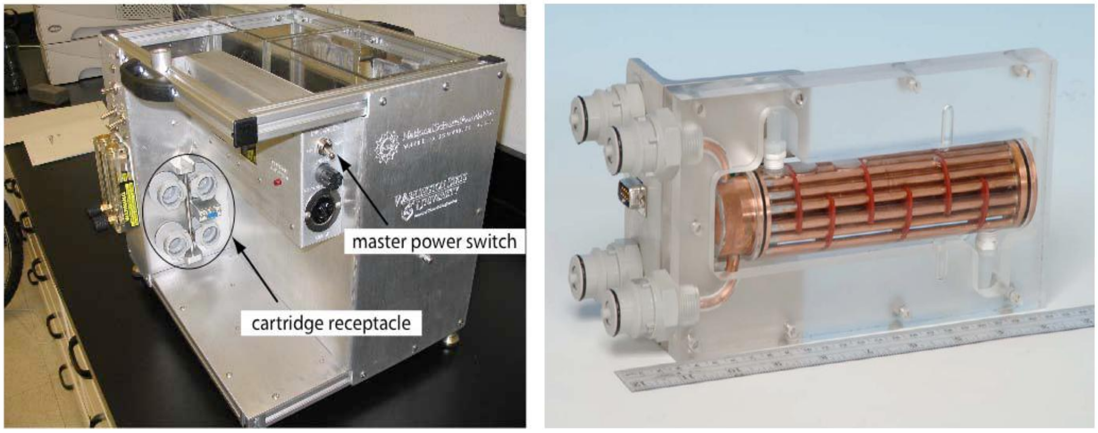

**Fig. 1. The DLM base unit and the shell & tube plug-in cartridge used in this study are shown side by side in this picture.**

In this work the venturi, orifice, double pipe and shell and tube heat exchanger cartridges were used for the learning activities.
*Fluid mechanics DVD*: Homsy's fluid mechanics DVD was employed as a study aid for visualizing some fluid dynamic phenomena. Students were encouraged to get a personal copy and the videos were also projected onto the screen during class.

*Other apparatus*: Other apparatus like the injection pump (used to demonstrate mass flow measurements), squirt guns (used to demonstrate inertial force exerted on an obstacle by a moving fluid) were used to enhance learning.

*Concept inventories*: Concept inventories can be described as painstakingly assembled quizzes, usually multiple-choice questions (MCQs), designed to represent the salient concepts in a domain. Strictly speaking, experts in a domain get together and brainstorm on the commonly held misconceptions about pivotal concepts in a domain and then design questions with answer options which contain these misconceptions as distracters [9, 11]. Well designed MCQs were used to assess students' understanding (cognition) of fluid mechanics and heat transfer concepts covered in this course. The questions were collated from different sources including Miller's [22], unpublished MCQs being developed on an education grant at the University of Wisconsin and some that were made up by the researchers using some of Zhao's MCQ design principles [23] (which include equally reasonable options to novices in the domain, at least 4 options and 8 questions to mitigate pure guesswork) for better alignment with the hardware used and principles covered in the activities.

*Worksheets*: Worksheets containing short experiments, insightful essay type questions that elicit understanding of principles and procedures, and numerical problems focusing on the most important concepts and procedures relevant to the class were designed based on the principles of guided inquiry [24-25]. The worksheets represent a sort of scaffolding device [19] leading the learner gradually through the steps essential for the construction of significant learning in FMHT.

*Surveys*: Questions focused on the affective domain of learning ("caring", an important aspect of significant learning [17]) were developed to capture the learners' feelings about FMHT and the structure of the learning intervention. The questions were designed on the same lines as the flashlight surveys [26] and the responses based on Likert's technique for the measurement of attitudes [27].

### *3.2 Methods*

This subsection outlines the transactions in the learning environment and the procedures followed in implementing assessment with the primary objective of answering the research questions.

Activities were implemented during a 7-day 2-hour per day class period of ENGR 1510, Intensive Hands-on, Interactive Fluid Flow & Heat Transport, at the University of Oklahoma OU during the December 2010 intersession. The activities for this 7-day period were designed based on the principles of backward design [28], guided inquiry [25] and best practice in undergraduate education [29-30]. The desired learning outcomes were first established, acceptable evidence of the achievement of these outcomes was then determined and learning activities were built around these.
The 8-student class comprised of 7 Chemical Engineering majors and one Civil Engineering major was split into 4 pairs for the think-pair-share protocol and 2 groups of 4 students each for the hands-on group learning. In deciding what we wanted to achieve in this time-limited intersession offering, we felt it was desirable to target significant learning, especially the foundation, application, integration and caring dimensions of the Fink's taxonomy [17]. Learning objectives for the course were stated succinctly in the syllabus as follows:

> "At the end of this intersession course, the student will have an intuitive grasp of important fundamental processes in fluid mechanics and heat transfer".

Performance improvements from pre to post concept tests, in-class questions, and group discussions, positive attitudinal changes, appropriate analyses of short in-class experiments, analyses of insertion meters, piping networks and other fluidic systems, and prediction of heat-exchanger performance from fundamental engineering principles were deemed to be adequate evidences of achievement of the learning objectives of this class.

The learning activities started off with the professor leading a discussion on the importance, indispensability and omnipresence of FMHT in human experience such as in applications like cooking, heating, industrial processing and natural phenomena such as tornadoes, floods and wildfires. He also reiterated some points of interest contained in the course announcement such as how the principles learnt in this class could be used to design a depth gauge for a scuba diver and, predict the muzzle velocity of a squirt gun. Next was a PowerPoint presentation on hydrostatics and fluid pressure which was followed by a classroom demonstration of absolute and gauge pressure and visuals from the DVD. Numerical examples on pressure and force on a surface were discussed after which the students were asked to pair up and discuss a problem on design of a simple depth gauge for a scuba diver. This problem was then left as pair homework to be turned in the next day. Activities for some of the other activities followed this protocol.

For the hands-on learning experience with the DLMs, the students were split into two groups of 4. Each group was assigned a DLM and each person was given a worksheet. The instructor led them through the operation of the DLM and the worksheets. Students were encouraged to discuss the questions and problems on the worksheet amongst themselves and ask the instructor for help if they had any concerns. The instructor went around the class listening to and interacting with the students. Whenever a general misconception(s) was noted, the instructor halted the activities and gave a mini-lecture to correct the misconception(s). The worksheets were thereafter assigned as individual homework at the end of the class.

The 25-question concept tests were posted on the course website on the first day of class to be turned in individually on the third day.

On the last day, a 90-minute open-book exam on the materials covered in class was administered to the students.

## 4.0 Results and discussion

Table 1 below shows the results for the multiple-choice concept questions used in this work. It is clear from this table that there was a statistically significant improvement between pre and post for the FM but not for the HT concepts.

**Table 1**: Depiction of statistical test (homoscedastic t test [31] ) results for concept tests

| | *FM Pre* | *FM Post* | *HT Pre* | *HT Post* |
|---|---|---|---|---|
| **Mean** | 8.875 | 11.5 | 5.625 | 6.375 |
| **Variance** | 5.553571 | 1.714286 | 3.125 | 3.410714 |
| **Observations** | 8 | 8 | 8 | 8 |
| **Pooled Variance** | 3.633929 | | 3.267857 | |
| **Hypothesized Mean Difference** | 0 | | 0 | |
| **Df** | 14 | | 14 | |
| **t Stat** | -2.75405 | | -0.82977 | |
| **P(T<=t) one-tail** | 0.007761 | | 0.210295 | |
| **t Critical one-tail** | 1.76131 | | 1.76131 | |

| | | |
|---|---|---|
| **P(T<=t) two-tail** | 0.015521 | 0.420591 |
| **t Critical two-tail** | 2.144787 | 2.144787 |

This is attributable to the fact that about 78.6% (5.5 out of 7 days) of class time was spent on FM activities (one of the principles of good practice in undergraduate education advocates spending time on task [29]). Some of the material students encountered on the MCQ test were not adequately internalized prior to the post-test because of the low exposure time. Fairness in interpretation of results also recommends that students should be given adequate exposure to the subject matter they are assessed on [32]. We cannot therefore in all fairness infer that the students failed to grasp the concepts of HT. In contrast, however, is the statistical improvement in FM scores. A close look at the table reveals that the average increased and the variance decreased (to less than 2 points) from pre to post, indicating that all the students improved. This is in part attributable to the use of the pre test as formative assessment [33-34]. The pre test was analyzed for concepts for which misconceptions were rife and this information was used to inform the learning intervention in subsequent classes. In our case we found that students struggled with the concept that pressure decreases when a steady flow passes through a constriction (6 out of the 8 students got the answer wrong in the pretest). This misconception was so robust that one of the students had to go confirm from one of the professors even after having it explained by an instructor (a graduate student). A mini-lecture and a video from the DVD were used to dispel this misconception with the result that all the students got questions associated with this misconception correct on the post test. This concept test results strongly suggest that the students have a good knowledge of the essentials of the material (Fink's knowledge dimension [17]) and will be able to "apply" and "integrate".

To further investigate their cognitive readiness for the learning in the subsequent class, the worksheets and problem solutions were analyzed. Table 2 shows scores for the fluid mechanics (FM) and heat transfer (HT) worksheets. The FM problems were application-type while the HT problems were integration-type because a lot of engineering systems deal with heat transport in flowing fluids. From the table it is evident that all but one of the students had satisfactory scores indicative of good preparedness to tackle further learning challenges.

**Table 2: Scores for the FM and HT worksheets**

| Serial number | FM scores, % | HT scores, % |
|---|---|---|
| 1 | 55 | 52 |
| 2 | 55 | 80 |
| 3 | 59 | 87 |
| 4 | 58 | Not turned in |
| 5 | 79 | 80 |
| 6 | 70 | 74 |
| 7 | 81 | 83 |
| 8 | 43 | 41 |

A closer look at the table shows that the students did surprisingly well on the HT problems and essay type questions in the worksheets even though much less time was spent on the HT than on the FM part of the class. This is attributable to a mastery orientation on the part of most of the students [15, 35]. Despite the fact that the *extrinsic* rewards were not very attractive (1 credit class, satisfactory/ unsatisfactory grading (S/U in grading policy statement), and, disruption of Christmas holidays), it is apparent that the students drew on some ***intrinsic*** motivation. This could also be due in part to the instructor impressing on them the value [12] of FMHT to their professional development, general human experience and otherwise. The interactive and "real-world" (principles of good practice in undergraduate education [29], easily identifiable examples from everyday life, and, miniaturized industrial equipment) manner in which the class was conducted could also have impacted their attitude in no small measure and contributed to the cognitive gains shown in the table.

Because of the importance of affective measures in the learning enterprise (especially its impact on cognitive measures), it was imperative to gauge students' motivations and attitudes and thus make inferences on how this might impact cognitive performance. To achieve this, an analysis of the designed survey instrument was carried out. When questioned about their motivation for taking the class, all of the students believed it would help them prepare more for the subsequent class. Seven of them believe that it will help them very much in the subsequent transport class while one of them thought it would help somewhat. This attitude reflects Fink's caring dimension of significant learning. All students reported a feeling of preparedness for the sequel class. One of the students (the civil engineering major) wrote:

> "Fluid mechanics is supposedly a really hard class and I want to keep my 4.0 so I thought I'd get prepared."

Another student (a chemical engineering major) wrote:

> "Prepare for heat and mass transfer class".
> "I have nothing to do in the intersession so I want to study."
> "I heard this class is taught in a new way."

When asked to state and explain what element of the learning intervention they considered had the most impact on their learning, 3 out 8 students chose the lecture part, 2 chose the classroom demonstrations, 1 chose video, 1 chose hands-on activity and 1 chose both lecture and videos. However we note that because the different elements of the class were combined so as to reinforce each other, it was difficult to isolate one element as being responsible for any particular observation but their choices does infer their preferred learning style. Further insight into students' predisposition was revealed by their answers to the follow-up question: "Please explain what about this you liked the most. The student who chose "hands-on activity" commented:

> "The part I enjoyed the most was getting to hold a physical object in my hand and evaluate it."

This student is evidently demonstrating a hands-on learning bias, which has been identified as a typical learning style for the practical engineer [36].

One of the students who chose "demonstrations" remarked:

> "The demonstration gives direct relationship in the physical world to theoretical principles brought up in the lecture."

This student is displaying a "live" visual learner bias which is also a typical engineering learning style. He or she suggests that visual reinforcement of lecture is important to learning.

The student who chose video commented:

> "Videos make me understand the material more. I can visualize the phenomena and understand it better."

This student apparently has a "virtual" visual learner bias which is also a typical engineering learning style. Video simulations of physical processes have been reported to be an effective and cheaper way to reinforce engineering learning [37-38].

One of the students who chose "lectures" commented:

> "I understand more about energy conservation with which I was confused. The lectures about pipe flow in combination with some visual demonstration helped me have the basic ideas of energy conservation in fluid flow."

This student apparently has listening learning style reinforced by visual components. The phenomenon of energy conservation in fluid has been found noted by the author as confusing to some students. Students find it counterintuitive that pressure decreases when a steady state flow passes through a constriction. The lecture in combination with the video was used to clarify that point.

In this small class we have observed some students who claim to be good listeners and some who need a reinforcing component for significant learning. This is to be expected in a random student population.

Questions to probe how students feel that the principles of good practice in undergraduate education are reflected in this class were also included in the survey. The options were designed using a Likert scale[27]. The wording of the prompt was:

> "Compared to other courses you have had (classes you have taken), how do the types of activities in this prequel class help you to…"

The options for these eighteen (18) questions were: "much more", "somewhat more", the same, "somewhat less" and "much less." All the students reported that they were more able (3 reported "much more" and 5 "somewhat more") to understand and visualize underlying course concepts in this class over other classes they have had. This reflects active learning, one of the principles of good practice, which recommends that learners actively construct their own understanding. Students report on appreciating other people's points of view and diverse ways of learning was mixed (1 reported "much more", 3 "somewhat more" and 4 "the same"). This is a little bit troubling because engineers are supposed to work in teams and therefore must appreciate each other's inputs. However this trend is not surprising given some of the comments made about group learning by the students and the tepid group interactions observed by the instructors. Some of the comments to the question: "Do you think the group learning used in this class is potentially useful and if so how? (Explain in at most 3 sentences)" are replicated below:

> "Yes, I think it's useful because we can discuss with each other and I can study from them. However I am international so I have trouble with language and limited me sometimes."
>
> "Generally group learning is always useful but for me it doesn't work well. It also depends on people who work in group with me. For some people I can work with very well"
>
> "Yes because it allows for different points of view to be seen and heard from by the group."
>
> "Yes, but not much. I don't know why??"

The instructors' observations and some of the comments suggest that the groups were not well blended due to personality or/and time constraints, and in the future we aim to improve on group dynamics by giving the students orientation in team importance and dynamics.
When asked for comments and suggestions for class improvement, 1 student suggested more practice problems and more model derivation explanations and another suggested balancing time spent on FM with that for HT.

Overall, all the students seem to agree that this class gave them a feeling of confidence to take the sequel class.

## 5.0 Conclusion

From the test scores and students comments, it is apparent that students feel prepared for further learning in FMHT. The cognitive measures indicate that students made significant gains in the first three components of Finks taxonomy (knowledge, application and integration). A follow-up to gauge how the students in this sequel compare to those who did not, especially in the cognitive domain, would be quite interesting. The survey also show gains in the "caring" dimension of the taxonomy which can also be tied to the "value" motivational theory. There was indication that the students have a high level of self-efficacy and self expectancy feelings towards this class and the sequel. A good number of the students, surprisingly, appeared to show an achievement goal orientation on the mastery level despite "weak" extrinsic factors such as the satisfactory/unsatisfactory grading policy, and 1 credit earned. This is attributable to some intrinsic factor(s) which may be related to the value that the student places on learning and the engineering profession, and the class atmosphere and dynamics put in place by the instructors. Students also attested to the inclusion of good practice principles in this class and made some insightful comments and suggestions for improvement.

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