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# How to Increase the Ability of a Student to Learn

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An instructor is always challenged when covering the materials in a course (according to the syllabus) and at the same time making sure that all students have the opportunity to learn and understand the materials presented in the classroom. In this paper we will present some ideas and tools that enable one to try to achieve a balance. These are based on the author's experience and perspective in teaching deterministic and stochastic operations research courses.

## 1. Introduction

Education, in our opinion, is one of the noblest professions (the second best with medical taking the top berth). A concerned educator gets the most satisfaction and takes pride when everyone in the class exhibits the required skills of learning and understanding the materials presented in the course. However, in any given class we always encounter a diverse background in the student body. By diverse student body we refer to students who have different study habits, different absorption skills, different perspectives, different attitudes, different background, etc. While such a diverse background is generally healthy for any learning environment, it also poses some challenging situations and problems for the instructors as well as the students. Some of these are: (a) students, not keeping pace with others who are performing well, get frustrated and lose motivation; (b) students who take more time to understand the concepts and ask (rightly so) questions in the class slow the progress of the class and hence decrease the motivation of the others who understand better; and (c) constant slowing down (for various other reasons) of the class hinders in the way of covering the objectives and goals of the course. Thus, the real challenge of a concerned and dedicated teacher is to bring the students who are slow at learning and understanding pretty much on par with the students whose pace is moderate to fast, within the scope of the course and in the allotted time frame.

While it is impossible to have one-on-one periodic meetings with the (slow paced) students due to time constraints of both the instructors and these students, it is imperative to find alternate ways that will at least give opportunities for these students to learn better and faster. Also, from years of teaching experience, we have found that no matter how many "outside class" opportunities the students are encouraged to utilize, only a handful (in any given quarter) use such opportunities and again these are the students who always find ways to seek help. Hence, this proves the need to provide "in-class" opportunities for needy students as discreetly and as quickly as possible.

Students learn better when the environment is very friendly and conducive for them. By friendly environment we mean an environment where there is an opportunity (a) for students as well as instructors to ask questions without the students and the instructors feeling intimidated; (b) for students to discuss among their peers without feeling uncomfortable; and (c) for students to think clearly without feeling the undue pressure that exists in an environment where quizzes/exams are taken. Our experience indicates that while many students take full advantage of such an environment, there are some who do not fully exploit this opportunity. This clearly distinguishes the student body into two groups: (i) one group sincerely interested to learn. This group includes students who probably would have felt lost if a friendly environment were not provided; (ii) the other group of students who simply are not interested to learn no matter how good the environment is. The attitude of the students in this group is very difficult to judge and understand. The number of such students is relatively small in any given class. However small this group is, it is very dissatisfying for the concerned instructor if not everyone utilize such an opportunity. The famous phrase, "you can take the horse to the water, but you cannot force it to drink", fits very well here, but again it is really disheartening to instructors who work very hard to motivate all students to learn.

Learning and transfer are two main ingredients for success of any student [see Bransford, et al[1]]. Learning could be based on (a) new materials; and (b) pre-existing knowledge of the student on the materials. As is known [see, for example, Bransford, et al[1]] pre-existing knowledge may be a hindrance to learning new materials. In order to see how much the students know about the current course, a questionnaire (see Exhibits 1A and 1C) is given at the beginning of the class. A similar questionnaire (see Exhibits 1B and 1D) is given at the end of the quarter to see how far the students feel that they have learned the concepts from the course. These questionnaires are designed to assess the students' learning of the materials and their awareness of the subject materials before and after taking the course(s). There are questions that are common to both the questionnaires. The transfer of knowledge is one of the major ways of assessing the students' understanding of the concepts. To achieve this objective, the concepts seen in the classroom need to be reinforced in such a way that the students can relate to situations outside the classroom.

In this paper we will discuss some of the tools that we have been using in the courses and how the students reacted in such an environment. The paper is organized as follows. In section 2, we will discuss the tools used in the context of two operations research courses. The lessons learned and possible ideas for future work are summarized in section 3.

## 2. Experiences with the two courses:

In this section, we will summarize our experience in teaching two courses by implementing some of the tools that seem to help the students learn and transfer knowledge.

### 2.1. Deterministic Models in Operations Research:

All students in the Industrial Engineering Program at Kettering University are required to take a first level introductory course on operations research. The course is titled as "Deterministic Models in Operations Research". This is a first-level course in modeling in which the students are exposed to basic concepts and techniques in deterministic optimization. In the original version of this course, the pre-requisite for this course is a matrix algebra course. However, in the newer 160-credit curriculum (which started in July 2001) the students are not required to take a matrix algebra course (some alternative ways are being explored currently) and hence a brief introduction to linear algebra and elementary matrix operations is given at the beginning. The course includes the following topics: Operations Research (the need and the history), introduce linear programming, sensitivity analysis, transportation problems, assignment problems, transshipment problems, network models, and integer programming. The primary software is LINDO/LINGO and students are encouraged to use Excel.

The course basically comprised of weekly activity reports, in-class activity reports, in-class group homework assignments, quizzes, homework sets, miniprojects, in-class projects, midterm exam, a term project, and final exam. Blackboard was used extensively as a medium of communication and the students were encouraged to send the assignments electronically. This is a four-credit course and is offered in 2-hour blocks twice a week for 11 weeks. Since July 2001 the teaching of this course has evolved through a number of improvements. These are captured in Exhibit 2 below.

The in-class group activity that involves students solving problems that are based on key concepts seen in the class was added as part of the course assessment during the last two times (specifically summer 2003 and fall 2003) the course was taught. This in-class group solving is done as follows. As soon as major concepts are seen, groups (usually not more than 3 or 4 students per group) are formed and some selected problems that use the concepts are assigned for the groups to solve. Any group or a student within a group needing a clarification is given an one-on-one consultation. The main purpose of this is to make sure that everyone understands the major concepts and be able to apply. This, in our experience, really helps students not only to break the ice as far as asking questions to clarify any concepts not fully clear, but also puts pressure to learn and apply the concepts right away. While most students take advantage of such an opportunity, there are a few students who appear to stay aloof and refuse to capitalize.

The in-class activity report form is filled out by all students in groups for every lecture class held during the quarter. The main purpose of this is to let the students write (a) the objective(s) of the class lecture; and (b) the concepts that are not clear or need more clarification and or examples. The students are given the form at the beginning of the class and the class takes a short break for 5 minutes half way through the 2-hour lecture format. Towards the end of the class the students are given about 5 minutes to fill in the details for the second half of the lecture before handing in the report. As an incentive the students whose names appear on the reports are given points. Two samples of in-class activity form are shown in Exhibit 3. The students are given an opportunity to write freely any concerns/suggestions they may have that will improve their learning and transfer of knowledge. Since students are asked to circle appropriate ABET criteria that are met, they are provided in the footnote for ease of reference.

It is mandatory that all students individually submit electronically the weekly activity report for every week (except the last one) during the quarter. The students are given, as an incentive, additional points for the submission. A sample weekly activity form is shown in

Exhibit 4. In this weekly activity form the students fill in what they leaned outside the class and to convey any concerns/suggestions that will help them understand the concepts better.

The concerns/suggestions that the students write in the reports (both in-class group activity and individual weekly activity) are addressed (without revealing the identity of the students) immediately in the follow-up classes. This is one of the most important tools that we have found to be very informative and useful not only to students but also to instructors. From the student point of view, this gives an opportunity for them to express their concerns and suggestions in their learning right away rather than wait until the end of the term to write them in their teaching evaluation form. It should be noted that the students still fill out the end-of-the-term teacher evaluation form. From years of teaching experience we find that only a few students offer constructive criticisms in the "end-of-the-term evaluation" as students believe (rightly so!) that they are not going to gain anything in that term for that course by doing so. Furthermore, while the faculty benefits from such criticisms by fine tuning the teaching in the following quarters (or semesters), it is disappointing to see such improvements are not immediately shown to the students who offered them in the first place. Hence, getting feedback and showing the students that the feedback is very important by addressing them immediately gives immense satisfaction to both the parties.

The in-class group project activity requires the students to solve simple, detailed and concept-based projects in groups. The purposes of these projects are to (a) emphasize some of the key concepts in a very simple terms under concrete situations; (b) let the students discuss among themselves to see how to set up the problems and solve using appropriate software. Furthermore, the students have a better understanding of the concepts when presented with their associated properties rather than memorizing the concepts. This is one of the key findings as reported in Bransford, et al[1], and the in-class group project activity is another proof to this finding.

The miniprojects are given to further emphasize the usefulness of the concepts and tools seen in the class. These are small-scale projects that require a report no more than two to three pages in length. Most students pick up applications from their work area. This gives an immense satisfaction to them as well as to us since the subject matter is so practical and Kettering University students spend half their university life doing co-operative education. For illustrative purposes we list some sample miniprojects below.

**Miniproject 1:** Identify a problem in your area (work area if you are working; otherwise you can consult any journal or technical report. In the latter case, include the reference) that uses Linear Programming for modeling and discuss the following very briefly in **one or two** pages. (a) Objective of the study; (b) Brief description and goals of the study; (c) Formulation of the problem; and (d) The conclusions, if any, of the modeling aspects.

**Miniproject 2:** There are two parts to this miniproject. Both are group ones.

**Part 1:** Identify a problem in your area (work area if you are working; otherwise you can consult any journal or technical report. In the latter case, include the reference) that uses

Transportation/Transshipment/Assignment/CPM/PERT and discuss the following very briefly in one or two pages.

**Part 2:** Referring to the article "...P&G's SUPPLY CHAIN..." posted in Articles folder, write a brief report summarizing the article, the tools used, conclusions, etc. The report should not exceed two pages. The report format should be:
(a) Objective of the study; (b) Brief description and goals of the study; (c) Formulation of the problem; (d) The conclusions, if any, of the modeling aspects.

**2.2. Analysis of results from initial and final surveys:**

In this section we will summarize the statistics based on the initial and final surveys (see exhibits 1A and 1B) that were given over four quarters (summer 2002, fall 2002, summer 2003 and fall 2003). It should be pointed out that Kettering University operates on a quarter system and hence our summer session is like any other session. For sake of brevity we will report only the key points here. Note that the five categories: Strongly Disagree to Strongly Agree are scored 1 through 5.

- At the beginning of the quarter the students enrolled in the course did not have a clue about what operations research is all about. However, at the end of the quarter they not only felt that they know what OR is all about but also can apply what they learned in practice. These views have been very consistent from quarter to quarter (see figures 1 and 2). The visual significance of figure 1 is also statistically significant.
- After taking the course the students felt that they can see the importance of the materials seen in the course as well as gaining a significant knowledge in optimization methods (see figure 3).
- The students on the average felt neutral to the weekly activity reports (see questions 25 and 26 in Exhibit 1B). The students felt it is redundant to have weekly activity reports since they were filling out the in-class activity reports, which they found to be very useful.

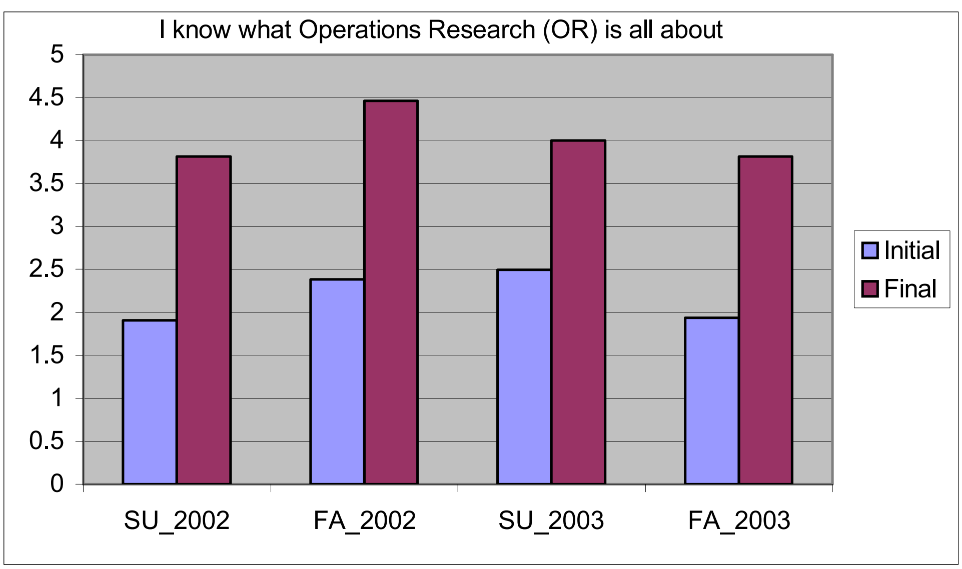



**Figure 1**

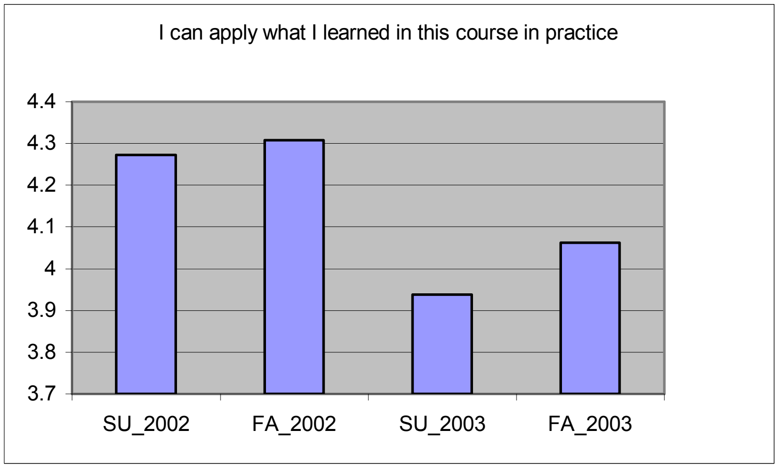



**Figure 2**

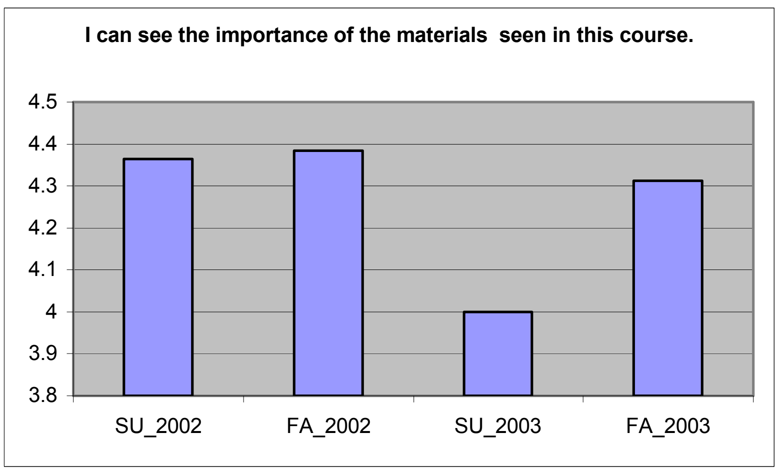



**Figure 3A: Average Score for Question 22 in the Final Survey**

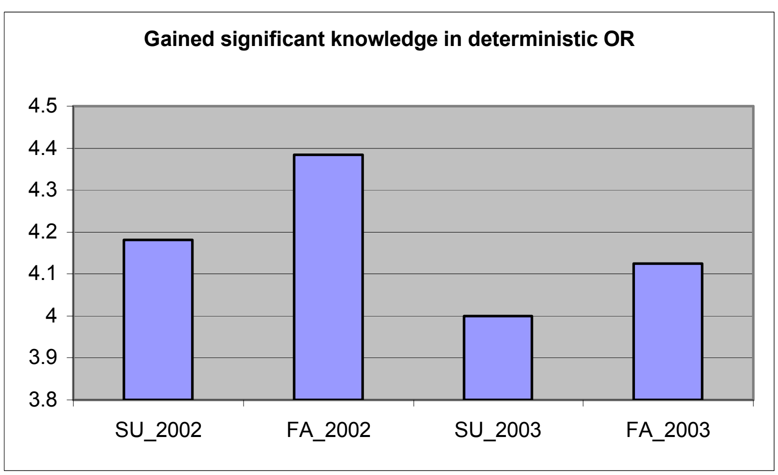



**Figure 3B: Average Score for Question 24 in the Final Survey**

### 2.3. Stochastic Models in Operations Research:

This is a second-level course in modeling in which the students are exposed to basic concepts and techniques in stochastic models. In the original version of this course, the pre-requisites for this course are Deterministic Models in Operations Research and Probability. The course includes the following topics: A brief review of matrix algebra, Introduction and history of stochastic modeling; Introduction to Markov chains; Applications of Markov chains; Computation and interpretation of steady-state probabilities of Markov chains; Discrete and continuous time phase type distributions; Introduction to queuing theory; Birth-and-death processes; Basic queuing models involving Poisson arrivals and exponential services; Advanced queuing models including phase type arrivals or phase type services; The primary software is EXCEL and students were also given FORTRAN executable codes to run examples. The author developed the FORTRAN executable codes and hence the students do not need to possess any knowledge in FORTRAN.

The course basically comprised of weekly activity reports, in-class activity reports, quizzes, homework sets, miniprojects, in-class projects, midterm exam (in some quarters), a term project, and final exam. Blackboard was used extensively as a medium of communication and the students were encouraged to send the assignments electronically.

The approach to teaching this course is very similar to the deterministic operations research and hence we will refrain from duplicating them here. However, in this course the students were given assignments and projects that require them to do computer experimentation. The main purpose of this is to bring out the qualitative nature of queuing models that are useful in practice. The textbook for this course has been Wayne Winston's book on operations research. However, the book does not contain any advanced queuing models that senior undergraduate students can be exposed to and hence a number of supplementary materials were handed out. Specifically the handouts were on (a) Markov chains (both discrete and continuous time); (b) Applications of Markov chains and Stochastic Models in practice; (c) Introduction to discrete and continuous phase type distributions (this includes some very well-known distributions such as geometric (in discrete case), exponential, Erlang, and hyperexponential (all these in continuous time)); and (d) queuing theory (specifically the ones involving phase type arrivals or services in continuous time).

A sample miniproject in which the students are required to perform experimental work is displayed below. The students were given the Fortran executable codes and in some cases Excel files so that they can concentrate more on the qualitative interpretation of the models rather than get bogged down with coding the queuing models either in Excel or in Fortran (see Exhibits 5 and 6).

MINIPROJECT 3: EXPERIMENTAL WORK: **This work involves the analysis of PH/M/s and PH/M/s/K queuing models using Fortran executable codes. The purpose of this work is to perform sensitivity analysis of the mean number in the system with regards to buffer size, service time distribution and the traffic intensity.**
Consider the following three arrival time distributions: (I) Exponential; (II) Erlang of order three; and (III) 3-stage hyperexponential. In order to make proper comparisons, all three service time distributions

will be set to have the same rate of arrival rate $\lambda$. However, the arrival time distributions will have different variances. When you use the Fortran code for this experiment, all you need to do is input the arrival rate ($\lambda$), service rate ($\mu$) along with the arrival time representation ($\boldsymbol{\beta}$, $S$) of order 3. Note that by inputting $\lambda$ the matrix $S$ will be normalized so as to get the required arrival rate. You can fix $\lambda = 10$. You need to vary the values of $\rho$ by modifying the service rate. No need to modify the arrival rate. This way you can do sensitivity analysis when $\rho$ is varied.

**PROBLEM 1:** First calculate the performance measures: (a) mean number in the system; (b) mean waiting time in the queue for PH/M/s queue. Do this for $\rho = 0.1, 0.5, 0.8, 0.9, 0.99$ by taking s = 1, 2, and 5. Generate a table to summarize the measures for various values of $\rho$ and for the arrival time distributions for three sets of values for s. Compare these two measures for the three arrival time distributions and write a report.

**PROBLEM 2:** Look at PH/PH/s/K queueing model. Now vary the buffer size ($K$) from, say, 10 to 50 in increments of 10, and see how the mean number in the system change. Do this for $\rho = 0.1, 0.5, 0.8, 0.9, 0.99$ and for s = 1,2, 5. For each combination of arrival and service time distributions and $\rho$, plot (a) the mean number in the system; (b) P(an arrival will see no delay); and (c) P(an arrival will be lost) as a function of $K$. Now compile the data in table format for each of the three quantities: mean number in the system, P(no delay) and P(lost). It should be in the format mentioned earlier.

### 2.4. Analysis of results from initial and final surveys:

In this section we will summarize the statistics based on the initial and final surveys that were given over three quarters (summer 2002, fall 2002, and summer 2003) for the stochastic models course (See Exhibits 1C and 1D). For sake of brevity we will report only the key points here. Note that the five categories: Strongly Disagree to Strongly Agree are scored 1 through 5.

- At the beginning of the quarter the students enrolled in the course did not have a clue about what a stochastic model is all about. However, at the end of the quarter they not only felt that they know what a stochastic model is all about but also can apply what they learned in practice. These views have been very consistent from quarter to quarter (see figures 4 and 5).
- After taking the course the students' felt that they can see the importance of the materials seen in the course as well as gaining a significant knowledge in stochastic models (see figure 6).
- During summer and fall quarters of 2002, the students on the average felt neutral to the weekly activity reports. However, during summer 2003 there was a positive response to the weekly activity reports.

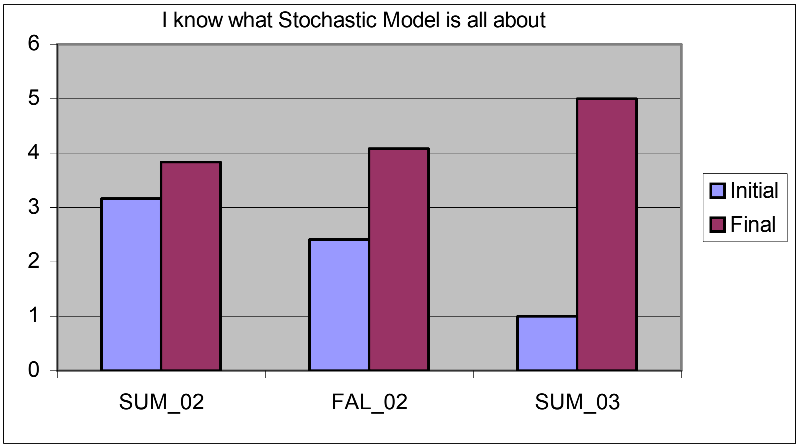



**Figure 4**

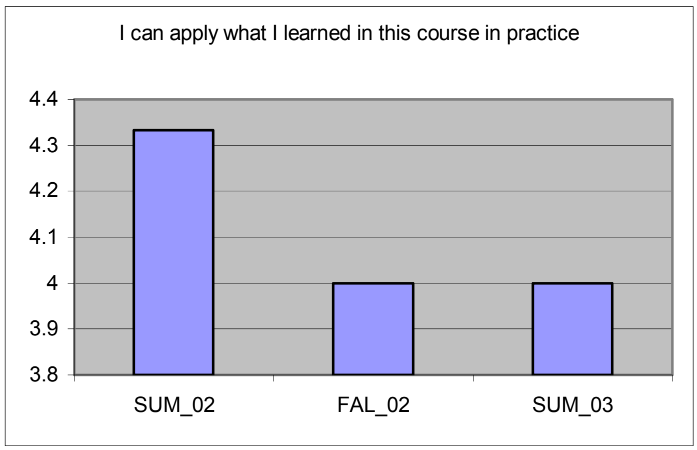



**Figure 5**

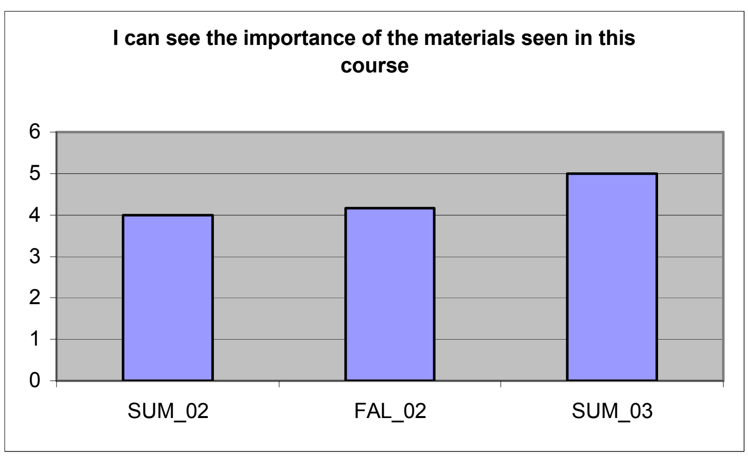



**Figure 6A: Average Score for Question 21in the Final Survey**

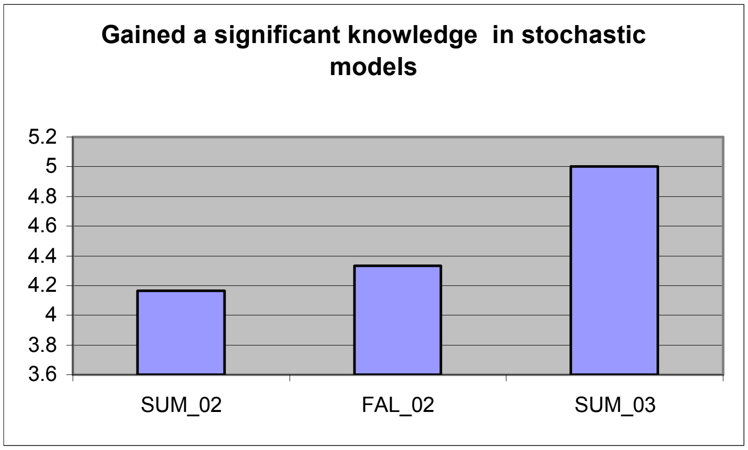



**Figure 6B: Average Score for Question 23 in the Final Survey**

## 3. Lessons Learned and Future Work

Traditional way of teaching in the classroom provides very limited opportunities for students to understand or make sense of the concepts and to interact with fellow students as well as the instructors (see Bransford, et al[1]). Knowing concepts with their associated properties is important to understand the concepts rather than memorizing them. Students learn better when teachers interact with them on a regular basis not only outside the class but also inside the class. The more interaction seen inside the class the higher the motivation for learning and transfer of knowledge. The ways the opportunities are given vary from course to course and from instructor to instructor. The purpose of this paper is to point out and promote an approach that this author has found to be a significant learning experience. The in-class group solving activity, in our opinion, seems to be one of the best tools not only to assess how well the students are learning the concepts but also for providing students a "friendly" environment to show their understanding of the concepts. Also, the in-class activity reports enable both students and the teacher to get a grip on where the students stand and how they are learning the new concepts. Furthermore these reports help to direct the students, especially the ones lagging behind, to ask questions frequently. Hence, having this as a classroom assessment tool will be very useful and should be encouraged in every course. The number of students in the class during the quarters studied in this report varied any where from 15 to 25 for IME-321 and for IME-422, the number varied from 1 to 12. While this number may be small (compared to other courses taught not only at Kettering but also at various other universities) and ideal for implementing such a tool, it is possible to adopt this in a class setting that is not only large but also meet in one-hour block. One way to accomplish this is to make this activity not on a weekly basis but in a limited way (say once in three weeks) so as to make sure the students understand the concepts and exhibit their knowledge of understanding.

Furthermore, the in-class group activity currently consists of a minimum of 3 but a maximum of 5 students per group. Most of the times the individual groups consist of the same set of students. This is primarily due to students sitting pretty much in the same place and the groups are formed without disturbing the students' seating arrangement. This invariably creates situations in which some students "ride" on the others. Trying out a group of no more than 2 students and or forming random groups each time may alleviate this problem. This will be tried out next time when we teach this course.

Regarding the weekly activity reports, there were mixed feelings among the students. Some felt that it is redundant considering that they fill in in-class activity reports. A few others indicated that the weekly activity reports helped them to focus more on where they stand in the class with respect to their preparations of the class. Since a few students benefit from the weekly activity reports we think it may be a valuable tool to be used as part of assessment in the classroom in addition to the in-class activity reports.

In-class group projects have been well received by the students. Hence, they will be used in the future. However, the group size for the in-class group projects has been about four. These groups are randomly formed at the beginning of the term. However, the groups remain the same throughout the term. Along the lines indicated above, it would be nice to see how the students perform by reducing the size of the group and also form the groups randomly for all the projects. Also, we have been doing about two group projects in the class. Increasing this to three or more would give students more opportunity to see the impact of the subject in practice and thus give more motivation for learning and transfer. This will be a challenge as more class time is taken away for doing the projects. Also, if the class size is large, then having more groups of smaller size will significantly increase the time consumed for this activity. Thus, the instructor has to balance the group size with the class and at the same time making sure that the members within the groups take advantage of such learning opportunities.

Earlier we remarked on one group of students who fail to take advantage of "friendly" environment for their learning and transfer of knowledge. We strongly believe that this group of students needs to be confronted individually on an one-on-one basis regularly. We are planning to use this strategy (after identifying this group early in the course) next time this course is taught. The idea behind this is to give them an opportunity to come out of the shadow of the others and take individual responsibility to perform well. If the attitude of these students does not change even after giving them ample opportunities to improve and increase their learning skills, then no amount of extra efforts on the part of the teacher as well as fellow students will make them learn. This is really disheartening on the part of the teacher!

From our experience (we are sure a lot of other teachers have experienced too) one of the common questions asked by students who do not perform well in the course, at the end of the term is: can you give me some extra work so that I can improve my grade? Sometimes this question was also asked even after the student gets the final grade for the course. These are the students who not only fail to avail the opportunities provided in the classroom, but also fail to seek help outside the classroom. While the percentage of such students is small in any given quarter, the fact that there is at least one such a student in the class who wasted the opportunities frustrates this author and other concerned teachers. What can and should be done to help these students in such a way that (a) the other students in the class will not be treated differently? (b) these students will not consider this to be a vehicle for passing the course at their own leisure and hence resort to this process in the future? Learning is a two-way process that students should also reach out to the teachers. This issue, we are sure, will not only stir the interests in the teaching community but also be addressed in a forum to benefit the entire teaching community.

Finally, based on twenty plus years of experience in education and by constant interaction with fellow educators in other universities, we feel that

- Motivation and pride both seem to be not at the level that they used to be about 10 years ago.
- Technology has helped the education in a number of ways, but also has decreased the “appetite” for motivation in some areas including the “feel for urgency”. For example, when I started my teaching career students frequently visited my office to express their concerns about not performing well and wanted to know the course of actions so that they can pass the course with “decent” grade. But now a days some students do not seriously consider the consequences of “not doing well” in the classroom.
- While students are getting brighter in a number of aspects, there seems to be a decrease in the “conventional” thinking. For example, the general trend among the students is to put more focus on the use of software and computers, and less on the fundamental aspects without which the software cannot be written. Some educators, who insist on this approach, should share part of the blame. Also, the quality of written and oral presentations seems to have gone down significantly. Some students’ writings reflect more of “casual” (like informal talking) thinking rather than real report writing skills.
- Reading habits have gone down significantly. Some students tend not to read the book or the notes (neither before the lecture nor after the lecture). When I started my teaching career I noticed students spending significant amount of time going through worked out examples from the book. I always make it a point to solve problems that are not worked out in the book. This way the students have opportunities to see variety of problem solving skills.
- The number of opportunities available makes it convenient in one aspect; however, this also inhibits a lack of drive on the part of students to procrastinate doing their work. Finding a balance is very important!

**Acknowledgment:** This work is partially supported by a travel grant from Kettering University’s Center for Excellence in Teaching and Learning.

## 4. Reference

[1] Bransford, J.D., Brown, A.L., and Cocking, R.R. (2000). Eds., *How People Learn: Brain, Mind, Experience, and School*, National Academy Press, Washington.

## Srinivas R. Chakravarthy

Dr. Chakravarthy is a Professor of Operations Research and Statistics in the Department of Industrial and Manufacturing Engineering and Business at Kettering University. His areas of research interests include applied probability and stochastic modeling. He received Kettering University Alumni’s Outstanding Teacher Awards (1990 and 2001) and Kettering University’s Outstanding Researcher (1996) and Distinguished Researcher (2003) Awards.

# EXHIBIT 1A: INITIAL SURVEY - IME-321

NOTE: This survey is meant to gather information that will better prepare students (with regards to their background, knowledge retention, etc) in the future. THE RESULTS OF THIS SURVEY WILL NOT AFFECT YOUR FINAL COURSE GRADE. This ID is required when you fill in the final survey, which will be compared to the initial survey. BOTH THE SURVEYS ARE MANDATORY! YOUR COOPERATION IS GREATLY APPRECIATED!

**My identification number is:** ____________

(Please enter your last four digits of KU ID number)

| | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|
| 1. I am confident in my math skills entering into this course | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2. I am confident in my computer skills entering into this course | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3. I am confident in surfing the Internet w.r.t researching a particular topic | ☐ | ☐ | ☐ | ☐ | ☐ |
| 4. I enjoy solving problems in different ways | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5. Creative thinking is one of my strengths | ☐ | ☐ | ☐ | ☐ | ☐ |
| 6. I have strong problem solving skills | ☐ | ☐ | ☐ | ☐ | ☐ |
| 7. I know what Operations Research (OR) is all about | ☐ | ☐ | ☐ | ☐ | ☐ |
| 8. I have seen OR being used in my co-op company | ☐ | ☐ | ☐ | ☐ | ☐ |
| 9. I have read about OR being applied in practice | ☐ | ☐ | ☐ | ☐ | ☐ |
| 10. I have computer programming skills | ☐ | ☐ | ☐ | ☐ | ☐ |
| 11. I can write effectively | ☐ | ☐ | ☐ | ☐ | ☐ |
| 12. I am comfortable in making presentations in front of a group of people | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13. I enjoy team working | ☐ | ☐ | ☐ | ☐ | ☐ |
| 14. I enjoy word problems | ☐ | ☐ | ☐ | ☐ | ☐ |
| 15. I enjoy using computers in my subjects | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16. I strongly believe in spending at least an hour (outside the class) for each hour in the classroom | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17. I believe in regularly meeting with my professors whenever I need outside help | ☐ | ☐ | ☐ | ☐ | ☐ |
| 18. I believe in frequently asking questions in the class when I don't understand | ☐ | ☐ | ☐ | ☐ | ☐ |
| 19. I have been exposed to OR tools prior to taking this course | ☐ | ☐ | ☐ | ☐ | ☐ |
| 20. I have used computers in previous courses | ☐ | ☐ | ☐ | ☐ | ☐ |
| 21. I am aware of the prerequisites to this course | ☐ | ☐ | ☐ | ☐ | ☐ |
| 22. I have adequate prerequisite requirements for this course | ☐ | ☐ | ☐ | ☐ | ☐ |
| 23. I have used commercial software before | ☐ | ☐ | ☐ | ☐ | ☐ |

## EXHIBIT 1B: FINAL SURVEY - IME-321

**My identification number is:** ____________
(Please enter your last four digits of KU ID number)

| | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|
| 1. I am confident in my math skills entering into this course | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2. I am confident in my computer skills entering into this course | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3. I am confident in surfing the Internet w.r.t researching a particular topic | ☐ | ☐ | ☐ | ☐ | ☐ |
| 4. I enjoy solving problems in different ways | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5. Creative thinking is one of my strengths | ☐ | ☐ | ☐ | ☐ | ☐ |
| 6. I have strong problem solving skills | ☐ | ☐ | ☐ | ☐ | ☐ |
| 7. I know what Operations Research (OR) is all about | ☐ | ☐ | ☐ | ☐ | ☐ |
| 8. I have seen OR being used in my co-op company | ☐ | ☐ | ☐ | ☐ | ☐ |
| 9. I have read about OR being applied in practice | ☐ | ☐ | ☐ | ☐ | ☐ |
| 10. I have computer programming skills | ☐ | ☐ | ☐ | ☐ | ☐ |
| 11. I can write effectively | ☐ | ☐ | ☐ | ☐ | ☐ |
| 12. I am comfortable in making presentations in front of a group of people | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13. I enjoy team working | ☐ | ☐ | ☐ | ☐ | ☐ |
| 14. I enjoy word problems | ☐ | ☐ | ☐ | ☐ | ☐ |
| 15. I enjoy using computers in my subjects | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16. I strongly believe in spending at least an hour (outside the class) for each hour in the classroom | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17. I believe in regularly meeting with my professors whenever I need outside help | ☐ | ☐ | ☐ | ☐ | ☐ |
| 18. I believe in frequently asking questions in the class when I don't understand | ☐ | ☐ | ☐ | ☐ | ☐ |
| 19. I am aware of the goals and objectives of this course | ☐ | ☐ | ☐ | ☐ | ☐ |
| 20. I can apply what I learned in this course in practice | ☐ | ☐ | ☐ | ☐ | ☐ |
| 21. I have a good understanding of how the tools of this course will help me in other courses | ☐ | ☐ | ☐ | ☐ | ☐ |
| 22. I can see the importance of the materials seen in this course | ☐ | ☐ | ☐ | ☐ | ☐ |
| 23. I can see how the prerequisite materials are related to the topics of this course | ☐ | ☐ | ☐ | ☐ | ☐ |
| 24. I believe that I have gained a significant knowledge in deterministic optimization methods | ☐ | ☐ | ☐ | ☐ | ☐ |
| 25. The weekly activity reports helped me to learn the materials significantly | ☐ | ☐ | ☐ | ☐ | ☐ |
| 26. I would strongly recommend the weekly activity reports be a part of all courses | ☐ | ☐ | ☐ | ☐ | ☐ |

## EXHIBIT 1C: INITIAL SURVEY - IME-422

NOTE: This survey is meant to gather information that will better prepare students (with regards to their background, knowledge retention, etc) in the future. THE RESULTS OF THIS SURVEY WILL NOT AFFECT YOUR FINAL COURSE GRADE. This ID is required when you fill in the final survey, which will be compared to the initial survey. BOTH THE SURVEYS ARE MANDATORY! YOUR COOPERATION IS GREATLY APPRECIATED!

**My identification number is:** ____________

(Please enter your last four digits of KU ID number)

| | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|
| 1. I am confident in my math skills entering into this course | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2. I am confident in my computer skills entering into this course | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3. I am confident in surfing the Internet w.r.t researching a particular topic | ☐ | ☐ | ☐ | ☐ | ☐ |
| 4. I enjoy solving problems in different ways | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5. Creative thinking is one of my strengths | ☐ | ☐ | ☐ | ☐ | ☐ |
| 6. I have strong problem solving skills | ☐ | ☐ | ☐ | ☐ | ☐ |
| 7. I know what Stochastic Models (SM) is all about | ☐ | ☐ | ☐ | ☐ | ☐ |
| 8. I have seen SM being used in my co-op company | ☐ | ☐ | ☐ | ☐ | ☐ |
| 9. I have read about SM being applied in practice | ☐ | ☐ | ☐ | ☐ | ☐ |
| 10. I have computer programming skills | ☐ | ☐ | ☐ | ☐ | ☐ |
| 11. I can write effectively | ☐ | ☐ | ☐ | ☐ | ☐ |
| 12. I am comfortable in making presentations in front of a group of people | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13. I enjoy team working | ☐ | ☐ | ☐ | ☐ | ☐ |
| 14. I enjoy word problems | ☐ | ☐ | ☐ | ☐ | ☐ |
| 15. I enjoy using computers in my subjects | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16. I strongly believe in spending at least an hour (outside the class) for each hour in the classroom | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17. I believe in regularly meeting with my professors when I needed outside help | ☐ | ☐ | ☐ | ☐ | ☐ |
| 18. I believe in frequently asking questions in the class when I don't understand | ☐ | ☐ | ☐ | ☐ | ☐ |
| 19. I am aware of the prerequisites to this course | ☐ | ☐ | ☐ | ☐ | ☐ |
| 20. I have adequate prerequisite requirements for this course | ☐ | ☐ | ☐ | ☐ | ☐ |
| 21. I have been exposed to SM tools prior to taking this course | ☐ | ☐ | ☐ | ☐ | ☐ |
| 22. I have used commercial software before | ☐ | ☐ | ☐ | ☐ | ☐ |
| 23. I have used computers in previous courses | ☐ | ☐ | ☐ | ☐ | ☐ |

## EXHIBIT 1D: FINAL SURVEY - IME-422

**My identification number is:** ____________
(Please enter your last four digits of KU ID number)

| | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|
| 1. I am confident in my math skills after this course | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2. I am confident in my computer skills after this course | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3. I am confident in surfing the Internet w.r.t researching a particular topic | ☐ | ☐ | ☐ | ☐ | ☐ |
| 4. I enjoy solving problems in different ways | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5. Creative thinking is one of my strengths | ☐ | ☐ | ☐ | ☐ | ☐ |
| 6. I have strong problem solving skills | ☐ | ☐ | ☐ | ☐ | ☐ |
| 7. I know what Stochastic Models (SM) is all about | ☐ | ☐ | ☐ | ☐ | ☐ |
| 8. I have seen SM being used in my co-op company | ☐ | ☐ | ☐ | ☐ | ☐ |
| 9. I have read about SM being applied in practice | ☐ | ☐ | ☐ | ☐ | ☐ |
| 10. I have computer programming skills | ☐ | ☐ | ☐ | ☐ | ☐ |
| 11. I can write effectively | ☐ | ☐ | ☐ | ☐ | ☐ |
| 12. I am comfortable in making presentations in front of a group of people | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13. I enjoy team working | ☐ | ☐ | ☐ | ☐ | ☐ |
| 14. I enjoy word problems | ☐ | ☐ | ☐ | ☐ | ☐ |
| 15. I enjoy using computers in my subjects | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16. I strongly believe in spending at least an hour (outside the class) for each hour in the classroom | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17. I believe in regularly meeting with my professors when I needed outside help | ☐ | ☐ | ☐ | ☐ | ☐ |
| 18. I believe in frequently asking questions in the class when I don't understand | ☐ | ☐ | ☐ | ☐ | ☐ |
| 19. I can apply what I learned in this course in practice | ☐ | ☐ | ☐ | ☐ | ☐ |
| 20. I have a good understanding of how the tools of this course will help me in other courses | ☐ | ☐ | ☐ | ☐ | ☐ |
| 21. I can see the importance of the materials seen in this course | ☐ | ☐ | ☐ | ☐ | ☐ |
| 22. I can see how the prerequisite materials are related to the topics of this course | ☐ | ☐ | ☐ | ☐ | ☐ |
| 23. I believe that I have gained a significant knowledge in stochastic models | ☐ | ☐ | ☐ | ☐ | ☐ |
| 24. The weekly activity reports helped me to learn the materials significantly | ☐ | ☐ | ☐ | ☐ | ☐ |
| 25. I would strongly recommend the weekly activity reports be a part of all courses | ☐ | ☐ | ☐ | ☐ | ☐ |
| 26. I am aware of the goals and objectives of this course | ☐ | ☐ | ☐ | ☐ | ☐ |

**EXHIBIT 2: Course continuous improvement process**
**IEN-321: Deterministic Models in Operations Research**

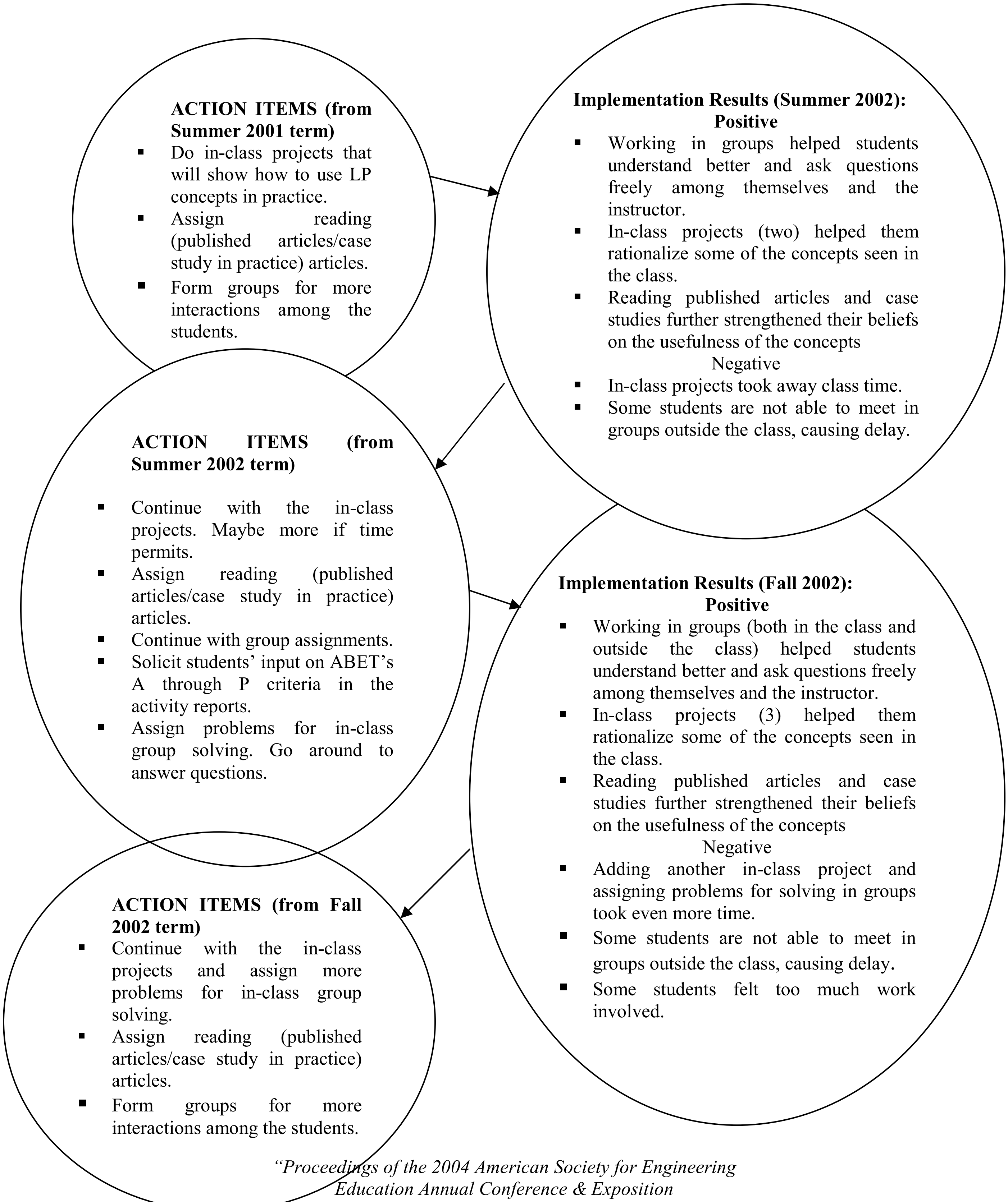


**EXHIBIT 3: Two Samples of In-class Group Activity Report Form**

[Note: This is as presented by the students with no corrections]

**IME-321: SYSTEMS MODELING I – Deterministic Models (FALL 2003)**

**WEEKLY ACTIVITY REPORT**

**IME-321: SYSTEMS MODELING I – Deterministic Models (FALL 2003)**
**IN-CLASS ACTIVITIY REPORT**

| Name(s): | WEEK NUMBER AND DAY<br>3rd Monday 10/20/03 |
|---|---|

**Objective:**

**CIRCLE WHAT ABET Criteria (A-P) are MET (based on your evaluation) TODAY:**

A B C D E F G H I J K L M N O P

**1. Concepts Used/Learned inside the classroom:**

graphical Solution of LPP, Simplex algorithm, convex set, extreme point, hyperplane, half-space, polyhedron

Applying graphical solutions to linear programming.

**2. Specific Questions/concerns on concepts that are not clear and any other remarks:**

Iso cost/profit lines how to determine & what is their function

A: An ability to apply knowledge of mathematics, science, and engineering; B: An ability to design and conduct experiments, as well as to analyze and interpret data; C: An ability to design a system, component, or process to meet desired needs; D: An ability to function on multi-disciplinary teams; E: An ability to identify, formulate, and solve engineering problems; F: An understanding of professional and ethical responsibility; G: An ability to communicate effectively; H: The broad education necessary to understand the impact of engineering solutions in a global and societal context; I: A recognition of the need for, and an ability to engage in life-long learning; J: A knowledge of contemporary issues; K: An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice; L: Understand and serve in Industrial Engineering roles; M: Describe, model, and measure current processes and systems and identify areas of improvement; N: Estimate current, and forecast future, resource requirements; O: Design and organize work spaces and places; P: Track the results of improvement efforts as part of a continuous improvement process

**IME-321: SYSTEMS MODELING I – Deterministic Models (FALL 2003)**
**IN-CLASS ACTIVITIY REPORT**

| Name(s): | WEEK NUMBER AND DAY<br>Monday 6th week |
|---|---|

**Objective:** to further investigate tableau's

**CIRCLE WHAT ABET Criteria (A-P) are MET (based on your evaluation) TODAY:**

A B C D E F G H I J K L M N O P

**1. Concepts Used/Learned inside the classroom:**

Lindo tutorial

Parametric analysis

tableau with unbounded regions.

Shadow prices and sensativity analysis.

**2. Specific Questions/concerns on concepts that are not clear and any other remarks:**

I'm not sure how/when to use artificial variables.

Still a little slow on how to find the shadow prices.

A: An ability to apply knowledge of mathematics, science, and engineering; B: An ability to design and conduct experiments, as well as to analyze and interpret data; C: An ability to design a system, component, or process to meet desired needs; D: An ability to function on multi-disciplinary teams; E: An ability to identify, formulate, and solve engineering problems; F: An understanding of professional and ethical responsibility; G: An ability to communicate effectively; H: The broad education necessary to understand the impact of engineering solutions in a global and societal context; I: A recognition of the need for, and an ability to engage in life-long learning; J: A knowledge of contemporary issues; K: An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice; L: Understand and serve in Industrial Engineering roles; M: Describe, model, and measure current processes and systems and identify areas of improvement; N: Estimate current, and forecast future, resource requirements; O: Design and organize work spaces and places; P: Track the results of improvement efforts as part of a continuous improvement process

## EXHIBIT 4: Two Samples of Weekly Activity Report Form

[Note: This is as presented by the students with no corrections]

**IME-321: SYSTEMS MODELING I – Deterministic Models (SUMMER 2003)**
**WEEKLY ACTIVITY REPORT**

**Name(s):**
[redacted]

**WEEK NUMBER**
5

**Objective:**

**CIRCLE WHAT ABET Criteria (A-P) are MET (based on your evaluation):**

A B C D E F G H I J K L M N O P

**Concepts Used/Learned outside the classroom:**

Worked on utilizing the methods taught on the Simplex Algorithms and Tablean, including variables that are unrestricted in their sign. I had to find optimum solutions using the Simplex Tablean. Using LINDO in some of the assignments, and continue to find the solutions to maximization and minimization problems. Learned and applied methods of formatting problems into Standard Format, and then finding the Extreme (Optimum) points. Utilized the Big M method of solving the LP. Used the sensitivity analysis to solve story problems and analyze to find the optimal solutions and such.

**Specific Questions/concerns on concepts that are not clear and any other remarks:**
We have to go over the sensitivity analysis again, because I was not the only student who was completely lost during your class example on Thursday. It would be highly beneficial to go over that information again, because you obviously said it was important, but yet I couldn't follow you because you pointed out so many important points so fast.

**IME-321: SYSTEMS MODELING I – Deterministic Models (SUMMER 2003)**
**WEEKLY ACTIVITY REPORT**

**Name(s):**
[redacted]

**WEEK NUMBER**
**Week 7 AND Week 8**

**Objective: Continuing to solve transportation, assignment, and transshipment problems. Beginning to understand the maximum flow problems.**

**CIRCLE WHAT ABET Criteria (A-P) are MET (based on your evaluation):**

**A** B C **D** **E** F G H I J K L M N O P

**Concepts Used/Learned outside the classroom:**

- **Transportation problems**
  - **Balancing transportation problems – parameter table**
  - **General framework of the problem**
  - **Concept of a loop**
  - **Generating an initial basic feasible solution**
    - **Northwest corner method**
    - **Minimum cost method**
    - **Vogel's method**
- **Assignment problems**
  - **Hungarian Method**
- **Transshipment problems**
  - **Identifying strictly supply nodes, strictly demand nodes, and transshipment nodes**
- **Network models**
- **Shortest path problems**

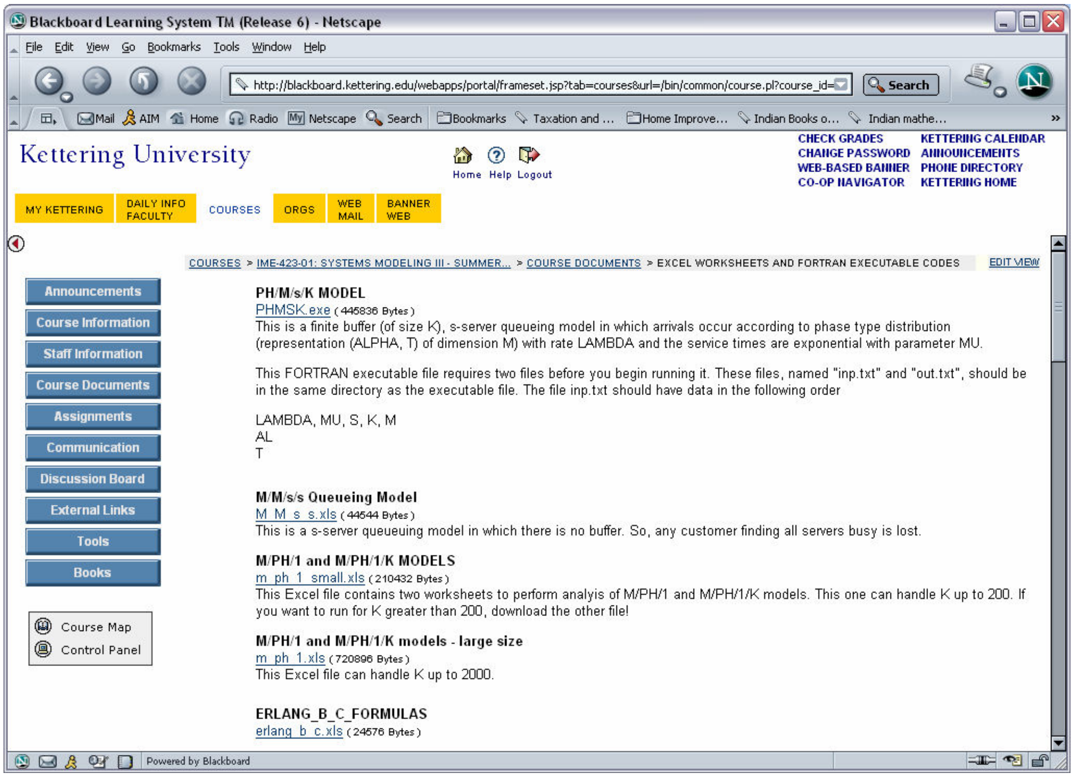
**Specific Questions/concerns on concepts that are not clear and any other remarks:**

- Week 5 homework – Page 349, Question #8
- Week 5 homework – Page 360, Question #2
- Week 8 homework – I do not fully understand how to set-up some of the "word problems"

- Could we possibly discuss in further detail what exactly is expected for our final project please?

# EXHIBIT 5: Samples of Fortran and Excel Files as seen in Blackboard

## IME-422: SYSTEMS MODELING II – Stochastic Models




# EXHIBIT 6: Sample of an Excel File

## IME-422: SYSTEMS MODELING II – Stochastic Models