AC 2012-4172: ASSESSMENT OF STUDENT PERFORMANCES IN OPERATIONS RESEARCH CLASS DELIVERED BY AN INNOVATIVE APPROACH

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Introduction

Operations Research (OR) provides the core foundation skills and knowledge set for Industrial Engineers (IE). It is one of the first courses to introduce crucial skills in its algorithmic approach to problem solving and abstract mathematical modeling of real systems. It provides the mathematical science of optimization that underpins functionality of the optimization tools and algorithms used by IE's. It is a gateway course for IE specializations such as Simulation, Production Planning and Control, Logistics, and similar analytical courses.

Given such critical importance, it is crucial for IE students to:

1. Develop understanding of the concepts of decision variables, constraints, and measures of performance.
2. Develop skills in creating abstract mathematical programming models (LP, ILP, NLP) from real world problems.
3. Develop operational skills in carrying out procedural steps necessary for algorithms (the HOW skill).
4. Develop in-depth knowledge of the logic behind algorithms and their concepts, and learn to extend them to new horizons (the WHY and WHAT-IF skills).

Looking at the above list of capabilities, it is clear that the majority of those skills to be developed rely on understanding the underlining concepts and being able to extend them to real world problems. Since assessment of student development in three of the above four categories is not an easy task, the majority of schools[6] that offer OR courses have their main focus on the implementation of the third item (developing operational skills).

Based on that, students learn how to perform the simplex method, its iterations, write the dual problem, and perform sensitivity analysis with or without the use of software. An instructor spends many hours trying to teach the procedural steps which are tedious, repetitive, and require careful attention to the details, but it is easy to learn.

The concepts, on the other hand, require a higher learning mechanism and instructors traditionally find insufficient time for such conceptual discussions.

Problem definition

To overcome that deficiency, to improve teaching, and enhance learning of students, instructors have over time developed novel and innovative concepts [7] that include, but are not limited, to:

1. Course projects
2. Software assignments

3. Journal reading and research
4. Online help, class handouts, and other ancillary materials.

However, most of such efforts rely on instructor's experience and his/ her desire and initiative to improve teaching skills. Since many OR instructors are not familiar enough with the vast resources available in the area of student learning, they usually do not take full advantage of research and proven methods and approaches that enhance student understanding of the course concepts and goals. On the other hand the dearth of published materials on the implementation of learning techniques in OR courses required the design of an innovative course delivery method that incorporated strong assessment tools to document learning enhancements.

Predesign phase - Factors not considered

Initially, a decision was made to not consider three factors. They were left for the future research when enough data were collected and analyzed with the possibilities of other universities joining in the effort.
They were:

1. Student Profile
   Morgan State University is a member of the Historical Black College and Universities (HBCU) and a majority of the students are from an underrepresented group, African-Americans. As such, the university type was left to future research when other universities could also provide data to form a statistical basis for comparison.
2. Student Skill Level
   Morgan State University is a doctoral granting urban university. Not only does it cater to large number of top quality students, but it also provides opportunity to students that are good, but not considered as top of their class. Hence, students attending classes clearly demonstrate a bimodal mix representing a real challenge to instructors; how much to cover without 'boring' one group or 'losing' another one?
3. Students' Financial Profile
   More than 76% of the students at Morgan State University receive some sort of financial aid, scholarship and/or loans without which most of them would not be able to pursue college or higher education. Those who do not receive aid, or receive partial aid, have to work long hours to pay for their education and living expenses. The negative impact of working hours on student performance [4] is well established and documented in educational research. Although the studies are mixed[1] regarding the impact of work on students' academic performance based on motivation, our experience has indicate that working students demonstrate different levels of alertness and readiness for learning mostly due to lack of rest and not having enough time to study and prepare for class.

The above three factors were considered "outside factors impacting students' performance". They were simply the issues that an instructor could not influence and were more related to university and school policies.

Predesign phase - Factors considered

Five other factors were determined to be "factors impacting students' performance":

1. Volume and level of the complexity of materials presented.
2. Level of knowledge and skills a student must have for traditional mid-term and final exams.
3. Students use of other students' work makes it difficult to assess one's real skills and knowledge level
4. Limited class time does not allow real assessment of students' understanding of the lectures delivered.
5. Competition for grades discourages students from developing a true learning community.

Phase I

From 1990 - 2000 the OR classes were taught using the traditional approach with gradual improvements in the teaching and the development of supporting materials for class instruction. However, the principal OR instructor who has taught the course for more than two decades in the same department, same school and the same student demographic had a wealth of experience and a track record along with an interest in engineering education research. So a strong case was made for a new design. [2][3][9] The new design was implemented and modified over the next several years based on the class assessment and student feedback and performance.

The partial success of the new design, limited mostly due to the volume of materials covered in the class and the lack of a coherent connection between all the topics taught in the prerequisite course of linear algebra and the OR course, prompted a reevaluation of the curriculum. After departmental consultation the need to expand the instructional percentage of the OR portion of the curriculum was agreed upon. Thus, resulting in replacing the linear algebra and OR course sequence with two OR courses. Where the first OR course having a large portion of the linear algebra topics included in it along with some OR topics that demonstrated the applications of these concepts.

Phase II - Implementation

The OR course lent itself to the development of this structural paradigm because it is favorable to the segmentation of the material into topics; where each segment works as pre-requisite for the next segment. Additionally to understand each segment, one needed to have understood the prior segment well enough to successfully learn the concepts presented in the new segment. The segmentation into topics allows the discussion to focus in one area while its connection to a subsequent segment is linked by "WHAT-IF" or "WHAT-ABOUT" type questions during discussion, thus a background is laid for the next segment.

The design effort enjoyed administrative support at the departmental level [11] allowing the curriculum to be adjusted. OR was changed from a one semester three-hour course (*IEGR440*) with a linear algebra prerequisite to a two course sequence (*IEGR361 and IEGR461*) three hours each incorporating the linear algebra knowledge and skill base into the first OR (*IEGR361)*

course as an introduction to the subject matter while eliminating the Linear Algebra requirement from the curriculum. The coopting of the linear algebra course allowed the re-emphasizing and expansion from three hours to six hours of the OR course material without adding an additional credit burden to the curriculum inventory. Thus, the OR class was completely revamped in an effort to give students greater exposure to this material.

The current form of the model described here was introduced in the fall of 2010. To ease the transition the department decided to offer IEGR 440 every semester to all students required to take that course until they are cleared from the system. During the fall 2010 semester the introduction of the new format (previously various parts of the new innovation approach were tried and modified) was transitioned from the traditional testing convention (two or three major tests plus the accumulative final) to the topic testing format to be described further on in this paper.

At the beginning of the semester all the students were introduced to the topic test format which was maintained during the first third of the semester. At that point, students were given a choice for the remainder of the semester between traditional testing régime (mid-term and a final) and the topic format.

Innovative format method

The method of segmenting the course material influenced by a competency based approach [8] was to divide the subject matter into ten topics. This covered the conventional level of information normally achieved in a one semester course offering.

The format of this new approach consisted of introducing a topic with a set of lectures. Once the topic was completed and students had an opportunity to ask any clarifying questions in the classroom, the students were placed 'on the clock'. This initiated a timeframe, usually a week, within which students had two challenges to complete in order to be eligible to take that topic test.

The first challenge, the student needed to acquire a completely worked-out problem that illustrated the concept of the just completed topic. This problem could be one of the students own devising or from a textbook, class web page, or any other source. The student then would schedule an appointment with the instructor to do an oral presentation of the problem. The student would explain step by step the procedure(s) used in the solution of the problem. This provides the instructor an opportunity to examine the students' critical thinking skills. If the student is unable to completely describe the problem and has a significant error in their presentation (either conceptually or procedurally) the instructor corrects errors and (time permitting) lets the student select another problem and reschedule another oral presentation. Students were free and actually encouraged to share any information gleaned during their individual presentations with their fellow students. Additionally, they were welcome to be present during the practice presentation of their peers. Upon the successful presentation, the

student is given an individualized homework problem to be completed within 24 hours. The student is free to schedule within posted hours the time they pick-up their homework problem.

The second challenge is the individualized homework problem. It is rigorous in its design; requiring students to do an expanded problem. This mandated homework ensures topic by topic practice of the underlining procedures. If a topic has more than one solution approach the instructor may prescribe a preferred solution method. Students have reported in the interview an estimated time of three to five hours to complete the homework during their 24 hour time limit. This homework is then corrected and graded. Although the grade is merely an indicator of insignificant error, allowing the student to pass while correcting arithmetic errors or small missteps. However, the homework itself is a pass/fail milestone to eligibility to take the topic test. If the errors are significant the student fails. If the student fails the homework and there is at least 24 hours before the topic exam they are allowed to request another homework problem. If time does not permit the student fails that topic.

The topic tests were timed, usually between 30 to 45 minutes duration. The course is taught twice weekly with a one hour, two hour lecture sequence. The exams are usually given during the two hour lecture class. The frequency of the exams and their number take instructional time away from the class. Students are offered the option of taking the topic test outside of class time; to do so it must be a unanimous decision of all eligible topic test takers. This is coordinated by the students, thus encouraging communication and cooperation in a community learning environment. Testing outside the scheduled class time allows the introduction of additional topics. Students recognize the advantage of more bonus topics giving them the opportunity to improve their chance for a more desirable grade (or pass the class). Here too the instructor is afforded flexibility adjusting lecture timing to both meet the needs of the class and cover the desired material. Dependent upon the tide of instruction and the cooperativeness of the students there may be time toward the end of the semester for two or three additional bonus topics.

An important aspect of the class structure is to organize and encourage the establishment of a learning community [7]. All class communication is conducted and archived through the YahooGroup. Each student is a member of the Internet group allowing open access. Students may communicate with each other and or the instructor through the YahooGroup. The students are asked to share insights or message-board queries using this method or post their exceptionally good homework assignment to the YahooGroup. The students are encouraged to work together and not to be in competition with each other. It is explained that each problem the students receives is a unique problem designed for them. However they are encouraged to work in a group in finding a solution. The students are encouraged to think of themselves as members of a wider Internet community of scholars in training. Asked to seek out relevant information on the Internet; it seems from the interviews of the first group of students they were more consumers of information in this process. Recognizing that the student is not going to be better than the instructor in explaining content, students are made aware of an open-door policy. The instructor or in some instances a designee is available to discuss points of interest to the student.

Assessment

At the completion of the course, students' motivations for choosing between the two formats were investigated by the use of video interviews and paper surveys. In the interviews seven of nine students in the topics group stated their reasoning for picking the topic group as the complexity of the class material. Choosing the topic by topic instructional mode was more desirable and advantageous as they were tested incrementally. Many of students that remained in the traditional group stated that due to time constraints (mostly related to work outside school) they needed to remain in the traditional format. Also mentioned as a reason for choosing the topic group was a sense of compelling attentiveness to the scheduled requirements; doing the work without procrastination.

To encourage the frank and candid expression of their views students, as part of the research, were assured that the videos would not be shared with the instructor. Of the sixteen students that volunteered for the interview, nine were from the topic group. The following information was collected from the nine during an unguided five to ten minute interviews of topic group members and consists of their responses to general questions related to three basic areas:

1. Why did they pick the topic group?
2. What did they think of the structure?
3. How did they adapt to the new structure?

Selection of topic

When given a choice between the topic and traditional groups the students offered several rationales for picking the topic group. The majority of the students thought the topic group offered the best chance of successfully completing the class. From the interviews this was the consensus even among the traditional group. Some of the responses: 'best chance to understand the material', 78%; liked the incremental testing aspect, 56%; benefited from the study routine, 44%. Other benefits that students noted were: learned and applied time management skills, 78%; increased individualized time with the instructor, 56%; enhanced presentation skills, 56%.

Students' reflections on the structure

This was an innovative method for teaching an engineering class. None of the students had encountered a format like it before. Students in the topic group were forced into various strategies in order to perform. An unarticulated goal of the format was to create a learning community. Toward this end students were encouraged and did form both formal and informal study groups. In the interviews 89% reported they worked in groups. The instructor used the YahooGroup for class communication, i.e. assignment updates, due date notifications, etc. However, this Internet tool was available for the students to engage in study forums where they informed and shared resources.

The oral presentation of a student acquired practice problem provides the instructor with a unique opportunity to assess and if necessary correct a students' conceptual interpretation of the lecture material. Students found the practice presentations: helpful in clarifying misconceptions, 67%; beneficial in allowing the student to demonstrate their level of knowledge, 44%; and appreciative of the opportunity to interact one-on-one with the instructor, 56%.

The students found the homework problems a challenge mostly related to the 24 hour time limitation. Although only 33% mentioned it as a good preparation for the test, the largest response came more as a negative reaction to the impact of the time limitation necessitating the development of time management strategies in order to cope. Again here a desirable unarticulated consequence of the format, enhanced time management skills. Students mentioned recognition that procrastination was not an option under this regimen.

Students' coping mechanism

The students spent an increased amount of time studying for this class; 33% spent 5-10 hours per week, 44% spent 11-15 hours per week, 22% spent more than 16 hour per week. This increased time was attributed to the format where students had to study the material presented in the lecture, prepare the practice problem and its presentation, and complete the homework which was designed to require a minimum 4-5 hours of work.

Supplemental materials were available to students via an instructor supported website. Each topic had extended step by step example problems and additional procedural approaches (tips and tricks). All of the topic group members used this resource and stated that it was helpful. Student had the option of using the assigned class textbook [10] or using one of several other textbooks available [5][12]. Students reported using the textbook 56% of the time mostly covering particular topics such as transportation, stipulating that the lectures and supporting format was sufficient.

Outcomes - Fall of 2010

At the time of the interviews students had not completed the semester. When asked about their self-assessment of their grades only 4 believed they would achieve a 'C' grade or better. However, all thought they should pass and 78% expressed a high confidence in tackling any OR problem. In their defense they cited the format itself, saying that they had demonstrated mastery of the concepts or they would have not been allowed to take the tests. From their perspective their failures on the tests were for the most part not conceptual, but rather insufficient time, arithmetic error, and missing some little 'tricky' point. At the of the semester start 21 students registered for the class, after the drop-date the size shrank to 17 students. Only 10 students passed the class resulting in a failure rate of 41%.

Outcomes - Spring of 2011

In the spring of 2011 the IEGR 361 course was taught for the first time. There were a few minor variations from the IEGR 440 class and one major change, the addition of a teaching assistant (TA) available to aid the students. The TA's availability was limited to approximately 10 hours a week and a number of the students were not able to access her services primarily due to scheduling conflicts.
Although, the number of students in the topic group was larger, there was basically no change in the rationale for selection. Also the percentage of students mentioning the acquiring of time management skills was also the same. There were no major changes in the student responses during end of the semester interviews with a few notable exceptions. Overall the students reported an increase in the amount of time studying with 93% spending more than 11 hours per week. In this larger group there were a smaller percentage of students who worked together, dropping from 89% to 64%. This is partially explained by an increase in the number of students who studied along, moving from zero percentage to 21%. However, they had access to the TA, thus reducing their need to participate in a group. In the self-assessment category, the number of students 'not passing but should' category increased from 56% to 71%. Although the number of students who suggested that the homework was good preparation for the topic test increased from 34% to 50% we still have a higher failure rate. At the start of the semester 31 students registered for the class, after the drop-date the size shrank to 25 students. Only 13 students passed the class resulting in a failure rate of 48%.

Outcomes - Fall 2011 IEGR 461

The student assessment for the fall of 2011 used an extensive survey at the end of the semester. Students were contacted electronically and asked to volunteer their participation via either an e-mail submission or printed paper returned to the researcher anonymously; with 5 out of the 10 students who completed the course responding.

The students attending the IEGR461 were already familiar with the structure of the class and its time requirements. They continued to report: a high self-confidence in their knowledge of the material; strengthening of their time management skills; and beneficial participation in a group learning environment. They unanimously agreed that enough help was available from the instructor, classmates, and the supplemental materials.

Although the students responding to the survey self-assessed their grades as either 'A' or B', a goal of the survey was to parse out problems areas related to the failure or reduce performance on the topic tests. When asked, 'what reasons negatively impacted achieving higher test grades? The response, by 80%, was time limitation during the test. Of errors committed by the student during the test, 60% reported initially using the wrong procedure. Only 40% reported that they thought the test was harder than the practice/homework. At the start of the semester 15 students registered for the class, after the drop-date the size shrank to 11 students. Only 2 students failed

the class resulting in a reduction of the failure rate to 22%. The drop in the failure rate was attributed to the fact that the students in this class had successfully complete IEGR361 and two who did not were the ones who had not taken the IEGR361 but rather they registered for the IEGR440.

Conclusion - Benefits of the rigor of the process

- Improved study habits and time management - the course delivery method forces students to follow a restricted study habit and time management for the duration of a semester, most of it retained as a good habit.
- Enhanced the overall awareness of importance of "doing the calculations correctly" as engineers.
- Adapting to community of learning concept and getting used to being accountable for knowledge contribution in that community.
- Enhanced research and critical thinking capabilities.
- Strengthening the foundation of analytical capabilities and developing the systematic approach to the problem solving.
- Positive self-assessed perception of learning.

P**roblem of increased failure rate**

Possible causes for the failure rate primarily associated with IEGR361:

- Lack of Clarity: Initially students insufficiently focused on the requirements of the structure of this class. This problem, making sure students understood the necessities of the class, was confronted by having the students write down in their notes the class syllabus culminating in their sending an e-mail request to be included in the mandatory class YahooGroup roster.
- Time Management: Lack of time management is a major contributor to a student's lack of success in so many areas within the design structure of this class.
- Failing Presentation: Failing to pass the practice presentation prevents a student from progressing to the next step. If the conceptual foundation has not been acquired the student is asked to review the topic. If time permits, they request another presentation opportunity.
- Failing Homework: Failing to pass the homework also prevents a student from progressing to the next step.
- No Opportunity to Improve: Strict adherence to a topic test only criteria. In order to reduce the impact of a pass/fail grading system, without compromising the rigor or objectives of the test design, additional options have been introduced. They include counting as a topic test: a semester-end accumulative class portfolio (graded); a poster topic board; and a test retake if the failure was due to late homework submission.
- Arithmetic Errors: Students have demonstrated knowledge of the topic concept and procedures by the time they are allowed to take the test. One overt cause of error on the tests is basic arithmetic. Students are not allowed to use programmable calculators; only simple basic ones are permitted. Many students use mental calculations and or pen and paper, stumbling in their use of factions.

- Test Anxiety: Part of the test design is for critical thinking. A thorough reading of a problem may give an insight into the solution approach which if overlooked results in time consuming unnecessary steps.
- Over Thinking: Students, both consciously or unconsciously, anticipate the critical thinking aspect of the testing process; and exhibit stress reaction that negatively influence their decision making.
- Test Indecision: Although familiar with the concepts, students faced with a choice of multiple procedures may choose incorrectly due to a lack of practice or lack of recognition of the indicators which determine one procedural method versus another or the sequence of the procedural application.
- Missed the Easy Ones: The initial topic tests early in the scaffolding process at the beginning of the semester are somewhat easier than later more involved topics. However, at the introduction to the class structure students have not developed strong time management skills and many fail these earlier easier topic tests making it more difficult to accumulate the required number of passed tests.
- Not Exploring Resources: The area of supplemental materials with fully illustrated examples and software tutorials must be sufficient to aid students.
- Not Dropping a Class: Students whose poor mid-term grades indicate that they should drop classes do not drop. Students who depended on financial aid thought that dropping a class would jeopardize their financial aid standing. This misconception was so prevalent that the financial aid office had to issue a clarification to prevent student from harming their GPA's by staying in classes they cannot pass for fear of losing their financial aid.

Workload

A major drawback of this method is the workload both on students and on the instructor. Based on the surveys collected from students, they report and average of at least 2.5 times more time devoted to the course. The workload for the instructor is even higher. Depending on the number of students in the class, using instructor's tally sheet, the course is equivalent to a full semester teaching load for a faculty for an average class size of 15-20 students. They include the usual preparation time for class lecture and office hours, plus time devoted to individual student practice problem presentations, design time for individual homework problems, homework grading, topic test design grading and management of whole system.

Although, the additional student workload has strong relation to the improved student performance and better time management skill of the student, the faculty workload is unsustainable and must be addressed. Obviously, one way that reduces the workload is using teaching assistants for grading homework and tests. But, training temporary assistants to look for the details that indicate students' learning often requires a considerable time. Building and encouraging student learning communities and collaboration with other universities will also reduce the workload. But at the end, it is the university administrators that need to make a decision of whether this approach can be justified and if so reward it with release time and or other incentives.

Adaptability

Can this concept be extended to other classes? In light of the above points, a natural question of whether this method can be extended to other courses can be easily answered. If a course can be broken down (segmented) so that each new topic relies on previous topic (s), and topics are short enough that can be delivered and assessed in a week or two the answer is affirmative.

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