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Project MINDSET

INNOVATIVE EDUCATION

Can You Imagine ... 500,000 Prep Proponents of O.R.?

Project MINDSET aims to develop, implement two-semester math course for high school seniors based on operations research and industrial engineering concepts.

By Kenneth Chelst, Thomas Edwards, Robert Young, Karen Keene and David Royster

Can you imagine 100,000 high school students in the year 2020 taking a mathematics course developed around operations research and industrial engineering contexts? How about 500,000 students?

In September 2008, more than four million students from the class of 2020 will enter first grade. More than three million of these students will graduate from high school in 2020, and more than two million of them will head immediately to college. Can you envision one in four of these college-bound students being engaged and excited by a high school mathematics course that is fully applications-based and problem-driven?

Can you imagine high school women excited about using the principles of queueing theory to petition their state legislature to adopt the public building codes of New Zealand [1] that were designed to reduce waiting times for bathroom facilities at concerts and theater events? If yes, can you imagine those same students knowing Little's Law, $L = \lambda W$, as well as they know the Pythagorean Theorem?

Can you imagine an INFORMS-sponsored competition funded by XYZ Corporation that dwarfs the Intel Science Talent Search, the premiere pre-college science competition? Can you imagine an Edelman-style competition in 25 states followed by regionals and nationals?

Can you imagine high school students challenging their local police chief on the merits of the Poisson process and its impact on staffing 911 and police patrol units? What about asking the members of the city council if they explicitly considered and quantified multiple objectives when deciding where to locate a new stadium or library? Can you imagine kids discussing with their parents the principles of Six Sigma and how it affects their respective work environment?

Can you imagine incoming college freshmen who assume multi-step problem solving is the norm and not the exception? Can you imagine

infamous "word" problems are no problem at all? Can you imagine students understanding that sensitivity is something to analyze and not just a personal characteristic?

Lastly, can you imagine yourself being a leader in your local school district, county or state in introducing, implementing and supporting a high school mathematics course built around O.R. and IE concepts?

Project MINDSET with your help and leadership can make all of the above a reality.

Project MINDSET (Mathematics Instruction using Decision Science and Engineering Tools) is a $3 million NSF-funded project designed to develop, implement and evaluate a two-semester course for high school seniors based on the mathematics of operations research and industrial engineering. The three partner universities involved in the project include North Carolina State University (Robert Young and Karen Keene), Wayne State University (Kenneth Chelst and Thomas Edwards) and University of North Carolina- Charlotte (David Royster). It will be implemented in high schools in North Carolina and Michigan within the next four years. The first semester textbook, which focuses on deterministic modeling, is already in draft form and ready to be tested. The second semester, which focuses on probabilistic modeling, will be ready for testing in fall 2009. More than 30 high school mathematics teachers from North Carolina and Michigan will take a two-week course in August to prepare them to use the material.

In thinking about this course it is important to emphasize that the goal is to develop and enhance mathematics skills by using OR/IE concepts and examples. This point must be kept foremost in mind, especially when speaking to local school district leaders. Despite this disclaimer, widespread adoption of this course will dramatically increase the public's awareness and knowledge of O.R. and IE. How far and fast this course spreads to high schools in other states is up to you, the members of the O.R. community.

Trend, Opportunity and Need

Two forces drive efforts to raise mathematics proficiency at the high school level: 1) minimum state standards for a high school diploma and 2) state university admission standards or expectations to be competitive. There is a growing trend both at the state level and university admissions level to require, or at least expect, four years of high school mathematics. The state of Michigan, for example, along with more than a dozen other states, is slowly phasing in a four-year math requirement for all students that will dramatically increase the need for a fourth-year course that appeals to a broad segment of the population.

The university expectation reflects the concern that a large number of students need a remedial mathematics course before placing into a college algebra course, typically the first college credited mathematics course. North Carolina already requires a fourth year of mathematics

with an Algebra II prerequisite for admission into any University of North Carolina system school. Other states' university systems provide incentives and strong guidance for students to take a fourth-year advanced mathematics course.

Broad flexibility exists at the school district and state levels as to the specifics of the fourth-year course, but one of the critical concerns is the relevance and appeal of this course to students who in the past have not opted for a fourth-year of mathematics. Driving our effort to achieve relevance is more than simply an answer to when "in the distant future" the student might need these skills. Rather, we will develop interesting and innovative contextual placement for mathematical concepts that high school students can relate to now, such as waiting in line, scheduling part-time jobs, forming project teams, developing a portfolio of college applications, buying a used car or selecting the size of the deductible on collision insurance.

As we develop a mathematical-based, decision-making high school course that builds upon the mathematics and models of industrial engineering and operations research, the primary objectives are:

1. Develop a new, one-year high school curriculum and textbook in mathematics using mathematical-based decision-making tools to teach standard content.
2. Through a multi-state, multi-school district assessment, show statistically significant improvement in students' mathematical ability, particularly in multi-step problem solving and interpretation of results, in motivation and attitude toward mathematics.

Tools for instruction of K-12 teachers:

3. Develop an infrastructure to effectively train and support teachers who will teach the curriculum.
4. Demonstrate that this infrastructure is sustainable and sufficiently flexible that it can be successfully reproduced and utilized by others.

The course will address the well-documented national deficiency in mathematics education that leaves U.S. students performing relatively poorly on multi-step problems and in interpreting results. For example, on the 1996 and 2000 National Assessment of Educational Progress (NAEP), only 24 percent of American 12th-grade students were able to correctly solve a multi-step problem involving multiple operations [2]. On the 2003 Programme for International Student Assessment (PISA), U.S. student performance was ranked 29th out of 45 developed countries [3].

Multi-step problem solving and interpretation of results are the heart and soul of operations research techniques, and the development of these key skills will be built into our operations research real-world problem

contexts. There is the notable example from the third NAEP mathematics test [4]:

> *An army bus holds 36 soldiers. If 1,128 soldiers are being bussed to their training site, how many buses are needed?*

Twenty-three percent of the students who worked this problem gave the correct response, while 29 percent responded "31 remainder 12." Clearly, interpretation of results was a problem for this item. We would expect that students completing an entire module on integer programming within Project MINDSET would be more likely to answer the army bus problem correctly. This hypothesis will be tested in our formal evaluation. Moreover, we will assess the course impact on students' motivation to study and achieve in mathematics. Student motivation, attitudes, interest and level of engagement are critical constructs related to learning [5,6].

Key to Success

The key to success of the project will be the teachers who implement the curriculum. At every stage of the project the view and needs of the teacher will be integral to the process. Project team members Tom Edwards and Karen Keane are professors of math education who each have more than 20 years of high school mathematics teaching experience. They will lead the effort of translating the O.R.- and IE-framed problems into text material for the classroom. They are supported by a group of high school math teacher-writers who work to finalize the text to be given to students and are part of the classroom user group. The text material will be presented to the teachers over a two-week period in the summer. In addition to working with the text, we will explore different pedagogical strategies for teaching multi-step problem solving in general and O.R. analysis in particular. After completing this course, teachers will be provided continuous support as they bring modules into their classrooms.

To support teachers in the classroom, we will develop a Web-based teacher support community of graduate and advanced undergraduate students in engineering and in math education who will be available daily, evenings and weekends, either online or by telephone. A practicing teacher will thus have immediate access to help and assistance. These classrooms will receive on-site assistance through a Traveling Help Team. The Traveling Help Team is a "rapid response" group with education and technical expertise that will go to classrooms to work with teachers and students.

Web-based teacher support will be a Web-site resource for teachers where they will go to get course material, lecture slides, quizzes, etc. and to find answers to frequently asked questions (FAQ). We will establish a teacher helpline similar to a helpline available for computer technical support. Teachers will either telephone or e-mail questions or requests for assistance. These will be logged into NCSU's information technology's REMEDY system to track questions and responses

archiving them into a searchable FAQ system.

State and Local Challenge

Because each state's mathematics curriculum has its own guidelines, implementation of Project MINDSET must be tailored to the state environment. In a state such as North Carolina, there is not only a requirement for a fourth-year math course to graduate, but there are also specific guidelines as to what is an acceptable fourth-year course. In contrast, Michigan, which has also adopted a fourth-year requirement, provides little or no guidance to local school districts as to what the fourth-year math-related course should contain. As a result, the project team will need to develop a strategy to sell each individual Michigan school district on the value of this new course.

Reach other states will require partnering with industrial engineering, operations research and math education departments that have good contacts in their locale. We are eager to lend support and guidance to any state or local initiative, but the key will be local O.R./IE leadership and excitement in adapting Project MINDSET to local needs and opportunities. We have already begun to develop partners in Georgia,

Missouri and Kansas. These states when combined with Michigan and North Carolina account for 12 percent of the U.S. population.

Where to begin? To get started, the typical professor of operations research or industrial engineering will need to find and engage a partner who understands the mathematics education environment of the state or locale. An established professor of mathematics education is an ideal first choice. That individual would understand state requirements and have local contacts through the many high school math teachers who have been his students. This individual would also be charged with the responsibility of adapting our course to become a regular part of the math education curriculum of his school of education. Each education course taught can reach 20 or more high school teachers who can teach two sections, or 50 students per year. Do the math. Five schools of education in your state teach 100 new teachers a year, who in turn teach 5,000 more students. In just five years, your project team could see as many as 25,000 students in your state enrolled in an O.R./IE-based mathematics course each year. In addition, the excited and engaged teacher can bring the concepts into some of their lower level courses as well.

When reaching out, the primary selling point for Project MINDSET is the unquestioned need for relevance in the mathematics curriculum. This need applies to both college bound and non-college bound students. In meetings emphasize real-world contexts and not O.R. techniques. Bring along a wide range of examples from *Interfaces* to demonstrate that these are not just techniques that might be used but are, in fact, routinely used by companies and governmental agencies across a broad spectrum.

In pursuing this initiative, it is important for the state project team to

understand and accept the responsibility for providing ongoing support for high school teachers using this material. We do not anticipate that high school mathematics teachers responsible for senior-year math courses will have difficulty with the mathematics content of our course. However, the whole approach to solving complex problems will be a fundamentally new experience for the vast majority of teachers. The in-class dynamics will be different from what they are used to as students work in teams on many of the activities.

It is the ongoing support that will likely require the most resources. We can provide the IT Web site structure for providing answers to FAQs and a framework for receiving new questions. In the end there will likely be a need for trained O.R./IE staff to answer specific questions, visit classrooms and provide ongoing training and feedback as the course is implemented. The entrepreneurial O.R./IE professor may view this as an ideal opportunity to provide funding for doctoral students to support implementation. Imagine obtaining funding for one doctoral student for every five to 10 high schools supported.

Are you interested? Are things changing in your state's math curriculum that make this an ideal time to introduce O.R. into your high schools? Lastly, do you have the entrepreneurial spirit and leadership ability to make it happen in your locale and ultimately throughout your state?

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