When will I ever use this stuff?

Operations research transforms the high school math "MINDSET."

By Kenneth Chelst (photo), Thomas Edwards, Robert Young, Karen Keene, Karen Norwood and David Pugalee

Does every new math concept taught in high school bring with it the ever-dreaded question, "When will I ever use this stuff?" In truth how many math teachers have used concepts in algebra 1 and 2 to tackle real-world problems? The textbooks they teach from rarely offer anything of relevance to the intended careers of the vast majority of students. Often the most they can offer is that students need to master algebra to prepare for more advanced courses in mathematics and the sciences they might see in college.

Even the common two decision linear programming examples seem no more relevant than finding the length of fence needed to close in a field or the time it will take for two trains to collide or overtake one another. How many times can you calculate the impact of interest rates on total loan payments and still see broad mathematical relevance?

Equally disturbing was an observation by a perceptive high school student who was turned off by mathematics instruction. He wondered why mathematics was the only high school class in which the teacher was not interested in what students had to say.

The Project MINDSET (Mathematics INstruction using Decision Science and Engineering Tools) curriculum is designed to answer the dreaded question even before it can be voiced. In contrast to the high school instruction we all experienced, Project MINDSET starts with a realistic context. It then moves on to the mathematics needed to formulate and explore the problem. Although the mathematics of Project MINDSET is within the technical grasp of senior-level math teachers, it will be challenging to teach. The approach is foreign to the way the vast majority of high school teachers have experienced and viewed mathematics: as a tool to find the single correct answer to a problem. They will be required to think and act differently in the classroom. It is this change in perspective, a new mathematics MINDSET, which we explore after reviewing the project's status.

Project MINDSET

PROJECT MINDSET 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 are North Carolina State University (Robert Young, Karen Keene and Karen Norwood), Wayne State University (Kenneth Chelst and Thomas Edwards) and University of North Carolina- Charlotte (David Pugalee). The course is designed to address the following well-documented performance gaps and motivational issues in high school mathematics in the United States:

- improve multi-step problem solving,
- improve ability to results in context, and
- increase motivation and positive attitude toward mathematics.

Project status – end of year 3. In August 2010, we successfully completed the third year of the five-year project. We are on target in terms of project timeline, deliverables and finances. We have developed drafts of two semester-long texts, one in deterministic decision-making and the other for probabilistic decision-making. (See www.mindsetproject.org for information about course content.) Each text has 10 chapters that have been individually piloted in high schools in North Carolina and Michigan.

We have developed a support mechanism to assist teachers as they prepare and teach the course. This includes a Web site for submitting questions, discussion boards and a hotline to be staffed four evenings a week. The goal is to respond to most questions within 24 hours. Under the guidance Dr. Shlomo Sawilowsky, the external evaluator, we have developed instruments to determine if the course is achieving the three stated objectives. This summer, in preparation for rollout, 60 teachers in North Carolina and Michigan participated in week-long workshops developed around the textbooks. These groups are in addition to the dozens who have participated in workshops in the previous years.

Year 4 – full-semester implementation with 500 or more students. This is a critical year for piloting the entire curriculum in both semester and year-long format. We have commitments from teachers in more than a dozen high schools in North Carolina and Michigan to teach at least one semester of course material in their respective schools. In total, we expect more than 500 students to participate in this piloting. These schools cover the spectrum of high school environments from poor performing schools with low graduation rates to the highest performing schools with 90 percent admission to college. This piloting will provide critical insights into the effectiveness of the overall curriculum for diverse student populations.

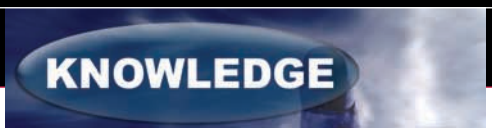
What next? It only takes 1. It only takes one highly motivated individual to begin bringing Project MINDSET to a local school district, a state and sometimes an entire country. Paul Brice, a high school teacher in suburban San Diego, hosted last year's high school teacher workshop that has been a mainstay of the annual INFORMS conference for the last 20 years. He has submitted, with our assistance, the MINDSET curriculum to the University of California system for approval as an advanced high school math course to be recognized as such by all colleges and universities in the University of California system. One of his peers is scheduled to pilot the course in his school district this year.

Dave Goldsman of Georgia Tech has been an active participant for more than a decade in our high school outreach efforts. When the state of Georgia was seeking new courses for fourth-year math, Dave led the effort to bring Project MINDSET to the attention of the appropriate decision-makers. As a result, the MINDSET curriculum is the first course proceeding through the state's review process for implementation as part of this new fourth-year math initiative. Once the course is formally approved, we expect to train a cadre of more than 30 master teachers. They will then have the responsibility of training math teachers throughout the state's one thousand high schools. The optimist amongst us can imagine almost every high school in Georgia offering a MINDSET course in the 2013/14 school year.

Andres Weintraub of Chile saw our earlier book that is designed to use O.R. models as stand-alone activities to motivate specific concepts in high school mathematics. He put together a team to translate into Spanish the book, "Does This Line Ever Move? Everyday Applications of Operations Research" (Chelst and Edwards, 2005). In late October, we will deliver in Santiago, Chile, a multi-day workshop for a group of pioneering high school math teachers.

Are you interested? Are things changing in your state's math curriculum that makes this an ideal time to introduce O.R. into

Project MINDSET ... is a course for high school seniors based on the mathematics of O.R. and industrial engineering.



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? We are ready to talk, plan and strategize alternatives for reaching out. Even better, if you can attract a cadre of 10 or more math teachers, we will come to your locale and offer a one-day workshop. It is up to you, individual members of the INFORMS community, as to how soon O.R. becomes part of the mathematics MINDSET of your local area high schools. To begin the journey contact Kenneth Chelst (kchelst@wayne.edu) or Robert Young (young@ncsu.edu).

New MINDSET for School Mathematics

TABLE 1 DISPLAYS THE WAYS Project MINDSET differs from traditional approaches to teaching mathematics in schools. In a traditional approach, class begins with a review of the previous night's homework assignment. Next a new mathematical procedure is introduced and explained in detail. Typically, several examples are worked out at the board, usually by the teacher. Finally, students are given several similar examples to practice in class as the teacher monitors their work. Sometimes in lieu of these practice examples, students are invited to begin the homework assignment for that night.

Only after sufficient proficiency with the mathematical procedures is developed is there any consideration of practical application. When applications do appear, they tend to be examples that are artificially created for the purpose of further practice with the set of procedures that have just been learned. If developing of computational proficiency takes longer than expected, the application problems are either skimmed over or skipped entirely. (See Devlin, 2010, for a more thorough discussion of the shortfalls of a traditional approach to teaching mathematics.)

Most often, the word problems contain just enough information to solve them. Not surprisingly, most students show no real interest in them, probably because problem-solving has been reduced to finding the one and only correct answer and moving on. Notice that in this approach, students take a more or less passive role in their learning, and there is little room for student discussion of key ideas. Small wonder, then, that so many students come away from their study of mathematics with a strange (to us) view of the goal of mathematical problem-solving as "solving artificial word problems rather than realistic world problems" (Mathematical Sciences Education Board, 1990, p. 4).

In contrast, the new MINDSET we are proposing is applications-based and problem-driven. Instruction on any given day begins with a real-world application with which most, if not all, of the students can identify. The mathematics is then developed within the context of the problem situation. There are ample opportunities for student discussion as the class struggles to understand the problem and develop a path to a solution. Once the problem is solved, student discussion continues, but now it is centered on interpreting the solution. Such discussions will also include some sensitivity analysis. How robust is the solution in the face of a change in one of the parameters of the problem? Is this the only solution for this problem?

We believe that school mathematics instruction that embraces our new MINDSET will evoke fundamental differences in the ways in which high school students view mathematics. Table 2 contrasts the views of mathematics held by most students taught using a traditional approach with those of students taught from the perspective of this new MINDSET.

When mathematics is taught using a traditional approach, students tend to view mathematics as a set of procedures to be applied to find the one "right" answer. Mathematics is all about manipulating algebraic symbols, and complexity arises from more difficult expressions or equations. Correctness in math-

Traditional	A New MINDSET
1. Mathematical procedure taught first.	1. Real-world application starts a discussion.
2. Next, mathematical procedure practiced.	2. The problem context is read and discussed. • Where do the numbers come from? • What do they mean? • What is the objective? • What are the constraints?
3. Possible applications added later, often only if time allows.	3. Students and teacher organize a mathematical representation of the problem.
4. Artificial word problems are used to make the situation appear "real."	4. Smaller problems are solved by hand; larger problems are solved with appropriate use of technology.
5. The word problem contains exactly the information needed – nothing more and nothing less.	5. The results of the problem solution are interpreted and explored.
6. Most students show no real interest in the problem.	
7. Problem-solving is reduced to a matter of finding the answer and moving on.	

Table 1: Contrasting approaches to school mathematics.

Traditional	A New MINDSET
1. Mathematics is a set of procedures used to find the "one" right answer.	1. Mathematics is a tool for problem solving.
2. Mathematics is about manipulating algebraic expressions.	2. Mathematics is about: • Formulating the problem. • Exploring a range of possible answers. • Identifying and evaluating better and best answers. • Exploring the robustness of an answer.
3. Complexity in mathematics means the expressions are more difficult to manipulate.	3. Complexity in mathematics is a result of the complexity of the real world.
4. Mathematical correctness is situated in an authority figure.	4. Mathematical correctness is based on logic and deduction.

Table 2: Contrasting student views of the nature of mathematics.

Traditional	A New MINDSET
1. Teach students new procedures, set-by-step.	1. Introduce real-world problem contexts.
2. Repeat with several (possibly) different examples.	2. Encourage students to read and discuss issues surrounding the problem.
3. Oversee student practice.	3. Ask lots of questions about the problem; e.g., • What decisions must be made? • What aspects of the problem affect those decisions?
4. Assess student practice.	4. Develop (with students) a mathematical model to help make the decisions.
5. Identify common errors.	5. Demonstrate a mathematical procedure that students then apply to the problem.
6. Help weakest students.	6. Oversee cooperative groups (teams) of students working problem solutions.
7. Use cooperative groups (teams) to help weakest students.	7. Next steps: • Lead discussions of answers including robustness, effects of changing parameters and other factors that might affect answers. • Identify and discuss errors.
8. Introduce more difficult problems involving more complex algebraic manipulations.	
9. (Possibly) embed algebraic manipulations in artificially constructed word problems.	
10. Next steps: • Practice more of the same. • Move on to the next mathematical procedure.	

Table 3: Contrasting teacher roles.

ematics is then situated in some authority such as the teacher or the textbook.

Evaluation of anecdotal evidence that we have gathered from field-tests of one or more MINDSET book chapters suggests that students who are taught using the MINDSET approach are more apt to view mathematics as a tool for solving problems. They tend to think that mathematics is about formulating problems, exploring a range of possible solutions, identifying better and best solutions, and exploring the robustness of a solution. From this perspective, complexity in mathematics derives from the complexity we are surrounded by in the real world. Finally, they tend to see mathematical correctness as based on logic and deduction.

Not surprisingly, the role of a teacher equipped with this new MINDSET is fundamentally different from that of most teachers using a traditional approach. Table 3 contrasts some of the ways these two roles differ. From a traditional point of view, the role of the teacher is to explain and demonstrate, oversee and assess student practice and identify common errors while helping the weakest students. However, from a new MINDSET point of view, the teacher's role truly is to be more of a "guide on the side" than a "sage on a stage." The teacher's role then shifts to things like encouraging students to read (and make sense of) the text, leading discussions centered on problem solving, developing mathematical models of problem situations with the full participation of students, demonstrating mathematical procedures when they arise in the context of solving a problem and overseeing teams of students working together to solve problems, rather than overseeing students' individual practice.

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Fostering such fundamental changes in high school mathematics instruction will not be an easy task. It will demand the continued hard work of the MINDSET Project staff in developing appropriate classroom materials and providing support for implementation. It will require cadres of dedicated teacher-pioneers who are willing to adopt and introduce a new MINDSET that is outside their comfort zone. Lastly, for the MINDSET to spread, we will need the support of professional organizations such as INFORMS whose members know full well the usefulness and importance of mathematics in the solution of interesting problems. It is only through the efforts of all three groups that the MINDSET Project can impact high school classrooms in the United States in ways that will produce high school graduates with a similar appreciation of the role of mathematics in the real world. IORMS

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