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# A Math Major, Polya, Invention, and Discovery

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**Synopsis**

An assistant professor of mathematics presents a nonmathematical application of George Polya's problem-solving strategies. In doing so, she suggests that Polya's ideas concerning invention and discovery apply to the world beyond the math classroom.

Renowned mathematician George Polya's book, *How to Solve It*, has sold over a million copies, has been translated into seventeen languages and has continuously remained in print since its 1945 publication. In the preface to the first printing, Polya writes that though he "pays special attention to the requirements of students and teachers of mathematics, (the book) should interest anybody concerned with the ways and means of invention and discovery" [1]. Practically speaking, however, *How to Solve It* is as well known to mathematicians as it is virtually unknown to nonmathematicians. To borrow the words of my late mother, this fact is a crying shame.

Polya has much to offer when it comes to invention and discovery in math and beyond. For example, my math department colleagues and I were very likely influenced by Polya when we began to concern ourselves with inventing and discovering a new major in mathematics. Our school had recently transformed from a regional business college to a comprehensive university. Prior to the transformation, the Mathematics Department existed solely to provide basic math literacy courses for undergraduates pursuing other majors. For better or worse, the task of creating a new major in mathematics was a "problem" to be solved at our university. We needed to write and submit proposals for new courses and the major to the appropriate school and university curriculum committees. We also needed to dismantle barriers that posed roadblocks and design paths leading to the math major. Finally, we needed to refute skeptics who doubted the need or demand for a math major.

"First, you have to understand the problem," directs Polya in the first of his four problem-solving steps. Students in our corner of the universe were accustomed to undergraduate majors that directed them towards single, specific career tracks: business, justice studies, sports management, hospitality, accounting, fashion merchandising, elementary education and game design, to name just a few. A math major, in contrast, is broad; it leaves options open for careers in business, industry, government and education. Our first task in "understanding the problem" was realizing that we needed to foster a culture in which a broad undergraduate major like math would be seen as valuable.

In attempting to understand the problem, Polya suggests asking, "what is the unknown?" He also encourages problem solvers to "draw a figure" and to "separate the various parts of the condition." To address the unknown, we produced flyers – disseminated to all students enrolled in 200-level math classes – detailing the math major requirements and listing the numerous, viable career options for prospective math majors. In an effort to "draw a figure" we have arranged a panel discussion of successful professionals – including a business person, actuary, math researcher and math teacher – who majored in math as undergraduates. In separating the various parts of the condition, we realized that our energies should not only be directed at students; the administration also needed to be confident that "if we built it, they would come."

In Polya's second step of problem solving – finding the connection between the data and the unknown – the individual is prompted to ask: "have you seen it before?" and "could you imagine an accessible, related problem?" Yes, we had seen an undergraduate math major before; after all, we all had majored in math in college and taught undergraduate math in our graduate programs. But it was not clear that we should simply import wholesale the undergraduate majors of our training. An accessible, related problem was to think about how we might create a math major that directly spoke to our career-minded student body. In particular, calculus, statistics and linear algebra could be taught from an applied perspective – with applications from business, justice studies, sports management and game design – rather than the theoretical perspective of our backgrounds. In restating the problem from, "how can we create a math major" to "how can we create a math major for our unique student body?" we made progress towards finding a solution.

In Polya's third problem-solving step – carrying out the plan – he reminds problem solvers that, "to conceive of a plan and to carry it out are two different things." Towards this end, he suggests asking, "can you see clearly that each step is correct?" Indeed, there was a great divide between the total absence of math majors in our university's recent past and our vision of a robust group of math majors in what we hoped would be our university's future. Bridging this divide required several persistent steps rather than a single, hopeful leap. As such, we conceived of ways that tentative students might explore the possibility of a major in math without requiring a full commitment at the start. The first step involved petitioning the general education committee to change the math general education requirement. Prior to our request, all students were required to take a basic math literacy course in their first year regardless of their math backgrounds. As a result, even strong math students had a built-in delay to advancing their studies in math, including access to those timeless, math-major on-ramps: calculus and statistics. Worse yet, while strong math students were sitting idle fulfilling a basic math general education requirement, other departments were poised to entice them with advanced courses in their fields. Changing the math general education requirement so that students could enroll in a challenging math class upon arrival was not a task we had initially planned for when we set out to create a math major. However, it was a necessary step to setting up our math major for success.

To be sure, we have fielded a few curve balls. A fashion merchandising student became interested in the applied math minor – another path we created that could lead to a major in math – upon discovering that she had enjoyed her statistics class. "I don't want prospective employers to think that I am just another girl interested in fashion," she told one of us, "the applied math minor will distinguish me from other fashion merchandising graduates." Still, she was concerned about how she would fit all of the required courses into her already-packed schedule. Upon looking at her schedule, we realized that one of the required courses for fashion merchandising – merchandising math – was likely unnecessary if she proved herself to have the mathematical maturity to succeed with the applied math minor. A quick email of explanation to the fashion merchandising program coordinator addressed this concern. That is, the student would be exempt from merchandising math if she succeeded in taking even the first required class of the math minor: calculus.

Carrying out the plan of launching a major in math was full of surprises. In our math major proposal that was submitted to the school curriculum committee, the dean, the university curriculum committee and the vice president, we specified precise dates concerning when the new courses would be offered. After obtaining such an impressive collection of signatures, we assumed that these dates were etched in stone. But then one day, one of us received an email from a student who was a junior: "I'm looking to add either a math minor or math major and have come across a bit of a problem" the student wrote, "I am ready to take applied linear algebra but it is not being offered this Fall." We had scheduled our course roll-out dates based on a hypothetical freshman who was interested in the math major, not an upperclassman. Nevertheless, we hesitated to discourage this student from her developing interest in the math major or minor. A quick call to the dean and a little fast talking with the registrar enabled us to list linear algebra one year earlier than we had expected. We understood that the course might have been cancelled due to low enrollment. Imagine our surprise when, by the time registration was complete, eighteen students – all of whom had taken the specified prerequisites – had enrolled. As a result, we will offer our first 300-level math class for the math major this fall.

We still have a lot of problem solving to do when it comes to rolling out the math major. In particular, how wide will the range of abilities be among the eighteen linear algebra students this fall? How will these students – who are accustomed to seeking help from our math learning center – be supported outside of office hours when the tutors have not yet caught up to the advanced math classes we are offering? Also, are all of these students simply intending to minor rather than major in math? Finally, is the current level of enthusiasm for math we have been able to generate in our community sustainable?

In Polya's last problem-solving step – examining the solution obtained – problem solvers are encouraged to ask, "can you use the result, or the method, for some other problem?" The answer, in our case, is a resounding, "yes." That is, we now have a concrete example to offer the legions of general education math students who, upon encountering new math concepts, persist in asking, "when are we ever going to use this?" That is, it turns out that problem solving in math is highly applicable to life, especially when the problem solver is interested in the ways and means of invention and discovery and has George Polya acting as a muse.

## References

[1] Polya, George. (1945) *How to Solve It: A New Aspect of Mathematical Thinking*, Expanded Princeton Science Library Edition. Princeton University Press, NJ.