Interdisciplinary Culture - a Result not a Goal

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John Dewey in his classic book *How to Think* grapples with the challenge of defining the process of reasoning. Dewey states that *reasoning* is the recognition of relations of interdependence between considerations previously unorganized and disconnected. Developing the process of reasoning in students requires practice in the "recognition of relations of interdependence" through the analysis of problems. The literature on learning tells us that the best types of problems to engage students are those they deem most relevant, that is "real world" problems that people encounter. Such problems are rarely confined to the artificial boundaries of academic disciplines. For example, an apparently simple problem to arrive at a model for census data collection can simultaneously involve mathematics, social science, geography, and law. Thus, interdisciplinary activities are an ideal mechanism to develop students' reasoning processes.

As a mathematician I know that mathematics is the ideal base from which to develop interdisciplinary activities because, as a well-known mathematician (I believe it was Buzz Light-year's cousin) stated, mathematics is the art of reasoning, the science of measurement, and the language of science. This definition is a gentle reminder that mathematics is not tethered to a specific set of courses or subjects, but rather that mathematics is a process. This process seems pleasant; however, a classroom journey to a lifetime of learning and discovery is extremely arduous. If the role of mathematics education is not well defined, this journey will be even more difficult. Mathematics reform is about defining the role of mathematics in education. This definition must be focused more on the process of reasoning than on the foundation of knowledge and information.

Information vs. Wisdom

Thanks to technology and the development of the internet, information is ubiquitous. Giving students more information is equivalent to giving a drowning person a cup of water. In this information age, education is valuable if it provides an individual with the ability to think and reason effectively and efficiently, that is, the ability to sort and evaluate the plethora of available information. Therefore, to prepare today's students to function effectively in this information-rich environment, mathematics education must be rooted in developing reasoning ability.

Often the applications in core mathematics are aligned with topics and not necessarily with the goal to enhance the progression of reasoning skills. Applications should allow the student to associate their knowledge with their experiences in order to learn how to solve new and complex problems. Students must become comfortable moving back and forth between facts and ideas if they are to become truly educated rather than simply receivers of information. “Information is knowledge which is merely acquired and stored up; wisdom is knowledge operating in the direction of powers to the better living of life” (Dewey, 52). Ideal instruments for the

development of wisdom are those "real world" problems that span different disciplines and departments. Thus, the "Interdisciplinary Lively Applications Projects" (ILAPs) a project of INTERMATH are an effective way to begin de-compartmentalizing traditional mathematical topics and to traverse course boundaries.

Reasoning

This broad responsibility to develop reasoning skills makes it very difficult to reach a consensus on which specific practices should be part of a mathematics program. Exposure to the art of reasoning, however, through the process of induction and deduction must be a component of mathematics education, The mathematics instructor must create learning opportunities where students move from "puzzling" data to a suggested meaning (induction). But just as importantly, we must require the student to move from the suggested meaning back to the data (deduction). In essence, a complete thought is a recursive process that involves both induction and deduction. The process of mathematics education requires a continuum of double movements. The first movement often departs the environment typically associated with mathematics and enters other academic disciplines linked by problems and concepts.

The inductive process requires the student to gain meaning from interdisciplinary perspectives. Data is the material of reflection (thinking). If this meaning is substantiated, these facts become evidence for new ideas. This meaning supplies a schema to understand the data more carefully. The second movement returns the student back to traditional mathematics as the schema is validated by reexamining the data with established principles and procedures. Deduction allows the student to seek additional observation to develop more powerful analyses through specialization. This return trip to the traditional mathematical environment becomes the starting point for another excursion into other interdisciplinary activities. The double movement of induction - deduction; expanding - contracting; generalization - specialization; interdisciplinary- disciplinary; reflects the processes we want students to assimilate. A journey outside the discipline requires an interdisciplinary environment. Our experience shows that the interdisciplinary expedition is demanding for both the student and the teacher.

For example, in an introductory mathematics course we often introduce the topic of logic with *propositions* and *connectors* such as "or", "and", etc, using truth tables. Tautologies are quickly introduced and discovered. The stage is now set to reveal how logic can become the foundation for circuit designs that govern every electrical device imaginable. These excursions into an "interdisciplinary" activity, however, should never be aborted because of a lack of knowing the applications. Our educators should be encouraged and comfortable dialoguing with members from other departments. For this example, a visit to the electrical engineering department would generate material to encourage students to discern the engineering importance of forming equivalent statements that minimize the number of operators. Other classes may explore the application of logic and valid arguments in law. Using activities from other disciplines, discoveries and return trips are made to the fundament constructs of logic.

It is not that case that interdisciplinary activities always represent advancement while the creation of discipline-specific activities is degenerative. It is the coordinated movement between discipline-specific and interdisciplinary associations that promotes effective education. We must recognize that in academia, interdisciplinary activities and specialization must work in concert to complete

the learning cycle. Education is a process that must involve both interdisciplinary activities and discipline-specific knowledge.

Ultimately, we want to simultaneously unleash and coordinate the development of our students, faculty, and our society. Interestingly, unleashing and coordinating are contradictory actions as are the concepts of unification (interdisciplinary) and specialization. Our challenge is to find ways to create a learning environment where the dynamics of dismantling academic boundaries while focusing on specific subject matter advance education and research.

Should calculus be taught?

Historically, in mathematics we have immersed students in detail and loaded them with disconnected facts. Simultaneously, the classroom discussions are rapid and directed. In the classroom once a student makes a conjecture, if it is correct, the teacher accepts it; if it is false, it is rejected. The teacher, who assumes responsibility for the students' intellectual development, usually amplifies the idea. Reform mathematics, however, encourages the student to form generalizations of the facts and then requires the student to examine the implication of these generalizations. This student-centered approach can be effectively only if students can relate to the problem, and real world problems tend to be those with most relevance for students, and those problems cross disciplinary boundaries. Hence, the process of induction and deduction flourishes in an interdisciplinary environment - providing motivation, meaning, and perspective to the reasoning process.

The "standard" mathematics courses, such as Calculus, Linear Algebra, Probability, Statistics that are immersed in topics, do not align very well with the concept of reform mathematics. Ideally, a traditional course in calculus should never be taught. Traditional courses by their very nature emphasize topics over process. A core program should furnish the students opportunities at transforming a problem statement into a mathematical model, conjecturing solutions, selecting or developing the appropriate mathematics, examining the analysis, and continuing to transform the conjecture into a solution. A core program should be part of a curriculum that is crafted to promote the reasoning process rather than carefully visiting a set of topics.

Conclusion

There is no single program or person that will propel mathematics education to great success in the next millennium. The foundation for change in mathematics education, however, must be based upon the development of the processes of reasoning. The result of this change will inevitably be an interdisciplinary culture. Interdisciplinary activities are a result of mathematics reform, not a goal of reform.

We live in a time of profound change. Changing technologies require us to continuously assess the appropriate role of human capabilities in the process of problem solving. The next twenty years promise to be an eventful journey in education.

References:

1. John Dewey, *How We Think*, Prometheus Boos, Buffalo, New York 1991 (Originally published: D.C. Heath, Lexington, MA 1910)

2. David Hume, *An Inquiry Concerning Human Understanding,* edited with an introduction by Charles W. Hendel *Imprint* New York, The Liberal Arts Press, c1955 *Edition* 1957 reprint of 1955 ed.