

## HOW DO STUDENTS ADJUST TO FUNDAMENTAL CHANGES IN MATHEMATICS CURRICULA?

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The “Navigating Mathematical Transitions” project is a three-year effort to examine how high school and college students cope with deep changes in mathematics curriculum and teaching. It examines and analyzes students’ experiences as they move between “traditional” mathematics curricula and those inspired by the NCTM Standards (1989). This paper presents an overview of our conceptualization of mathematical transitions, our methods for studying them, and our initial analyses of Year 1 data, including our attempt to characterize classroom teaching, some important differences that students report, and a framework for analyzing those differences. Our conference presentation will present a deeper and more elaborate analysis.

### Project Objectives

Ten years after the publication of the Curriculum and Evaluation Standards (1989), the design of curricula based on these standards is complete; implementation is well underway; and evaluation and assessment studies are appearing (e. g., Schoen, Hirsch, & Ziebarth, 1998; Hoover, Zawojewski, & Ridgway, 1997). But very little attention has been paid to the experience of students who move between “traditional” and “reform” curricula and pedagogy that appear to differ dramatically in their conceptions of thinking, knowing, and doing mathematics.

This project was designed to study these mathematical transitions in one locale (the state of Michigan) where many students cross such boundaries. Two Standards-based curricula, the Connected Mathematics Project (CMP) middle school materials and the Core-Plus Project (CPMP) high school materials were written in Michigan and have been adopted widely throughout the state. Likewise, the University of Michigan teaches calculus and pre-calculus to freshmen with the Harvard Consortium materials that are quite consistent with many of the central principles in the NCTM Standards.

## Theoretical Notions

We take a broadly cognitive perspective in examining the impact of curricular shifts. We understand students to carry forward knowledge, beliefs, dispositions, attitudes, and goals from prior experiences, in and out of school. These elements of their mathematical experience are reshaped in the context of new demands and expectations. This shaping and reshaping process is influenced by various social factors, including work and relationships with peers and parents and the norms and activities in their mathematics classrooms.

We distinguish three different conceptual components in clarifying the phenomenon of mathematical transitions. General issues of transition refer to developmental processes that are hastened by the move into high school or college that are not directly mathematical in nature, e.g., coping with increased freedom. Mathematical discontinuities refer to the differences that students report between current and prior expectations for thinking and acting mathematically. These may involve issues of curriculum, teaching, or the structure of the coursework (see below for details). Mathematical transitions are students' active responses and adjustments to such discontinuities (especially at points of struggle) and how they evaluate those actions.

The premise that the content of curriculum matters is central to the project (though students' transitions and our analysis of them involves more than written curricula). Our analysis began with the claim that the three Standards-based curricula named above differ from more traditional curricula in 6 important ways. (1) The objects of study are functions and functional relationships in multiple representations (in contrast to equations and symbolic expressions). (2) Typical problems require the analysis of situations where quantities grow and change (in contrast to request to solve, factor, etc.). Likewise (3), typical solutions are more likely to involve tabular or graphical analysis and significantly more verbal explanation (in contrast to numerical and

symbolic manipulations). (4) The role of practice changes as problems become longer, involve many parts, and do not belong to recognizable types. (5) Technology for representing and calculating, i.e., graphing calculators, is an integral component. (6) Deviations from the typical lesson pattern of review homework, present new content, and provide time for problem solving are common.

### Methods

Our project is tracking 20 to 25 students at each of four sites (two high schools and two universities in Michigan) as they move from a Standards-based program to a traditional one (or the reverse). The site-specific curricular shifts are summarized below.

Site A (high school) Connected Mathematics (CMP) → Traditional high school program	Site B (high school) Traditional junior high program → Core-Plus Mathematics
Site C (MSU) Core-Plus Mathematics → Traditional pre-calculus & calculus	Site D (UM) Traditional high school programs → Harvard Consortium calculus

We recruit students when they “land” in their new mathematics program and follow them for 2.5 years of coursework. At all four sites, the Standards-based curricula listed above have been in place for more than 3 years. Our principal methods of data collection are classroom observation, individual interviews, students’ journal writing, and survey questionnaires. We collect data in six domains of students’ mathematical experience: (1) achievement (grades), (2) content learning (key concepts), (3) daily experience, (4) career and educational goals, (5) beliefs about mathematics and themselves as learners, and (6) strategies of adjustment.

### Results

At present, we are analyzing Year 1 data. Though our analyses are on-going and our results preliminary and incomplete, sufficient support exists for some interesting findings.

• The practices of teachers using “reform” curricula have been more traditional than we expected. At Sites B and D, the use of “reform” curricula (Core-Plus and Harvard Consortium materials respectively) has generally been coupled with quite traditional teaching practices. This has not, however, negated the impact of new curricula, as indicated by our students’ characterization of changes (see below). It is powerful evidence that our efforts to understand students’ experience must be informed by analyses of the enacted curriculum, not only the written curriculum.

Based on extensive classroom observations, we have found it useful to characterize the teaching our participants have experienced in relation to a theoretical “ideal type.” This Standard Model (given below) is not a representation of any particular teacher’s (or teachers’) typical daily practice. Rather it is a common base-line against which we describe and compare the practices of all teachers we observe.

Teacher Actions	Teacher Expectations of Students
Collect or check students' homework	Listen to teachers' presentations of problems and solutions
Solicit students' questions from homework and produce solutions on the board	Take notes on the content identified by teachers' as important
Present the new content and provide examples on the board	Answer "small" (i.e., "what's the next step") questions from the teacher
Provide time for students to practice solving similar problems	Solve assigned problems (in class or as homework; in groups or individually)
	Study the notes and remember them for tests and quizzes

From our observations we (1) evaluate how well each teacher’s practice regularly conforms to these elements, and (2) document the important elements of his/her teaching are not listed in the Model. These analyses provide a rough but principled way of characterizing the enacted

curriculum, as background for our main efforts to track, understand, and interpret students' experiences.

- Students' report differences between their prior and current experiences but value changes in quite different ways. Students at all four sites have experienced elements of Standards-based curricula, either currently (Sites B & D) or in the immediate past (Sites A & C). The differences they report are various, and we are currently analyzing and tabulating them. Some are independent of curricular shifts. For example, some students at all four sites cite a faster pace through the content and less intimate relationships with their teachers than they experienced previously. But many other reported differences are closely related to curricular elements. We present three common ones and illustrate how students take different stances toward them.

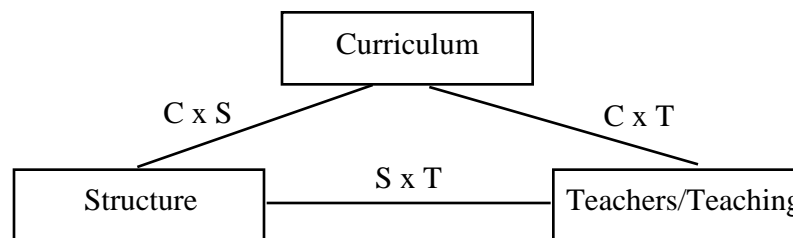
- **Typical Problems.** Many students have reported the greater frequency of "word" or "story" problems in the Standards-based curricula, in contrast to the prevalence of "book," "number," and "equation" problems in traditional curricula (students' descriptions of "non-story" problems vary widely). Those who value "story problems" cite greater personal meaning via the connections to their everyday world and their ability to make sense of such problems and their approaches to them. Those who prefer more traditional problems tend to complain that "story" problems are harder because they contain more elements to track and understand and because textbooks do not provide model solutions.

- **Explaining Your Thinking.** In different ways, students have said that more time, value, and attention is or was given to expressing their mathematical thinking in Standards-based programs, both orally (e.g., in whole class discussions) and in writing (e.g., in explaining their answers to problems). Students who value this orientation have cited the value of testing their ideas in discussion, developing their own methods of solution, and testing their understanding. Students

who have critiqued this orientation felt that they wanted or needed the teacher’s solution methods and that extensive written explanations often felt like “busy work.”

- **Group Work.** When it is a new and emphasized by teachers, solving problems in small groups is reported as a difference. This has been especially true at Site D, where the Harvard calculus courses include mandatory group work outside of class. But three other findings significantly complicate the role of group work in transitions. First, small group problem solving has not been limited to Standards-based programs. Second, “small groups” can mean pairs or groups of 3 or 4 students, and different arrangements affect what happens in small groups and students’ experience in them. Third, students have often found ways to ignore or subvert small group processes and work more or less individually.

- Curriculum, teachers/teaching, and structure. The term, “enacted curriculum,” expresses the idea that curricula and teachers jointly create the content that students experience in classrooms. We have found it useful to add a third component, “Structure,” to this scheme.



Under “structure” we identify aspects of mathematics courses that are attributable to broader departmental decisions. Issues of “structure” have proven most important at the university sites where many, many sections of the same course are taught and shared practices are mandated across the sections. For example, at Site D it was the Department, not the teachers or the curriculum, that specified challenging group homework assignments. We have found it useful to locate the differences reported by students at the most appropriate position in this conceptual

scheme, either under one specific factor or on the links representing interactions between two factors. This analysis helps us to understand the origins of students' experience and make sense of our results across sites.

### Significance

Research that investigates students' experience of Standards-based curricula in relation to more "traditional" curricula will not provide unequivocal evidence for or against either position.

Different students, whether by nature or prior influence, will find different programs desirable for different reasons. Such research can, however, provide insights into and analyses of students' experience as input for local, state, and national discussions of broad goals for mathematics education and of programs of curriculum and teaching likely to meet those goals. Students' experience is one important factor, though not the only factor relevant to mathematics education policy.

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