DISCUSSANT DRAFT

Students' perceptions of difference between traditional and Standards-based mathematics curricula

Jon R. Star (jonstar@msu.edu)
Jack Smith (jsmith@msu.edu)
Amanda J. Hoffmann (jansenam@msu.edu)
Michigan State University

Students' approaches to learning mathematics in Standards-based curricula

Gary Lewis (lewisgar@msu.edu)
Jon R. Star (jonstar@msu.edu)
Michigan State University

Papers presented at the 2004 Research Presession of the annual meeting of the National Council of Teachers of Mathematics, Philadelphia

All authors can be contacted at 513 Erickson Hall, Michigan State University, East Lansing, Michigan 48824, 517-353-9285 (voice), 517-353-6393 (fax). This and other related papers are available at www.msu.edu/~jonstar/MTPIndex.html. The research reported here was supported by a grant from the National Science Foundation to Jack Smith (REC-9903264).

DISCUSSANT DRAFT

1. Introduction: Moving beyond achievement as a measure of impact

We recently reviewed the literature on the impact of mathematics curricula written in the spirit of the NCTM *Standards* (Smith & Star, under review). Our review indicated that most research has focused primarily on student achievement and marginally on student attitudes. This observation, that understanding how K–16 reform materials have influenced the affective aspects of students' learning has been a clear secondary goal, is sensible: Achievement trumps all other forms of impact, especially early, when a new program must document its positive effects. But equally important, attitudes are harder to conceptualize and measure. No consensus presently exists in the field about which attitudes and/or beliefs we should target; how to assess them (e.g., standard surveys or semi-structured interviews); what questions, prompts, or situations to use; on what metrics (quantitative or qualitative) to score responses; and what should count as educationally significant change. We lack consensual terminology and meanings for attitudes related to learning mathematics, despite some common terms like "self-efficacy" (McLeod, 1992). Also, statistical significance has been achieved in large sample studies, either between groups or within groups over time, but with very small mean differences. Statistical difference does not necessarily imply educational significance. In addition, the advantages of large samples trade off against the depth and clarity of the assessment of attitudes. Surveys are an efficient means for gathering attitude data on many students, but they can also fail to reveal or even obscure those attitudes and how they change. Interviews, by contrast, can unpack attitudes in greater clarity and depth but are very difficult to extend to large samples.

It is also the case that studies of achievement and attitude that cast students as producers of outcomes (grades, level of self-confidence) are often ill-designed to examine the dynamics of change. Students' mathematics achievement and attitudes are not, we know, separable parts of their experience of reform. But we have not yet begun to conceptualize how these dimensions of experience (and others) interact. If students' grades or assessment performance rise (or decline) after experience with a reform mathematics program, what other aspects of their learning vary with that change? Do students feel more (or less) engaged or motivated to learn in this program? What aspects are *not* correlated with achievement change? When they organize themselves to learn the content, in their classrooms and outside, do they follow familiar patterns of study, adapt those patterns to the demands of the new program, or develop entirely new ones? Similarly, what features of the new programs effect students' attitudes toward the subject, either positively or negatively? Does attitude change accompany shifts in how they try to learn mathematics in a new program? Addressing such questions would begin to open up the "black box" of students' experience and activity. Studies that take on that challenge would come much closer to examining the impact of curricular reform on the students themselves.

These observations guide our present work. We argue for broader perspectives on impact and, in particular, for a focus on how students (1) compare Standards-based and reform calculus curricula to more traditional materials and (2) adjust their learning activities when using these new curricula. This shift would complement the prior focus on learning outcomes (achievement and attitude) with a comparable focus on processes (evaluating different curricula and responding to new demands). Fundamentally, we call for more attention to how students make sense of reform mathematics materials in contrast to more traditional ones. Our goal is not to represent any particular approach to studying the impact of reform on students' mathematical experience as optimal. Rather it is to argue and, to some degree, illustrate that researchers, and the educators they inform, have much to learn from the full range of students' experiences in reform programs.

2. Introduction to the Mathematical Transitions Project

The Mathematical Transitions Project (MTP), based at Michigan State University, has closely followed about 100 high school and college students for 2.5 years as they moved from a traditional to a Standards-based mathematics or reform calculus program (or vice versa). Two key design decisions of this project were (a) to broaden the conception of impact to explore students' experience more effectively (as discussed above) and (b) situate the study at key junctures in students' experience.

With respect to (b), we felt that students' reactions to and judgments of reform would be fresh after a fundamental curricular shift. Initially guiding our work as a weakly conceived notion: A mathematical transition was a "bump in the road" caused by a mismatch between the student's expectations from past mathematical experience and his/her current experience in a "new" program. We gradually refined that notion into a much more clearly articulated conception of four interacting factors, two of which are discussed in the present papers. "Transition" became our conceptual vehicle for studying impact.

Given our intent to locate and analyze mathematical transitions, we needed sites where relatively abrupt shifts between reform and more traditionally structured programs took place. We sought these curricular shifts at two major junctures in students' experience (junior high to high school and high school to college). We chose not to examine the elementary to junior high juncture for logistical and pragmatic reasons: We lacked the means to "cover" all three junctures at the same time and focused instead on the high school and college years where the controversy about reform was the most intense.

At the two junctures in our design, we sought schools and colleges with a solid history of using reform materials. At the K–12 level, our search was aided by numerous (though still very spotty) implementations of two Standards-based curricula written in our region—the Connected Mathematics Project materials (CMP) (Lappan, Fey, Friel, Fitzgerald, & Phillips, 1995) for grades 6–8 and the Core-Plus Mathematics Project materials (CPMP) (Hirsch, Coxford, Fey, & Schoen, 1995) for grades 9–12—and by these projects; professional development for teachers in many of these districts. We located a nearby district where CMP graduates moved into a relatively traditional high school program and another where high school students used the CPMP materials after a relatively traditional junior high program. Two local universities provided complementary college sites. One used materials developed by the Harvard Calculus Consortium (HCC) for all sections of Pre-Calculus, Calculus I, and Calculus II (Connally, et al., 1998; Hughes-Hallett, et al., 1994); the other a more traditional set of texts for these courses (e.g., Thomas & Finney, 1996). At the HCC site we recruited graduates of traditional programs; at the traditional college site, we recruited from a smaller pool of CPMP graduates and also added graduates of a nearby high school that had developed its own mathematics program based on the *Standards*. Because we wanted to understand these students' mathematical experiences in some depth and over a relatively long period of time, we limited our research design to a single site per cell. These choices produced the following site design matrix (Table 1).

(Insert Table 1 here)

This curricular shift by educational level design facilitated the exploration of questions and issues as yet unexamined in the impact literature. First, we could now analyze the impact of reform on students leaving as well as entering those programs and contrast the resulting patterns. We could also identify factors that could be conflated with impact, but were relatively independent of the reforms. For example, it is reasonable to expect that mathematics becomes more difficult at each successive educational level. If most students at the same educational level (e.g., at both $HS1_{R\rightarrow T}$ and $HS2_{T\rightarrow R}$) report that mathematics is more difficult after the curricular shift, that would indicate that the difficulty of new content has an impact on students, but not one due to either curricular tradition.

We also sought firmer ground for claiming that these three curricula (CMP, CPMP, and HCC) shared important common features as "reform" programs, over and above their funding and development as such. Our analysis identified five features that distinguished them from more traditional materials (Star, Smith, & Herbel-Eisenmann, 2000). These involved changes in: (1) *fundamental mathematical objects* (from equations and symbolic expressions to functions); (2) *typical problems* (from symbolic manipulations and "word" problems to contextualized problems with multiple representations); (3) *typical solutions* (from numerical or symbolic answers only to written explanations of these results); (4) *the role of practice* (from frequent work with the same problem type to little structural similarity across problems), and (5) *the use of technology* (from limited use of graphing calculators to an integrated use throughout the course). Our distinctions differ from, though are not inconsistent with Trafton, Reys, & Wasman's (2001) analysis of *Standards*-based materials, in part because we have focused on only three reform curricula.

In designing our student sample, other conceptual and methodological decisions (e.g., breadth and depth of our assessment) limited the number of students we could effectively track. We settled on a target 25 students per site, thinking this was large enough to explore both diversity and substantial commonality in students' experience within and across sites. We recruited students in the first semester of their freshman years (9th grade or first year of college). We also systematically observed instructional practice at the two sites where reform curricula were currently being used ($HS2_{T\rightarrow R}$ and $U2_{T\rightarrow R}$, Table 1) to assess their implementation.

3. Conceptualizing impact

We conceptualized and measured impact in terms of four interacting factors. Though we have critiqued the relatively narrow focus in prior research on achievement and attitude, both are clearly important domains of students' experience. Achievement, in particular, is the most common yardstick of learning, for students themselves as for others. We measured *achievement* in terms of the change in students' course grades from one mathematics course to the next (absolute change) and also in relation to changes in their overall academic performance (relative change). We focused primarily on the first year of students' experience with their new program.

We also assessed students' attitudes toward and beliefs about learning mathematics, via interviews and surveys. Following McLeod (1992), we integrated attitudes and beliefs into a broader composite construct of *disposition* toward mathematics. This construct embraced five components: (1) students' attitudes (their likes and dislikes of aspects of school mathematics), (2) self-efficacy (their confidence in their ability to be successful), (3) emotion (strong affective responses to classroom events), (4) career interests (educational and occupational goals), and (5) preferences (desire for specific learning activities). For disposition (and the other two factors below), individual interviews were the richest but not the sole data source.

Since we know relatively little from past research about how students contrast the features of reform curricula with traditional materials, we also carefully assessed what our participants saw as different between their old and new mathematics programs. We attended to a wide spectrum of *differences*—not only to features of the written curricula. Frequency of report, use of magnitude terms, e.g., "that was really different," and descriptive detail distinguished differences that were important and consequential for individual students from those that were merely noticed.

Finally, we determined whether students had changed how they went about learning mathematics, both in school and on their own time, in their program. To conclude that their *learning approach* had changed, we required clear evidence that students had exercised some measure of autonomy in their learning actions and were not only responding to their teachers' demands.

For each of these four factors, we developed qualitative and/or quantitative methods of analysis that enabled reliable determinations of whether students experienced significant change as they moved between programs. For achievement and disposition, change either involved a rise or a fall. With the individual results for all students in hand, we then examined where and for whom change in any one factor co-occurred with change in another. Important questions here have included: (1) Which patterns of change (and no change) were common and which rarely, if ever occurred, and (2) did the type of curricular shift (reform to traditional or traditional to reform) or educational level (high school or college) exert a clear influence? Then, at a deeper level of interaction, we have searched for the aspects of students' experience that led to significant change in any factor. In particular, we were interested in those aspects that (1) could be linked to change on more than one factor and/or (2) were conceptually related, e.g., features of the written curricula or reform teaching practices. It is at this level that we can achieve the deeper and more insightful analysis of impact we have sought.

The present papers report our findings with respect to students' perceptions of difference and students' approach to learning mathematics. We begin by describing our overall method, and then we discuss how we assessed the two dimensions of impact of interest here.

4. Overall method

Participants. Our goal was to recruit a diverse group of 25 students at each site who could make time for this work. Our demands on students' time and attention were substantial, including interview time, regular journal work, and, for college students, assistance with observations of their work in mathematics. For this reason, we paid college students $250 per semester and high school students $250 per year if they completed all project tasks. We never revealed our specific interests in the effects of Standards-based or reform mathematics programs. Instead, we said that we were interested in how the students were making the transition from mathematics in their former school to mathematics in their new educational context.

At the high schools, which were both small, we first consulted with staff, choose 9th grade mathematics classes, and observed instruction before recruiting participants. Since both "tracked" their students in mathematics, we balanced our attention between "advanced" and "regular" track. At $HS1_{R\rightarrow T}$, advanced track students took Geometry as 9th graders (skipping Algebra I) where regular track students took Algebra I. At $HS2_{T\rightarrow R}$, advanced track students took Core 2 (after Core 1 in the 8th grade) where regular track students took Core 1. Based on our classroom observations, we also recruited for balance on gender, level of past success in mathematics, and social and personality characteristics, such as relatively extroverted vs. introverted interaction patterns. Recruitment involved classroom presentations from the project staff and follow-up meetings with small group of potentially interested students. The student body at both sites was predominately white and so were our resulting samples.

At the university sites, we advertised the project and contacted potentially interested students primarily by e-mail. At $U2_{T \to R}$, we sent messages to all sections of our target mathematics classes (Pre-Calculus, Calculus I, and Calculus II) and posted notices with various undergraduate advisors and programs. A project staff member then met with each student to review the required set of research activities. $U1_{R \to T}$ was the most challenging recruitment site because relatively few feeder high schools had implemented Standards-based programs and many of those who had maintained both Standards-based and traditional sequences in mathematics. We sought volunteers from high schools that had implemented Core-Plus and one additional high school whose teachers had developed an “in-house” Standards-based curriculum. We identified students from these high schools who took Pre-Calculus, Calculus I, or Calculus II as first semester freshmen and then met with potentially interested volunteers.

We recruited a total of 93 students across the four sites. Table 2 presents the number of participants at each site by mathematics track and gender.

(Insert Table 2 here)

As shown, participants divided roughly equally by gender at all sites and by mathematics track at the high school sites. The lower of number of advanced students at the university sites (those placing into Calculus II) reflects the smaller number of freshman enrolled in that course at both sites. The lower number of participants at $U1_{R \to T}$ primarily reflects the small available pool of graduates of Standards-based high school programs at $U1_{R \to T}$.

Data collection. The project’s overall data collection involved a wide range of activities and measures. However, the current papers rely exclusively on individual interviews and weekly journal writing. We also used our classroom observations as a check on how students were describing their current program. These observations indicated that, overall, students were accurately reporting what was happening in their current mathematics classrooms.

With respect to interviews, we conducted, on average, two or three interviews per semester with each participant, and the resulting transcripts provided the bulk of our data. Interviews were typically 20-30 minutes in duration at the high school sites and 30-60 minutes at the university sites. Our goals, focal activities, and specific questions were generally different in each interview. The goal of the first interview was for students to describe their prior mathematics program and their experience in it. Another type of interview in each semester involved solving a mathematics problem and explaining their solution method. At the university sites, the first interview of the second semester involved a review and evaluation of the math course just completed. At the high school sites, the final interview of the year asked students about their sense of difference (new to old) on such specific dimensions as the content, homework, types of problems, textbook, group work, calculator use, and teaching. Overall, we sometimes asked direct questions about what students saw as different (and usually received relevant responses), but we also received responses about differences even when we did not ask. Overall we conducted 482 interviews with 93 students, at an average more than 5 per student.

Students also wrote to us about their mathematical experiences, in and out of class, when we were not present. On average, they wrote journal entries once or twice a week, either via e-mail or in journal books we provided. The requested focus on these entries varied, from reporting on their experience doing homework, to studying for assessments, to working in groups outside of class (at $U2_{T \to R}$).

We also conducted systematic observations in the students’ classrooms. These observations served many purposes in the larger project including providing us a direct sense of the teaching and classroom processes in students' current ("new') program. Observations at the university sites were more sporadic than at the high school sites because many more classrooms were involved.

5. Assessing students' perceptions of differences

There were three main stages of analysis of what the students said and wrote: (1) coding scheme development, (2) coding all statements of differences, and (3) determining the most major differences and an overall judgment for each student. Our results concern which differences had the most impact (overall and at each site) as well as which students found their "new" mathematics program as "significantly different" from their old. Because one contribution of this work may become its coding scheme and scoring methods, we describe them in some detail.

Coding scheme development. When we began our work, we knew of no prior study that reported a systematic listing of student-reported differences between reform and traditional mathematics curricula. Our first task, therefore, was to develop such a scheme. Because a major project goal was to see reform through the eyes of students, we developed our scheme "bottom-up." We selected a representative subset of interview transcripts, read them as a group, identified dimensions of difference, and then progressively developed clear language to define these categories. Generally, we found four main sources of differences: (1) the curriculum, e.g., what sort of problems students were asked to solve; (2) teachers and teaching practice, e.g., how teachers' structured daily lessons; (3) the students' perspective or experience, e.g., how relevant they found the mathematics they were taught; and (4) the school or university's implementation of the curriculum at their site, e.g., department mandates for pace of instruction and assessment. We refined the definitions of each code until we could reliably code student statements as (a) stating a difference (or not) and (b) an instance of a particular difference code. This process yielded the 26 differences listed and defined in Appendix A. Though the four sources of differences given above were useful in development of the scheme, it became apparent that grouping each difference under one and only one source was impossible. For example, differences in instructional pace could be due either to individual teachers or site-wide decisions (or both). As an aid to readers, we have grouped the differences under the category that makes the most sense to us, with the understanding that some differences originate at the interactions between sources.

Statement coding. To ensure the objectivity of the scheme and the coding, we decided not to code the transcript data ourselves. Instead, we trained undergraduate education and psychology majors with the scheme and employed them to code all the transcripts. Two coders read each transcript, independently coded each student turn they felt included the statement of a difference, and them met and discussed their results. In the few cases were they disagreed after these resolution meetings, they consulted with a member of the research team for clarification. In all cases, this process produced a unified evaluation of each transcript (a list of turns and difference codes). (The journals contained relatively few difference statements and were coded by a member of the project team.)

Determining an overall judgment. Our research questions required steps beyond the coding of individual statements. We saw the mere one-time mention of a difference as far less important than reports of differences that expressed substantial impact. We sought to reliably and consistently distinguish between students who merely noticed differences and those for whom these differences significantly impacted their experiences in their new mathematics class. We refer to whether noticed differences significantly impacted a student as the "overall judgment," which has value of either yes or no. Developing a procedure for determining students who viewed the new curriculum as "significantly different" required a complex analytical framework, one that we developed over the course of many iterations. This framework, described below, has two steps. The first step required the identification of a subset of mentioned differences that were considered "Major" by each participant, and the second step involved looking at the proportion of all differences mentioned that were Major to arrive at an overall judgment.

We first looked at all differences mentioned by a participant in all interviews, and we determined which of these mentioned differences was "Major" for that student. To qualify as Major, a difference must have been reported with at least two of following three criteria: *Frequency*, *magnitude*, and *detail*. To qualify as *frequently* mentioned, a difference had to be mentioned in more than one-third of the students' interviews, with the exact proportion determined according to a sliding scale based on the number of interviews conducted. (If a student was interviewed 2 to 6 times, this required mention in at least 2 interviews; for 7 to 9 interviews, mention in at least 3; and for 10 interviews, mention in at least 4.) *Magnitude* required that the participant, in mentioning the difference, use emphasis words such as "a lot," "very," and "big" to modify the difference. *Detail* required substantial descriptive richness in the students' report of the difference, well above the level of a simple report, e.g., "The book was harder to read." We felt that the presence of at least two of these three criteria strongly suggested that Major differences "made a difference" in students' experience.

As with the scoring of individual statements, we required agreement between two scorers on all issues related to Major differences. Two members of the project team created a table of difference statements by interview, made independent judgments about which differences qualified as Major, and then met and resolved each case in discussion. Resolution was achieved in all 93 cases. One of the two then prepared a final table and wrote a companion narrative that summarized this logic and described how the student experienced all Major differences.

When these participant-level analyses were complete, we aggregated results by site to see which differences had the greatest impact overall, by educational level and curricular shift, and by individual site.

6. Assessing changes in students' approaches to learning mathematics

Our analysis of changes in students' approaches to learning mathematics was very similar to the approach described above for differences and included the same three phases: coding scheme development, coding all statements of learning approach, and determining whether each participant experienced a significant change in learning approach.

Our first task was to develop a scheme to code the learning approach data. We selected a representative subset of transcripts and developed a coding scheme "bottom-up." As was differences, we repeatedly refined this scheme until we could (a) reliably code an utterance as a learning approach statement, and (b) reliably categorize a statement into one of our learning approach codes. This process resulted in seven categories of learning approach statements: (1) *Physical Participation*, which included whether students attended class, when they chose to arrive and leave their math class, where they chose to sit in the room, etc.; (2) *Intellectual Participation*, including whether students chose to take notes, ask questions of the teacher or peers in order to learn, or offered their thinking to the class; (3) *Textbook Use*, including how, when, and how often the student uses the textbook; (4) *Graphing Calculator Use*, including how when and how often the student uses a graphing calculator; (5) *Homework*, including how often, when and how fully students complete their homework assignments; (6) *Assessment Preparation and Follow Up*, including what students did to prepare for quizzes and tests, when they chose to prepare, and how much time they allotted for these activities; and (7) *Working with Others*, including how often and when students sought help from others, such as teachers, instructors, parents, other adults, classmates, peers outside the classroom, siblings, paid tutors, math help tutors, etc. See Appendix B for additional description of these seven categories of Learning Approach.

All interviews were coded for learning approach by trained undergraduate and graduate research assistants, using the same process as was used for differences.

Once all transcripts were coded, secondary analysis was undertaken to distinguish between those who merely reported a minor and inconsequential change in their learning approach from those whose approach to learning underwent a significant change. Two members of the project team were assigned to each participant. Each analyst independently prepared a learning approach table for each participant, which listed all turns coded as relating to learning approach. Each statement was categorized as relating to students' learning approach *before* and *after* the curricular shift. The analysts used each participants' table to independently decide whether the participant had reported non-trivial change in each category. Non-trivial change was defined to be change that was *meaningful* to a student, *autonomous* or showing some agency by the student, *timely* or initiated in the first year of mathematics instruction after the curricular shift, and *lasting* or regularly occurring and long-lived. Finally, the analysts independently determined whether each participant experienced an overall change in learning approach, combining all seven categories according to the following rule: If the participant non-trivially changed learning strategies in at least two of the seven categories, analysts judged the participant as undergoing an overall change in learning approach towards mathematics.

When both analysts had independently completed a table and the overall learning approach judgment for each participant, the analysts met to compare their results, resolving all disagreements. When consensus could not be reached, the analysts took the issue to the entire project team to resolve. After consensus was reached, a final version of a table and an accompanying explanatory narrative were compiled for each participant. When all participant analyses were complete, we aggregated results by site to see which learning approach categories participants reported most often, by educational level, curricular shift, and individual site.

7. Results – Differences

Table 3 lists, for each of the 26 differences, the percent of students at each site who mentioned it and found it to be Major. Below, we briefly elaborate on a few observations gleaned from the information in Table 3.

(Insert Table 3 here)

7.1 First, it is clear that students at each site noticed and found to be Major a somewhat dissimilar constellation of differences. There was not uniformity across sites, either by educational level or direction of curricular shift. As an example, consider whether students noticed differences in *Assessment*. Across all four sites, 14% of participants found *Assessment* to be a Major difference. But this mean value obscures the quite disparate patterns of responses at each site. *No* participants at $HS2_{T\rightarrow R}$ found *Assessment* to be a Major difference, as compared to 6% of $U1_{R\rightarrow T}$ participants, 15% of $HS1_{R\rightarrow T}$ participants, and 31% of $U2_{T\rightarrow R}$ participants. Whether or not *Assessment* was found to be different was highly dependent on site. Similarly, when considering whether the relationship between teachers and students was different (*Teacher-Student Relationship*), *no* participants at $HS2_{T\rightarrow R}$ found this difference to be Major, as compared to 18% of $U1_{R\rightarrow T}$ participants, 30% of $HS1_{R\rightarrow T}$ participants, and 38% of $U2_{T\rightarrow R}$ participants.

7.2 The exceptions to 7.1 were differences in *Typical Problems* and *Content*, which were found to be relatively important at all sites. Other differences that were frequently found to be Major by at least 10% of participants at all sites were (listed in order of frequency): *Homework*, *Teacher-Student Relationship*, *Textbook*, *Lesson Format*, *Assessment*, *Pace*, *Group Work*, *Use of Calculators*, and *Teaching Style*. Each of these differences will be discussed below. Because of the variation between sites, we present our findings for each of these differences site by site.

7.3 *Typical Problems* was found to be Major by 49% of all participants and was mentioned by almost all participants at all sites. Students at all sites reported that story problems were more common in reform programs. At $HS2_{T\rightarrow R}$, participants reported also that typical problems in the reform curriculum were less repetitious and required more thinking and more writing. At $HS1_{R\rightarrow T}$, however, students reported that the high school, more traditional problems required more thinking. The biggest issue at $U2_{T\rightarrow R}$ was the written explanations required as solutions to reform problems.

7.4 *Content* was also found to be Major by almost half of all participants, including at least one-third of participants at each site. Students at all sites reported that their new program had content that was both new and more difficult (though these were not necessarily reported together). Students at both high school sites, but neither college sites, reported that reform content was more diverse than traditional. $HS1_{R\rightarrow T}$ students generally found the high school traditional curriculum content to be “more in-depth,” “more involved,” “more complex,” or “complicated.” However, $U2_{T\rightarrow R}$ students reported that the HCC content had a more “conceptual” as well as “more in-depth” focus. Greater “depth” was also mentioned by $U1_{R\rightarrow T}$ students, though in smaller numbers.

7.5 In marked contrast to *Content* and *Typical Problems*, *Homework* was not an especially important difference at all four sites. It was mentioned by about half of the participants at $HS2_{T\rightarrow R}$ and $U1_{R\rightarrow T}$ but was Major for no one at either site. However, it was an important difference at $HS1_{R\rightarrow T}$ and $U2_{T\rightarrow R}$, where it was a Major difference for 44% and 69% of students respectively. At $U2_{T\rightarrow R}$, *Homework* was an important difference because of the introduction of group homework and the change in emphasis from individual to group homework. At $HS1_{R\rightarrow T}$, *Homework* was salient because of three primary factors: High school homework was more frequent, had more problems, and could be started if not completed in class.

7.6 *Teacher-Student Relationship* was an important difference at three of the four sites ($HS2_{T\rightarrow R}$ being the exception). At both university sites, students found college teachers less accessible, less personable, and less caring than high school teachers. At $HS1_{R\rightarrow T}$, students seemed to miss aspects of their relationships with their middle school teachers.

7.7 Generally, *Textbook* was only an important difference at $HS1_{R\to T}$, where students reported differences in the appearance (small booklets in reform vs. large tomes in traditional) and comprehension of the text (students found the reform text to be easier to understand).

7.8 Differences in *Lesson Format* appeared to have the most impact at $HS1_{R\to T}$ and $U2_{T\to R}$. At $HS1_{R\to T}$, students noted more teacher presentation in high school and more time to work on homework in class in high school. At $U2_{T\to R}$, students noted a decrease in the amount of time spent on review in college classes.

7.9 At the three sites where students found *Group Work* to be a Major difference, the main issue was whether there was more or less group work in their current program. Other than at $U1_{R\to T}$, where all students noted more group work in reform programs, we did not find unanimity. At both high schools, about half of the students who found Group Work to be Major noted more group work in middle school; for the other half of participants, high school had more group work.

7.10 Although *Use of Calculators* was not widely found to be a Major difference, there was some evidence (from $HS2_{T\to R}$ and $U1_{R\to T}$) that students felt that calculators were used more frequently in reform programs. At $HS1_{R\to T}$, most students who mentioned *Use of Calculators* noted that its use dropped from 8th grade to 9th grade, but rose again to 8th grade levels by 10th grade. However, there was evidence, particularly at $HS1_{R\to T}$, that students saw graphing calculators used mostly for graphing (as well as tables and equations) in reform programs and for computation in traditional programs.

7.11 It is also worth noting what students did *not* note as different. In general, students noticed but did not find particularly important differences in the relevance of mathematics to their everyday lives, issues of classroom management, and opportunities for participation. Other differences that students failed to even notice, on average, concerned basic classroom communication, use of symbolic notation, use of mathematical language, and the level or depth of understanding required to succeed in mathematics class.

(As we continue to investigate and write about these results, we will provide additional detail and interpretation for each point, including illustrative quotes from participants.)

8. Results – Learning Approach

Table 4 lists, for each of the 7 facets of Learning Approach, the percent of students at each site who experienced non-significant change in their learning approach in each category and overall. Below, we briefly elaborate on a few observations gleaned from Table 4.

(Insert Table 4 here)

8.1 First, and as was the case with differences, there was great variation by site both in overall change in Learning Approach and in each specific dimension of Learning Approach. Approximately one-third of all participants experienced a significant change in their approach to learning mathematics, ranging from a high of 59% of $U1_{R\to T}$ students to a low of 4% of $HS2_{T\to R}$ students.

8.3 Despite this site by site variation, it appears that significantly more students at the college sites (49%) experienced change in Learning Approach, as compared to the high school sites (18%). Our notion of "significant" change in approach to learning required some degree of autonomous change. Not unexpectedly, we found that 9th grade students were less likely to implement such autonomous change, at least in part because they had relatively less control over their environments.

8.4 In addition, it appears that students moving into traditional programs ($HS1_{R \to T}$ and $U1_{R \to T}$) were somewhat more likely to implement changes in their approaches to learning than those moving into reform programs: 41% of students in R→T sites, as compared to 25% of T→R sites. However, a closer examination of each of the seven categories of Learning Approach indicates that this result is somewhat more complex than it appears. Differences between R→T and T→R sites were primarily found in three of the seven categories of Learning Approach: *Intellectual Participation*, *Graphing Calculator Use*, and *Working With Others*. We discuss each of these below.

8.5 With respect to *Intellectual Participation*, we found that R→T students were somewhat more likely to *increase* their intellectual participation as they moved into traditional programs, including paying more attention in class, asking more questions in class, and generally working harder. This finding was particularly striking at $HS1_{R \to T}$, where almost all students who experienced a significant change in *Intellectual Participation* indicated that they increased their participation in high school.

8.6 For *Graphing Calculator Use*, students moving into traditional programs were *less* likely to choose to use a graphing calculator for math class. This finding is primarily driven by students at $U1_{R \to T}$, where all students who had non-trivial change in this category reported a decrease in the calculator use.

8.7 With respect to *Working with Others*, the difference between R→T and T→R sites is an artifact of the earlier finding that students at the college sites were much more likely to change their approach in this category, particularly by working *more* with others in college. Over half of $U1_{R \to T}$ students and almost one-third of $U2_{T \to R}$ students non-trivially changed the ways they worked with others in and out of math class, and most worked more with others.

Our analysis of Learning Approach is not as advanced at this point as our work in Differences; we have identified several areas that need more careful exploration in order to interpret the raw findings for this construct. For example, we continue to explore connections between approach to learning and achievement, as we have found these to be clearly related, according to students. *(In addition, as we continue to investigate and write about these results, we will provide additional detail and interpretation for each point, including illustrative quotes from participants.)*

9. Discussion and implications

While students did notice differences between traditional and *Standards*-oriented curricula, their perceptions of these differences did not always align with the views of researchers and curriculum designers. In a few cases (e.g., *Typical Problems*), students noticed what many might have expected that they would. However, many other students either failed to notice a dimension of differences often commented on by researchers and/or found a difference to be in the opposite direction as some might expect. Similarly, some students decided to change their *Learning Approach* as a result of the curricular shift that they experienced. However, these changes were somewhat site- and age-specific and thus not always consistent with what some researchers and curriculum designers might have predicted.

We continue to explore our very rich data set. Our analyses of *Differences* and *Learning Approach* continues; we also are looking at students' dispositions toward mathematics, their achievement, and the correlations between these four distinct but related dimensions of students' experiences. *(This section is currently under construction. We welcome feedback on points that merit discussion, based on our emerging results.)*

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Table 1: Site design matrix

Educational Level	*Type of Curricular Shift*	
	Reform to Traditional	*Traditional to Reform*
Junior High to High School	$HS1_{R \to T}$ From CMP to Traditional	$HS2_{T \to R}$ From Traditional to CPMP
High School to College	$U1_{R \to T}$ From CPMP to Traditional	$U2_{T \to R}$ From Traditional to HCC

Table 2: Participant sample by site, mathematics track, and gender

Site	*Track*		*Gender*		*Total*
	Advanced	*Regular*	*Male*	*Female*	
$HS1_{R\rightarrow T}$	13	14	15	12	27
$HS2_{T\rightarrow R}$	10	13	9	14	23
$U1_{R\rightarrow T}$	4	13	8	9	17
$U2_{T\rightarrow R}$	4	22	10	16	26
Total	31	62	42	51	93

Table 3: Percent Major, by site, all *Differences*

Difference	*Site*				*Total*
	$HS1_{R \to T}$	$HS2_{T \to R}$	$U1_{R \to T}$	$U2_{T \to R}$	
A. Content	74	35	41	38	48
B. Textbook	41	13	6	15	20
C. Typical problems	48	57	12	69	49
D. Use of mathematical language	7	0	0	0	2
E. Use of non-verbal representations	4	0	0	0	1
F. Use of symbol notation or manipulation	4	0	0	0	1
G. Class size	0	0	12	0	2
H. Class duration	0	0	6	4	2
I. Pace	11	4	35	12	14
J. Assessment	15	0	6	31	14
K. Basic communication	0	0	6	4	2
L. Classroom management	15	0	6	8	8
M. Group work	41	0	18	0	15
N. Homework	44	0	0	69	32
O. Lesson format	33	4	12	19	18
P. Opportunities for participation	7	0	12	0	4
Q. Teacher's fidelity to the textbook	0	0	6	0	1
R. Teacher-student relationship	30	0	18	38	23
S. Teaching style	11	9	29	0	11
T. Use of calculators	26	4	12	0	11
U. Use of examples	4	4	0	12	5
V. Autonomy	0	0	0	12	3
W. Coherence & connections	7	0	0	4	3
X. Relevance of mathematics	11	4	12	8	9
Y. Level of understanding	0	0	0	4	1
Z. Other	0	0	0	8	2

Table 4: Percent non-trivial change in *Learning Approach*, by site and dimension

	All sites	$HS1_{R\to T}$	$HS2_{T\to R}$	$U1_{R\to T}$	$U2_{T\to R}$
Overall change	32	30	4	59	42
Physical Participation	8	0	0	12	19
Intellectual Participation	22	37	13	29	8
Textbook Use	19	15	4	24	35
Graphing Calculator Use	9	7	4	29	0
Homework	19	7	13	35	27
Assessment Preparation	24	22	0	35	38
Working with Others	24	15	4	53	31

Appendix A: *Differences* categories and definitions

Source of difference	Difference	Description	Subcodes
I. Curriculum	A. Content	Differences in the typical mathematics content addressed in the textbook(s), including global differences in the difficulty of the course material and whether or not it was "review."	
	B. Textbook	Differences relating to the textbook	*Appearance*. Differences in the appearance or packaging of the textbook(s), i.e. in their color, number, size, or length.
			Comprehension. Differences in how understandable the textbook(s) was, i.e., its "reader-friendliness."
	C. Typical Problems	Differences in the type of problems that typically appeared in the textbook(s) or were assigned by the teacher, either in the body of the section or as homework problems.	*C1. Directions provided for solving problems*. Differences in the guidance provided by the textbook(s) for solving problems, such as (1) explicit steps or procedures for solving specific types of problems, (2) general descriptions of how to solve a class of problems, or (3) worked out examples.
			C2. Expectations for solutions. Differences in what was expected in solutions to typical problems, such as requiring an answer only, a written explanation, or a picture or diagram to accompany the solution.
	D. Use of Mathematical Language or Terminology	Differences in the mathematical vocabulary/language used in the textbook(s), such as the use of standard or conventional, non-standard or informal, or invented terminology.	
	E. Use of Non-Verbal Representations	Differences in the use of non-verbal representations of mathematical relationships (tables, graphs, equations, diagrams), including the presence/absence of representations, or a difference in which were emphasized.	
	F. Use of Symbol Notation or Manipulation	Differences in the use of symbolic notation, including the amount of symbolic manipulation presented in the textbook(s).	

II. Site Implementation	G. Class Size	Differences in the number of students in class.	
	H. Duration	Differences relating to the duration or time of the class.	*H1. Course*. Differences in the length of the course, e.g., semester vs. year-long.
			H2. Class meetings. Differences in the amount of time the class met each day.
	I. Pace	Differences in how quickly the student felt that the teacher moved through the content in the class, either due to a math department policy about how much of the curriculum must be covered, or due to the teacher's own choices.	
III. Teachers and Teaching	J. Assessment	Assessment refers to all student work that contributed directly to their grade. Differences include both changes in the assessments given and how they were scored. These include but are not limited to (1) the kind/nature of or difficulty of the problems; (2) the length of assessments—number of problems or time allotted; (3) their frequency in a given course; (4) the relative weights assigned, e.g., tests and final exams relative to quizzes and homework; (5) the kind of support allowed, e.g., notes or calculators; and (6) how they were scored, e.g., whether partial credit is assigned and whether "retakes" are possible. *Note:* Assessment was often shaped by decisions at the site level as well as those of individual teachers.	
	K. Basic Communication	Differences in how students understood what their teacher said in class, that is, their literal comprehension: e.g., whether they can hear, understand, or follow the teacher's speech.	
	L. Classroom Management and General Organizational Patterns	Differences in how the teacher organized and managed work in the classroom independent of the lesson. Issues of organization and management include: discipline; seating (open vs. fixed seating; individual desks or tables); required notebooks, folders, or book covers; and the extent to which the teacher has students' behavior under control.	

	M. Group Work	Differences in how the work in small groups was organized, in the classroom. Specific issues include (1) frequency of use (from "never" to "all day, every day"); (2) size of groups (pairs, trios, fours, or larger); (3) selection of groups, e.g., student- or teacher-chosen; and (4) how students were encouraged to work with each other.	
	N. Homework	Differences relating to course homework.	*N1. Individual*. Differences in the written work that students were expected to produce outside of class time, including (1) the number of problems in typical assignments; (2) the frequency of assignments; and (3) the similarity or difference among problems in assignments.
			N2. Group. Differences in the requirement to complete homework assignments in groups. *Note:* Group homework at $U2_{T\rightarrow R}$ was site implementation issue.
	O. Lesson Format	Differences in either the kind of activities that make up typical lessons or the sequence or time allotted to them. Teaching activities include lecture or teacher presentation, checking and discussion of homework, and solving non-homework problems in class.	
	P. Opportunities for Participation	Differences in the opportunities that teachers provided for students to participate in mathematical activity in class, including (1) the nature of teacher questions and students' responses, (2) the nature of student questions invited by teacher; (3) opportunities to present solutions, (4) discussion of alternative solutions to problems; and (5) opportunities to work with other students in class.	
	Q, Teacher's Fidelity to the Textbook	Differences in how closely the teacher "followed" the book—that is, presented the content to the class as it is presented in the textbook. A teacher not following the textbook closely might regularly bring in supplementary lesson materials, such as projects or worksheets, not out of the textbook.	

	R. Teacher-Student Relationship	Differences in the student's feelings toward their teacher or their perceptions of their teacher's feelings toward them, including issues of accessibility, trustworthiness, care for students, ease of contact outside of class. *Note*: Whether the student liked or disliked the teacher was irrelevant here.	
	S. Teaching Style	Differences in how the teacher taught that were not captured in other categories, e.g.,, Lesson Format, Basic Communication, Opportunities for Participation, and Teacher's Fidelity to the Textbook.	
	T. Use of Calculators	Differences in if and/or how calculators were used in the classroom.	
	U. Use of Examples	Differences in the use and role of examples, such as the repetitiveness and frequency of the examples.	
IV. Students Themselves	V. Autonomy	Differences in the student's sense of their role or responsibility in learning.	
	W. Coherence or Connections	Differences in how coherent or connected the topics, chapters, or units in the textbook(s) seemed to the student, i.e. how well the various topics, chapters, or units fit together or built on each other.	
	X. Relevance of Mathematics	Differences in the relevance of topics and problems in the textbook(s) to the student's life, current or future, in or out of school.	
	Y. Level of Understanding	Differences in the character of the student's mathematical understanding.	
	Z. Other	Any difference between some aspect of the "new" relative to "old" program that did not fit any category listed above.	

Appendix B: *Learning Approach* categories and definitions

Category	**Definition**
Physical Participation	Whether student chooses to attend their mathematics class or not, to sit in a particular place in class for the purposes of learning, and/or to arrive early (to prepare for class) or late, in each case knowing the positive (or negative) consequences of each.
Intellectual Participation	Student's level of attention to the learning activities in class, including his/her willingness to ask questions to teacher or peers in class and to present his/her thinking to the class.
Use of the Textbook	Student's strategic use of the textbook, e.g., how often it is read; its use to understand the lecture, to work example problems, and/or to review for tests or quizzes.
Use of Graphing Calculators	Students' autonomous use of graphing calculators as part of in-class and out-of-class learning of mathematics.
Engagement with Homework Assignments	The amount of time and/or effort student devotes to completing homework assignments.
Preparation for Assessments	Student's time and/or effort allotted to prepare for assessments, as well as the nature of preparation for assessments.
Working With Others	Student's efforts to receive extra help from teachers, tutors, peers, and others, outside of class, to aid in the work of mathematics class. Includes participating in and/or organizing study groups, as well as providing help to other students.