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# HELPING TEACHERS UN-STRUCTURE: A PROMISING APPROACH

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# Helping Teachers Un-structure: A Promising Approach

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Abstract: The amount of overt structure in the presentation of a task affects students' engagement, creativity, and willingness to tolerate frustration. In a professional development project, with algebra teachers from nine American schools, we tried to help teachers make judicious decisions in their use of structure by having them facilitate low-structure tasks, remove structure from overly structured tasks, and observe "at-risk" students engaged in learning through low-structure tasks. Project schools that worked on structuring generally improved their algebra passing rates, both overall and for African-American students.

*Keywords*. Professional development, task structure, underrepresented minority students, US teachers, algebra, teacher change

Generally, people become teachers because they want to help others. They enjoy their work when through their effort and ingenuity, students actually learn and can do things they could not do before. Their instinct is to try to make things easier for their students; however, this desire to help can have the unintended effect of creating boring classrooms full of disengaged students. One of the major themes of our teacher development work has been to find effective ways to help teachers to structure their classroom tasks just enough so students are able use their creativity and inventiveness to reason their way to solutions.

Three of us were the co-directors of a National Science Foundation Math Science Partnership project, REvitalizing ALgebra, (REAL), which aimed to improve the performance of secondary students in elementary algebra and college students in remedial elementary algebra (Hsu *et al*, 2007a and 2007b). Our fourth author was the outside evaluator of the REAL program. Our specific goal was to improve the performance of students from underrepresented populations. We worked intensely with some lead teachers from six high school and two middle school math departments. There were two groups of about nine teachers who came together in successive years. Each group met for three hours a week during their first academic year and daily for three weeks the following summer. During their second academic year they met daily with other department members at their schools in an extra preparation period paid for by the NSF grant. There were about nine graduate students and nine undergraduate mathematics majors who also met with each group of teachers during their first year, but we will focus on the pre-college teachers.

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Six months before we began work with secondary teachers, we spent time in classrooms at their schools as "flies on the wall," putting ourselves in the shoes of the students. During those initial classroom visits, most teachers were asking questions that required short computations and little or no reasoning. On further inspection the problems, even those originally designed to be open to multiple solution methods, had been augmented with "scaffolding" which reduced the tasks to a series of small steps that required little thinking. For example, directions were added to tell students to make a chart and look for a pattern. Sometimes the directions even gave the column headings for the chart. In other cases explorations were limited. For instance, in a problem that originally asked students to come up with many kinds of function output patterns, the directions gave only linear patterns to "discover" and then broke down the process of finding the linear patterns into a to a step-by-step algorithm.

Based on our observations and on the work of researchers on engagement and success (National Research Council and the Institute of Medicine, 2004), we knew we needed to help teachers to get their students more engaged in learning and doing mathematics. We concluded that one way to get more students to succeed in algebra was to convince the teachers to structure their assignments differently, and generally to use less structure in the tasks they assigned both in class and for homework. Advantages of less structure can include:

1. more student creativity, flexibility, active problem solving, and the sense that mathematical struggle is an essential part of math and not something shameful;
2. more and higher quality mathematical discourse in student groups;
3. more student exploration, and assumption of responsibility for learning;
4. student belief that math is more than a small number of computations to be done quickly and a large number of problems whose solution methods must be memorized; and
5. more student engagement and interest in the mathematics!

On the other hand, we realized that by restricting the choices and creativity of students and directing their thinking to a prescribed solution method, teachers often felt:

6. more certainty about the mathematics being used and less anxiety about the complexity of managing different groups working in different ways;
7. more control over any resulting whole class interaction and greater ease of grading student work;
8. more certain of student confidence as they succeed at tasks a teacher thinks they can accomplish;
9. more control of the class, as students feel certain of how to start and which "direction" their thinking should take.

Our concern was that most of the lower-level algebra classrooms, where students from underrepresented populations had been tracked and where lessons were highly structured, lacked all of the benefits of (1)-(5) above and showed none of the positive aspects of (6)-(9) anticipated by teachers. We saw students who were unsure of themselves, unable to begin to work, and unable to take any risks. Their goal was to get the right answer, and they were unwilling or afraid to try something and learn from the consequences. Students hid their work from each other and gave up quickly when they didn't find answers right away. Teachers would explain how to do many of the problems, classes were boring, and students often exhibited their lack of engagement through disruptive behavior.

We were concerned that the heavy structure used in their mathematical tasks did not reflect a careful balance of advantages and disadvantages, but instead stemmed from:

a. teachers' fear of or aversion to letting their students struggle with a problem;
b. an unexamined belief that their students were not capable of succeeding at less structured tasks;
c. lack of awareness of the resulting gains and losses from structure choices;
d. teachers' own lack of experience with good, creative problem solving in a less structured task.

Based on our observations, we decided to make "structure" an important theme. In most meetings we discussed readings and movies that addressed (a) and (b), and to a lesser extent (c). In addition to reading about the advantages of reducing the amount of structure in problems teachers worked on several assignments dealing with questions of how much structure. They worked on low-structure mathematics problems themselves and then team-taught those problems to the other participants. We gave them overly structured problems to redesign using less structure, and they discussed a provocative movie of a lesson study where teachers improved a task by redesigning it with less structure for the students. In addition, some observed their peers who were using less structured tasks in their classes.

**Un-Structuring Tasks, First Try**

Experiencing low-structure tasks. Participants worked on low-structure math problems in groups every week. We used problems from the Interactive Mathematics Program, from other sources, and of our own invention. The key features of the problems were that they required some inventive thinking and exploration and rewarded multiple approaches. We acted as group work facilitators, challenging groups to justify their work and to explain their work to each other, and asking key questions when groups were stuck.

Teaching low-structure tasks. Once each semester, we divided into groups and gave each group a low-structure math problem that they would "teach" to subgroups of their classmates. They would, of course, first have to work on the tasks themselves. After the problem was sufficiently explored, one of us would facilitate their planning of what outcomes to aim for, how to guide the exploration, and what to anticipate. Then they would "teach" their problem to subgroups of 6 to 12 classmates. Finally, we helped them to reflect on their teaching experience.

These tasks were not solely about un-structuring, but we definitely wanted people to notice and enjoy the benefits of mathematical exploration in safe and encouraging environments. After a month of getting to know each other, teachers were enjoying doing math together. However, two issues worried us. First, many participants failed to grasp important aspects of facilitating the solution of unstructured problems. When some teachers taught their lessons to their peers, they added a lot of scaffolding to the problem, even though they themselves had enjoyed a less structured version. Other teachers erred in the opposite direction. They had not noticed the teaching moves we had been making as facilitators, but interpreted "un-structuring" as doing nothing. They had missed the fact that we had carefully considered in advance probable student reactions and had appropriate questions in our pockets, we were monitoring issues of status differences and work imbalance, and we were looking for excellent ideas and different strategies that groups might share with others. Second, we were concerned that the teachers who had gained some new awareness were not adjusting their classroom practice. This lack of progress could be seen in classroom observations and in the exceedingly structured lesson plans teachers submitted when we worked on planning. Several people commented that low-structure activities were fine for well disciplined groups (like ours), but were not possible in their classrooms.

Figure 1

Consider the following problem:

The Statue of Liberty in New York City has a nose that is 4 feet 6 inches long. What is the approximate length of one of her arms?

1. Solve the problem. (Think about your own nose and arms.)

2. Pick two other body parts and find the approximate length that these parts should be on the Statue of Liberty.

3. Examine what you did with the three examples from Questions 1 and 2. How was your work the same in the three cases? How did it change from case to case?

A Fairly Open Version

We want to solve the following problem:

The Statue of Liberty in New York City has a nose that is 4 feet 6 inches long. What is the approximate length of one of her arms?

1. How long is the Statue's nose in inches?
2. Estimate how long your nose is, in inches.
3. What is the ratio of the length of the Statue's nose to your nose?
4. Estimate how long your arm is.
5. Multiply the answers from (4) and (3). What is the relationship between this number and the length of the Statue of Liberty's arm?
6. Write down a brief explanation of why you gave the answer you did in (5).
7. Pick two other body parts on the Statue of Liberty, and using the strategy from (1) through (5), figure out their lengths.
8. Explain this strategy for figuring out lengths on the Statue of Liberty. Make sure a classmate can understand it.

A Closely Structured Version

**Un-Structuring Tasks, Follow-up**

Explicitly removing structure from a task. We decided we were being too subtle and that we should directly call attention to the issue of structure. Midway through the second semester, we gave an assignment, the Statue of Liberty's Nose, (See Figure 1) with two versions of two different activities, one version was fairly open and one closely structured. We then asked for a list of the pros and cons of the more structured approach. As a homework assignment, they were given another structured activity and were asked to rewrite it so it would to be more open. In the following class, we discussed the pros and cons of each approach and how to prepare questions to use with the less structured activity to get the benefits that the more structured activities promised. Our goal was to drive home the idea that the support that students might need could come from sources other than breaking the problem down into little, tiny directed steps. Methods for facilitating effective small group mathematics discussions were discussed and sometimes illustrated in video clips, and teachers worked on what we called "pocket" questions for specific problems. These are questions teachers have ready to ask, to challenge a complacent group, restart a frustrated group, or to give a gentle hint to a group. Pocket questions are often the questions that would be written out in an overly-structured task; we argued that it is better to structure as the need arises.

In addition we asked participants to teach a specific problem in their own classes. ("What can you say about the repeating decimal expansion of fractions?") We gave them the problem to work on themselves, and then they worked in groups on plans for teaching the problem in their own classes.

<u>Responding to provocative videos</u>. We showed several videos. One was a movie, "Brown Eyes" about a Korean boy on his first day at a new elementary school. Both teachers and students made many assumptions because he did not speak. It was unclear whether he was just shy or did not know English. Before and after school, the film showed him at home where he was a resourceful and responsible problem solver. The discussion following the showing of this film was emotionally charged as participants examined their own assumptions about the problem solving and reasoning abilities of their students.

We also arranged a viewing of a video of a group of elementary teachers working on lesson study (Lewis, 2005). The task is for students to analyze a changing geometric pattern of triangles. For the initial lesson, students are told to fill out a pre-made table with data in a specific order and then to identify the pattern. When it is taught, the students fill in the table without thinking much about it, and the teachers notice that the over-structuring sabotages the students' understanding. They revise the lesson in a perfect example of "un-structuring" by asking individuals to collect different data and to have them synthesize it as a group. The students who participate in the new lesson display deeper engagement and more creativity along with better reasoning in their explanations.

<u>Peer observation-live unstructured tasks</u>. Project teachers still needed to see that it was possible to teach classes of "at-risk" students using problems with less structure. In each of the two cohorts there were a few teachers, who were already moving in the direction of using less structured problems, and we arranged for some teachers to be able to visit them.

**Results**

Immediate results were mixed, but over time the teachers continued to change their practices. Through interviews with teachers, through reading their written reflections and listening during their planning sessions with their home departments, we observed an increased appreciation of the amount of structure in a mathematical task as a choice that can have important consequences such as those described in (1) - (9). Their discussions indicated that they realized there were careful choices and teaching moves required when leading low-structure activities, though they were not always sure what they were. Deconstructing the roles of students and teachers in low-structure classrooms to understand how their roles differ from a traditional classroom was not something most participants did on their own. Participants began to focus on questioning as a key to facilitating low-structure tasks. It takes time, practice, and thoughtful reflection to become a good questioner who can create a safe learning environment where students can risk showing what they know and explaining their reasoning. For many teachers becoming a good questioner seems to be a fairly advanced developmental stage of teaching. In one high school, where teachers had already embraced many of the principles advocated by REAL, it took two years for teachers to fully realize the importance of the questions they ask when facilitating groups.

Many of the teachers seemed to believe that using low-structure activities was an ideal to aspire to, and they realized that they must teach their students how to work together, take risks, make mistakes, look for multiple strategies, and explain their thinking, but they still needed to learn how to make these things happen.

We asked teachers to respond to questionnaires before and after the program began. Unfortunately, before it began we did not realize how crucial restructuring would be in improving teacher practice. So, we did not ask whether they considered that a factor when planning lessons. However, in the post questionnaire, we can compare two groups of respondents: a "fully REAL" group of teachers that were at the school during all of the REAL program and “newer” teachers who came to the school sometime after REAL began. When asked to what extent “Unstructuring lessons so students can use their own strategies for solving problems” was a key consideration in their planning math lessons, the "fully REAL" group had 65% rank it 4 or 5 (the highest two scores) out of 5. The "newer" group had only 43% do so. We also asked teachers to check three top considerations out of a list of ten, and 23% of the "fully REAL" group picked unstructuring in their top three considerations, while only 4% of the newer group did.

The REAL Project has collected data on academic achievement by algebra students in the partnership schools. Our original project involved two years work with two cohorts. For five sites, we continued working actively with their teachers and funding teacher projects. For three other schools we gave no continuing support. Two departments were not interested in continuing, and when the district moved the third school to a new site, all of the REAL leadership left, leaving only first year teachers at the new location.

In general, the "continuing work" schools gave above-average ratings for unstructuring in terms of importance in their planning. They also showed gains in algebra performance by African-American students and overall. This is in contrast to the "no continuing work" schools which showed no change in student performance and rated unstructuring as 3.3 and 3.4 (below the school average of 3.6) in terms of importance in their planning. On the one hand, it is satisfying to feel that our work can lead to improved results in schools. On the other hand, one of our hopes was to create lasting change in all our departments.

The table shows data for the "continuing work" schools in more detail.

Table 1

| REAL support after second year | Algebra Failure 2003 or 2004 | Algebra Failure 2007 | Importance of Structure |
|---|---|---|---|
| High School (1) | Total: 35% | Total: 25% | 4.1 |
| | AfrAm: 40% | AfrAm: 22.3% | |
| High School (2) | Total: 56.5% | Total: 45.0% | 3.2 |
| | Afr.Am: 64% | Afr.Am: 49% | |
| High School (3) | Total: 39.3% | Total: 43.3% | 3.6 |
| | Afr.Am: 62.2% | Afr.Am: 48.5% | |
| | 2003 Percent of all 8th Graders Passing Algebra | 2007 Percent of all 8th Graders Passing Algebra | |
| Middle School (1) | 20.2% | 26.5% | 4.3 |
| Middle School (2) | 11.2% | 27.2% | 4.7 |

The data from High School 1 shows a truly impressive drop in algebra failure rates both collectively (25% down from 35% at project start), and disaggregated by ethnicity. Especially notable was the failure rate of African-Americans who are the second largest ethnic subgroup, and about a quarter of the student body (22.3% down from 40% at project start). Teachers at that school rated the post-survey question about unstructuring an average score of 4.1 for importance on the 5 point scale, where the average for all schools was 3.6. Note that this school was unusual for several reasons. First, the school had started changing their practices and improving their success with algebra classes before they joined the REAL program. Second, we funded it directly for two years of co-teaching following the first year work with teacher leaders, instead of one year of teacher meetings as the other schools had.

In High School 2, we met our targets for reducing absenteeism in every ethnic group, and we met our passing rate targets for every ethnic group (except Asian students). The absentee rates are down remarkably from the project start (down to 4.0 yearly absences/student from 12.3). Most encouragingly, the failure rate of African-American students has shown a big drop from 64% to 49% since the start of the program. This rate is still unacceptably high, but we are encouraged that significant change has occurred in the right direction. The overall failure rate dropped from 56.5% to 45.0%. That school did not rate unstructuring as a key concern in planning lessons.

Their average was 3.2, which is below average, but note that most of their teachers are using a reform curriculum whose activities did not need unstructuring.

In High School 3, the African-American failure rate has gone from 62.2% in the normal first year math course to 48.5%, which is very good progress. However, notice the curious overall drop in the passing rate. Statistically, this is due to the failure rate for Latino students increasing from 30.6% to 45.6%. This presents a very mixed picture that we cannot explain but that could be related to changes in the Latino student population. This school rated unstructuring an average of 3.6 in importance.

The challenge in middle school is to give more students a chance to take algebra, while maintaining healthy passing rates. For this reason, our main benchmark for Middle Schools 1 and 2 is the number of students passing algebra as a percentage of the total student population (not just a percentage of the number of students taking algebra). At Middle School 1 the passing rate of students in their algebra classes has met our target and improved to 26.5% of all eighth grade students taking and passing algebra from an initial rate of 20.2%. of all eighth graders. At Middle School 2 the rate went from 11.2% to 27.2%. The two middle schools rated unstructuring as 4.3 and 4.7 on the average.

**Conclusion**

On the whole, there was much more <u>discussion</u> of reducing structure than <u>action</u> in the classroom. Some lead teachers (teachers who directly participated in the REAL professional development class) did loosen up their activities with some excellent results. One lead teacher mentioned that she now assigns the book's enrichment problems, whereas in the past she skipped over them. Other lead teachers began trying low-structure problems as supplemental activities or as introductions to new topics. But many teachers reported that low-structure tasks were beyond their reach as teachers because of (1) their own limitations (fear of losing control, feeling mathematically unprepared to handle spontaneous questions, fear of a lack of skill in bringing tasks to resolution), (2) the limitations of their students, and (3) the limitations of their schedules by the demands of state standards and testing programs.

We do take some consolation in the broad acceptance among our lead teachers that low-structure, exploratory tasks are a positive idea. Of the psychological obstacles (a) - (d) listed above, we think we successfully addressed all but (b) the belief that their minority and remedial students were not capable of succeeding at less structured tasks. A proclaimed change of heart has yet to be matched by a change in teaching practice; however, with further support the latter change may occur. When teachers described their work in the second year, they would usually contrast their work against an ideal of lowering the amount of structure and express some guilt (with reasons) for falling short.

Participants in REAL repeatedly said that their honors track or Advanced Placement students could work in groups on unstructured problems quite successfully. However, they believed the students in their lower track algebra courses, who had previously struggled with math, could not. These students, teachers said, couldn't work together collaboratively and resisted thinking out loud and explaining their strategies to each other. By high school, students have learned that right answers rather than well reasoned solution processes lead to success in school. When asked about their reactions to less structured activities students tended to react negatively, complaining that their teachers weren't explaining enough.

In one sense, the behavior of the REAL teachers paralleled the behavior of their students. The teachers in REAL, like their students, resisted when pushed to think deeply and share with their peers their thinking about what math was important to teach and why, and how they might best teach it. Some teachers came to REAL thinking that the project directors had already worked out those answers. Similarly, students generally don't question the norm that giving the right answer is what it takes to be successful in school. In fact, what REAL advocated for both teachers and students was the value of the process of thinking and struggling with questions. We could be more explicit in our future work about getting teachers to reflect on this parallel experience in their own learning as a preliminary step to shaping the learning experiences they create for their students.

We did influence the classroom practice of most of our lead teachers. We also had significant effects on the work and culture of many departments, especially in how they spend their time together. In particular, departments indicated increased communication about math course content, discussing common instructional strategies, and reflecting on lessons together, and attributed REAL with these increases. The project seemed to have given many partners the courage to undertake changes they had quietly hoped for in the past such as revision of curriculum, regular peer observations and collaboration, and even elimination of some tracking.

On the other hand, we had to learn patience. First, we had hoped for more movement and growth during the first school year. This proved unrealistic, and in retrospect it seems difficult to ask teachers to change their practice dramatically in the middle of a school year. Indeed it was difficult for teachers to change their intellectual perspectives on their teaching during the year. The fall and spring semesters were marked by slow, cautious change and an opening of minds, followed by great leaps of attitude and ambition during the subsequent summer session, followed by slower but more visible change during the following school year. There is no easy way around this dynamic, which was clear in both groups and across all schools.

Second, we needed patience in the second year waiting for our lead teachers' visible changes of heart, mind, and talk to result in changes in their classrooms. A few teachers were not influenced by the program, but for the majority of participants changes of attitude were visible in their work, in their rhetoric, in their discussions with their peers, and in their private interviews with the outside evaluator. Indeed, most teachers did try different things in the classroom, and as discussed above, some were profoundly influenced. But many of them would try to teach differently in one class, then return to their comfort zone for a few classes, and then try something different again (often when one of us came to visit). This is probably a very natural way for change in teacher practice to occur when the teacher gets to choose the pace. And in fact, we intentionally set up the program's structure and incentives to allow teachers to change at their own pace. Nonetheless, it taxed our patience to see the difference in the verbalized hopes and intents and the classroom reality.

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