

How Complex Instruction led to High and Equitable Achievement:  
The Case of Railside School.

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**Introduction.**

This short paper will introduce you to the work of a group of equity-oriented teachers in an inner city school in California, who brought about amazing achievements in mathematics. The teachers used an approach called ‘complex instruction’, which is not well known in the UK, to bring about high achievements and great enjoyment of maths among students. I worked with a team of doctoral students to research the impact of the school’s approach and we compared the students’ learning experiences to students in other schools who worked differently. In this paper I will describe how the teachers worked and the results they achieved, in a related paper on this website (called ‘Complex Instruction in England – the journey, the new schools, and initial results’.) I will describe my trip to Downing Street to show the approach to government ministers, which resulted in schools in England bravely taking on the innovative and unusual approach.

One of the most difficult challenges faced by teachers of maths is the wide range of students they teach. Even when taught in sets, maths classes often include students with low motivation and weak knowledge alongside others with advanced understanding and high motivation. Not surprisingly many teachers are supporters of ability grouping as it seems too hard to teach very mixed groups. In two different research studies I have conducted, in England and the US, I have followed students through secondary schools that teach and group students differently, investigating the impact of the different teaching and grouping methods upon achievement and enjoyment. In both studies the schools that used mixed ability approaches resulted in *extremely* impressive outcomes, including higher overall attainment and more equitable outcomes (Boaler, 2009). But in both cases the maths departments that achieved such goals used *particular methods* to make the mixed ability teaching effective. In this short paper I will describe the approach of “Railside school”.

Railside School.

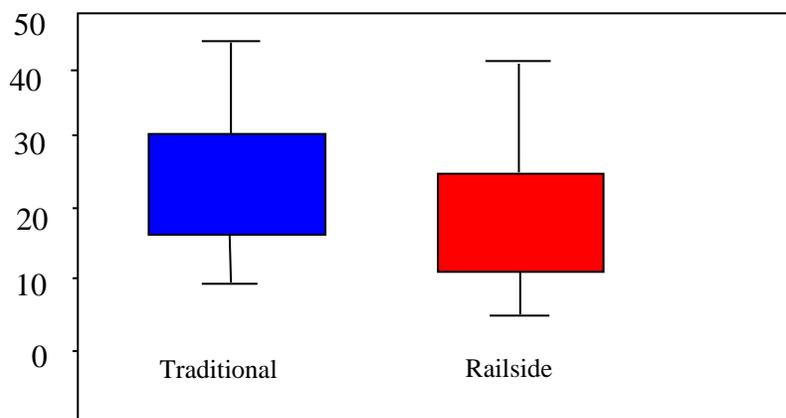
Railside High School is an inner-city school in California and lessons are frequently interrupted by the sound of trains passing right next to the playground. As with many inner-city schools the buildings look as though they are in need of some repair, but Railside is not like other inner-city schools. When I have taken visitors to the school and we have stepped inside the maths classrooms, they have been amazed to see all the students hard at work, engaged and excited about maths and advanced level classes filled to capacity. I first visited Railside a few years ago, when I was a professor at Stanford University, because I had learned that the teachers collaborated and planned teaching ideas together and I was interested to see their lessons. I saw enough in that visit to invite the school to be part of a longitudinal research project investigating the effectiveness of different mathematics approaches. Some four years later, after we had followed 700 students through three high schools, observing, interviewing and assessing students, we knew that Railside's approach was both highly unusual and highly successful.

The mathematics teachers at Railside originally taught using traditional methods, but the teachers were unhappy with the high failure rates among students and the students' lack of interest in maths. The teachers decided to engage students in more group work and to follow a pedagogical approach designed to make group work equal, because they knew that group work often fails when students work unequally. They changed their classes from those taught in sets, to those taught in mixed ability groups and they designed a new curriculum together, that was based on what they called "group-worthy tasks". They moved from questions and exercises that gave students practice on mathematical methods such as 'factoring polynomials', or 'solving inequalities', and designed their curriculum around bigger mathematical ideas, with unifying themes such as "What is a linear function?" They also introduced an important theme of 'multiple representations' – this meant that they always asked students to communicate mathematical ideas in two or more ways, such as through words, diagrams, tables, symbols, objects, and graphs. They also asked students to discuss the different representations with each other and to move between the different representations, for example colour coding their diagrams and graphs to show where the same information was communicated (an example of one of their group-worthy, multiple representation tasks is given in the accompanying paper: 'An example of a group-worthy task in Railside school'.). When we interviewed students and asked them what they thought maths was, they did not tell us that it was a set of rules, as most students do, instead they told us that maths was a form of communication, or a language, as one student explained: *"Math is like kind of a language, because it has got a whole*

*bunch of different meanings to it, and I think it is communicating. When you know the solution to a problem, I mean that is kind of like communicating with your friends."*

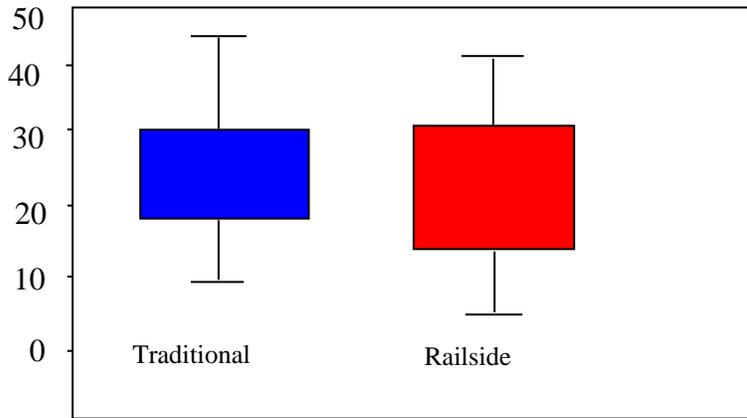
I was studying the learning of the Railside students as part of a larger, four-year study of three American high schools, during which we followed 700 students who were taught differently. The students at Railside worked on group tasks, in mixed ability classes, whereas the other students learned traditionally – practicing methods that a teacher demonstrated, through individual work. During the four-year study we collected a range of data, including approximately 600 hours of classroom observations, assessments given to the students each year, questionnaires and interviews. Railside school was more diverse than the other two schools, with more English language learners and higher levels of cultural diversity (approximately 38% of students were Latino/a, 23% African American, 20% White, 16% Asian or Pacific Islanders and 3% from other groups). We tested all of the students at the beginning of high school, before they had started working in different ways. At that time the Railside students were achieving at significantly lower levels than students at the other two schools, which is not atypical for students attending inner city schools, but within two years they were achieving at significantly higher levels. The following graphs show the achievement of students at the beginning of the study (year 1 pre-assessment) and at the end of year 1 (equivalent to Y9 in the UK) and the end of year 2 (equivalent to Y10):

**Year 1 Pre-Assessment.**



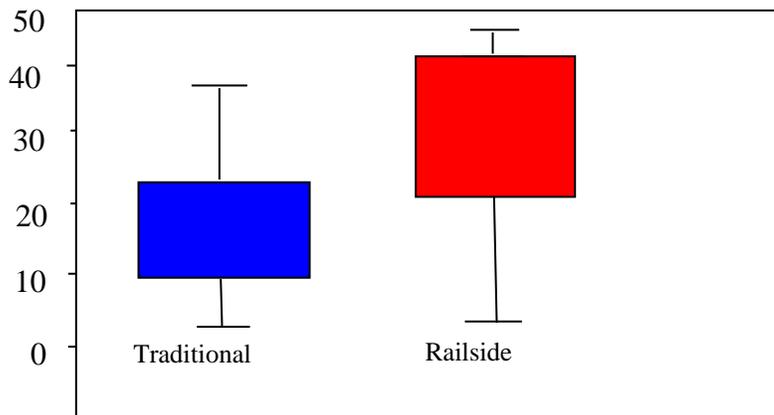
n=658, t = -9.141, p <0.001

### End of Year 1



n=637, t = -2.040, p <0.04

### End of Year 2



n=5128, t = -8.309, p <0.001

At the end of year 2 (similar to Y10 in the UK) the average achievement of the students taught traditionally was equivalent to a GCSE grade D, at Railside the average achievement was equivalent to a GCSE grade C. In other words, the Railside students learned in one year what it took the students taught traditionally to learn in more than two years. This result was achieved at Railside even though the students started the school at significantly lower levels, with severe gaps in their mathematical knowledge and understanding.

Students at Railside were also more positive about mathematics and took more courses. In year 4, *41% of seniors were enrolled in calculus*, compared with approximately 27% in the other two schools. The number of students taking advanced maths at Railside was incredibly high, for any school but particularly for a diverse, inner-city school where students arrived with low levels of mathematics knowledge. Importantly, inequities between students of different ethnic groups disappeared or were reduced in all cases at Railside whereas they remained at the other schools that employed ability grouping (for more detail see Boaler, 2009). Our statistical analysis showed that the students who were most advantaged by the mixed ability Railside approach were the high achievers, as they improved more than all other students. The high achievers at Railside also learned significantly more than the high achievers who went into top sets in the traditional schools. Many people are concerned about mixed ability teaching as they worry about the high achieving students who may be held back in mixed groups, but we found that the students were advantaged because they spent time explaining work, which helped their own understanding, and they were able to think more deeply about maths, rather than rushing through more and more work, as typically happens in top set classrooms.

The Railside classrooms were all organized in groups and students helped each other as they worked. The Railside teachers paid a lot of attention to the ways the groups worked together and they taught students to respect the contributions of other students, regardless of their prior attainment or their status with other students. One unfortunate but common side effect of some classroom approaches is that students develop beliefs about the inferiority or superiority of different students. In the other classes we studied, that were taught traditionally, students talked about other students as smart and dumb, quick and slow. At Railside the students did not talk in these ways. This did not mean that they thought all students were the same, but they came to appreciate the diversity of the class and the various attributes that different students offered. As Zane described to me: *“Everybody in there is at a different level. But what makes the class good is that everybody’s at different levels so everybody’s constantly teaching each other and helping each other out.”*

The teachers at Railside followed an approach called ‘complex instruction’ (<http://cgi.stanford.edu/group/pci/cgi-bin/site.cgi>), which is a method designed to make group work more effective and to promote equity in classrooms. They emphasized that all children were “smart” and had strengths in different areas and that everyone had something important to offer when working on maths. There were many reasons for the success of the Railside students. Importantly, the students were given opportunities to work on interesting problems that required

them to think, and not just reproduce methods, and they were required to discuss mathematics with each other, increasing their interest and enjoyment. But there was another important aspect of the school's approach that is much more rare – the teachers enacted an expanded conception of mathematics and “smartness”. The teachers at Railside knew that being good at mathematics involves many different ways of working, as mathematicians' accounts tell us. It involves asking questions, drawing pictures and graphs, rephrasing problems, justifying methods and representing ideas, in addition to calculating with procedures. Instead of just rewarding the correct use of procedures the teachers encouraged and rewarded all of these different ways of being mathematical.

In the remainder of this short paper, I will outline seven of the key methods that teachers used to bring about the incredible successes they achieved. I have already mentioned that the teachers used an approach called ‘complex instruction’, designed by Liz Cohen and Rachel Lotan (Cohen, 1994; Cohen & Lotan, 1997), to make group work equal. It is a pedagogical approach designed for use in any subject areas, and most schools use it in other subjects such as humanities. At Raiside the maths department was the only department using the approach at the time of our research, although now other departments have started to use the approach as the maths department had the best state test results in the school.

Some maths departments employ group work with limited success, particularly because groups do not always function well, with some students doing more of the work than others, and some students being excluded or choosing to opt out. Complex instruction (or CI) aims to counter social and academic status differences in classrooms, starting from the premise that status differences do not emerge because of particular students but because of group *interactions*. The approach includes a number of recommended practices that the mathematics department employed and refined for use in their subject area. In the next section I will review seven of the practices that the teachers employed and that our long term observations, interviews with students, and detailed analyses, showed to be important in the promotion of high achievement and equity. The first four (multidimensional classrooms, student roles, assigning competence, and student responsibility) are recommended in the complex instruction approach, the last three (high expectations, effort over ability, and clear expectations) were consistent with the approach and they were important to the high and equitable results that were achieved.

## Complex Instruction.

### (1) Multidimensionality

In many mathematics classrooms there is one practice that is valued above all others – that of executing procedures correctly and quickly. The narrowness by which success is judged means that some students rise to the top of classes, gaining good marks and teacher praise, while others sink to the bottom with most students knowing where they are in the hierarchy created. Such classrooms are uni-dimensional – the dimensions along which success is presented are singular. A central part of the complex instruction approach is what the authors refer to as *multiple ability treatment*. The idea is that when a more open set of task requirements is given, that values many different ‘abilities,’ then students will be more engaged and more successful. At Railside the teachers created multidimensional classes by asking the question – how does a mathematician work? Of course it is important to execute procedures but this is only one aspect of mathematical work and a mathematician also needs, for example, to ask good questions, connect methods, communicate ideas in different representations, use logic and reasoning, explain well and so on. What was unusual about Railside was that they did not only value all of these ways of being mathematical, but they assessed students on them. This meant that a student who may not have been the fastest or best at following and executing methods, could be very successful if they asked good questions, or saw problems in different ways, explaining them well to others. In analysing the success of the Railside approach, we concluded that *many more students were successful, because there were many more ways to be successful*. And this success transferred to state tests even though the tests were very narrow and did not assess the broad ways of working that students had learned, as the students had learned to feel good about themselves in maths classrooms and they had developed confidence in their own work.

The teachers created multi-dimensional classes by using what they referred to as *group-worthy problems* – open-ended problems that illustrated important mathematical concepts, allowed for multiple representations, and had several possible solution paths (Horn, 2005). The teachers had created the introductory algebra course themselves, adapting problems from different published curriculum to make them group-worthy. This enabled more students to contribute ideas and feel valued. When we interviewed the students from all three schools and asked them “What does it take to be successful in math class?” a stunning 94% of students from the traditional classes said the same thing - “you need to pay careful attention”. At Railside the students answered the same question with many different practices such as: asking good questions, rephrasing problems,

explaining well, being logical, justifying work, considering answers, and using manipulatives. The different dimensions that students believed to be an important part of mathematical work at Railside were valued in the teachers' interactions and the grading system.

The multidimensional nature of the classes at Railside was an extremely important part of the increased success of students. Students were aware of the different practices that were valued and all of them felt successful because they are able to excel at some of them (in contrast to students in many schools in England who believe that they are not good at maths). One of the messages that the teachers frequently gave was that "no-one is good at all of these ways of working, but everyone is good at some of them". The following comments given by students in interviews give an indication of the multidimensionality of classes –

*Back in middle school the only thing you worked on was your math skills. But here you work socially and you also try to learn to help people and get help. Like you improve on your social skills, math skills and logic skills. (Janet, Y1)*

*With math you have to interact with everybody and talk to them and answer their questions. You can't be just like "oh here's the book, look at the numbers and figure it out"*

*Int: Why is that different for math?*

*It's not just one way to do it (...) It's more interpretive. It's not just one answer. There's more than one way to get it. And then it's like: "Why does it work"? (Jasmine, Y1)*

It is rare to hear students describe mathematics as broader and more *interpretive* than other subjects. This breadth was important to the wide rates of success and participation achieved.

## **(2) Roles**

When students were placed into groups they were also given a particular role to play, such as *facilitator, team captain, recorder/reporter* or *resource manager* (Cohen & Lotan, 1997). The idea behind this approach is that all students have important work to do in groups, without which the group cannot function. At Railside the teachers emphasized the different roles at frequent intervals, stopping, for example, at the start of class to remind facilitators to help people check their answers or show their work or to ask the group "What did you get for number 1?" Teachers also used the roles to distribute authority in the room differently – when they wanted to give new information to the class, for example, instead of talking to the whole class they would call the team captains out to

the front and tell them the information the other students needed; they would then return to their groups and share the new information. Students changed roles at the end of each unit of work. The teachers reinforced the status of the different roles and the important part they played in the mathematical work that was being undertaken. The roles contributed to the complex interconnected system that operated in each classroom, a system in which everyone had something important to do and all students learned to rely upon each other.

### **(3) Assigning Competence**

An interesting and subtle approach that is recommended within the complex instruction literature is that of *assigning competence*. This is a practice that involves teachers raising the status of students that may be of a lower status in a group, by, for example, praising something they have said or done that has mathematical value, and bringing it to the group's attention; asking a student to present an idea; or publicly praising a student's work in a whole class setting. This practice was one that I could not fully imagine until I saw it enacted. My first awareness of it came about when a quiet Eastern European boy muttered something in a group that was dominated by two happy and excited Latina girls. The teacher who was visiting the table immediately picked up on it saying "Good Ivan, that is important". Later when the girls offered a response to one of the teacher's questions he said, "Oh that is like Ivan's idea, you're building on that". He raised the status of Ivan's contribution, which would almost certainly have been lost without such an intervention. Ivan visibly straightened up and leaned forward as the teacher reminded the girls of his idea. Cohen (1994) recommends that if student feedback is to address status issues, it must be public, intellectual, specific and relevant to the group task (Cohen, 1994, p. 132). The public dimension is important as other students learn about the broad dimensions that are valued; the intellectual dimension ensures that the feedback is an aspect of mathematical work, and the specific dimension means that students know exactly what the teacher is praising.

Two of the mathematical practices that the teachers valued that seemed particularly important in the promotion of equity, were justification and reasoning. At Railside students were required to justify their answers, giving reasons for their methods, at almost all times. There are many good reasons for this – justification and reasoning are intrinsically mathematical practices (RAND, 2002; Martino & Maher, 1999) – but these practices also serve an interesting and particular role in the promotion of equity. The following boy was one of the lower achievers in the class, and it is interesting to hear him talk about the ways he was supported by the practices of justification and reasoning:

*Most of them, they just like know what to do and everything. First you're like "why you put this?" and then like if I do my work and compare it to theirs. Theirs is like super different 'cos they know, like what to do. I will be like – let me copy, I will be like "why you did this? And then I'd be like: "I don't get it why you got that." And then like, sometimes the answer's just like, they be like "yeah, he's right and you're wrong" But like – why?" (Juan, Y2)*

Juan made it clear that he was helped by the practice of justification and that he felt comfortable pushing other students to go beyond answers and explain *why* their answers were given. At Railside, the teachers carefully prioritized the message that each student had two important responsibilities – both to help someone who asked for help, but also to ask if they needed help. Both were important in the pursuit of equity, and justification and reasoning emerged as helpful practices in the learning of a wide range of students.

#### **(4) Teaching Students to be Responsible for Each Other's Learning**

A major part of the equitable results attained at Railside was the serious way in which teachers expected students to be responsible for each other's learning. Many schools employ group work which, by its nature, brings with it an element of student responsibility for others, but Railside teachers went beyond this to ensure that students took their responsibility to each other very seriously. One way in which teachers nurtured a feeling of responsibility was through the assessment system. For example, teachers occasionally graded the work of a group by rating the quality of the conversations groups had. In addition, the teachers occasionally gave group tests, which took several formats. In one version – (which often prompts a sharp intake of breath from teachers in England when I tell them about it!) – students work through a test individually, but the teachers only take in and mark one test paper from one student in each group, and that mark stood as the mark for all the students in the group. That is a very serious way that teachers communicate to students that they are responsible for each other as they learn! A third way in which responsibility was encouraged was through the practice of asking one student in a group to answer a follow-up question after a group had worked on something. If the student could not answer the question, the teacher would leave the group to further discussion before returning to ask the same student again. In the intervening time, it was the group's responsibility to help the student learn the maths they needed to answer the question.

The teaching strategy of asking one member of a group to give an answer and an explanation, without help from their group-mates, was a subtle practice that had major implications for the classroom environment. This practice meant that students were responsible to everyone in their group. In the following interview extract the students talk about this particular practice and the implications it held:

*Int: Is learning math an individual or a social thing?*

*G: It's like both, because if you get it, then you have to explain it to everyone else. And then sometimes you just might have a group problem and we all have to get it. So I guess both.*

*B: I think both - because individually you have to know the stuff yourself so that you can help others in your group work and stuff like that. You have to know it so you can explain it to them. Because you never know which one of the four people she's going to pick. And it depends on that one person that she picks to get the right answer. (Gisella & Bianca, Y2)*

The students in the extract above made the explicit link between teachers asking any group member to answer a question, and being responsible for their group members. They also communicate the shared orientation that students at Railside developed, saying that the purpose in knowing individually is not to be better than others but so “you can help others in your group.”

The four dimensions of complex instruction – of multidimensional classrooms, student roles, assigning competence, and shared responsibility, were enhanced by the 3 practices that the department chose to implement and that I will review briefly.

### **Three Practices Leading to High and Equitable Achievement.**

#### **(1) High Expectations**

It was critical to the success of the students that teachers kept the demand of lessons high, both by providing complex problems and by following up with high-level questions. When students could not complete questions the teachers would leave groups to work through their understanding rather than providing them with small structured questions that led them to the correct answer. In interviews with the students, it became clear that they appreciated the high demands placed upon them. The students' appreciation was also demonstrated through questionnaires. For example, one of the questions started with the stem: “When I get stuck on a math problem, it is most helpful when my teacher...” This was followed by answers such as “tells me the answer” “leads me through the

problem step by step” and “helps me without giving away the answer”. Students could respond to each on a four-point scale (strongly agree, agree, disagree, strongly disagree). Almost half of the Railside students (47%) *strongly* agreed with the response: “Helps me *without* giving away the answer,” compared with 27% of students in the ‘traditional’ classes at the other two schools. In interviews with the Railside students it became clear that one of the things they most appreciated about their teachers was the fact that they gave them hard work which they interpreted as the teachers *believing in them*.

## **(2) Effort Over Ability.**

In addition to the actions in which teachers engaged, the teachers also gave frequent and strong messages to students about the nature of high achievement in mathematics. Unlike many teachers in England the Railside teachers did not believe in the idea of ‘ability’ and they, continually emphasised that mathematical success comes from hard work. I have already described the multidimensionality of classrooms and the fact that teachers took every opportunity to value something students could do, but they also kept reassuring students that they could achieve anything if they put in the effort. This message was heard by students and they communicated it to us in interviews. For example:

*To be successful in math you really have to just like, put your mind to it and keep on trying – because math is all about trying. It’s kind of a hard subject because it involves many things. (...) but as long as you keep on trying and don’t give up then you know that you can do it. (Sara, Y1)*

In questionnaires, we offered the statement “Anyone can be really good at math if they try” 84% of Railside students agreed with this, compared with 52% of students in the traditional classes.

## **(3) Clear Expectations**

The final aspect of the teachers’ practice that I will highlight also relates to the expectations they offered the students. In addition to stressing the importance of effort the teachers were very clear about the particular ways of working in which students needed to engage. For example, the teachers would stop the students as they were working and talking and point out valuable ways in which they were working. In one videotaped example of this, Guillermo, the department co-chair, helped a boy named Arturo. Arturo was working on a problem about the number of pennies a person would be able to carry, considering their weight. He stopped and told the teacher that he was confused, so Guillermo told him to ask a specific question; as Arturo framed a question he realised what he

needed to do and continued with his thinking. Arturo decided the answer to the question he was working on was “550 pennies” but then stopped himself saying “No, wait, that’s not very much.” At that point Guillermo interrupted him saying:

Wait, hold on a second, two things just happened there. Number one is, when I said “what is the exact question?” you stopped to ask yourself the exact question and then suddenly you had ideas. That happens to a lot of students. If they’re confused, the thing you have to do is say, “OK what am I trying to figure out? Like exactly”, and, like, say it. So say it out loud or say it in your head but say it as a sentence. That’s number one and number two, then you checked out the answer and you realized the answer wasn’t reasonable and that is *excellent* because a lot of people would have just left it there and not said, “what, 500 pennies? That’s not very much.” (Guillermo, Math department co-chair)

Prior to the beginning of new work teachers set out the valued ways of working, encouraging students to, for example, pick “tricky” examples when writing a book (one of the projects they completed) as they would “show off” the mathematics that they knew; they also encouraged students individually as shown in the example above. The teachers communicated very clearly to students how they could achieve and what the teachers were looking for. This was also true of the teachers in the school in England that I studied (see Boaler, 2009) who also brought about high achievement and equitable outcomes.

### **Relational Equity**

It would be hard to spend 4 years in the classrooms at Railside without noticing that the students were learning to treat each other in more respectful ways than is typically seen in schools and that ethnic cliques were less evident in the mathematics classrooms than they are in most schools. Further, such behavior did not just *happen* to take place in a mathematics classroom; it was fundamentally related to the students’ conceptions of and work within mathematics. Thus, the work of students and teachers at Railside was equitable partly because they achieved more equitable outcomes on tests, with few achievement differences for students of different ethnic or gender groups, but also because they learned to act in more equitable ways in their classrooms. Because the teachers valued different ways of seeing and solving problems, students learned to appreciate the contributions of different students, from many different cultural groups and with many different characteristics and perspectives. The students reported that ethnic cliques did not develop in their

school because of the ways they worked in their maths classes. It seemed to me that the students learned something extremely important, that would serve them and others well in their future interactions in society, which is not captured in conceptions of equity that deal only with test scores or treatment in schools. I propose that such behavior is a form of equity, and I have termed it *relational equity* (see also Boaler, 2008).

It is commonly believed that students will learn respect for different people and cultures if they have discussions about such issues or read about them in English or social studies classes. I propose that all subjects have something to contribute in the promotion of equity and that maths, often regarded as the most abstract subject removed from responsibilities of cultural or social awareness, has an important contribution to make. For the respectful relationships that Railside students developed across cultures and genders that they took into their lives were only made possible by a maths approach that valued different insights, methods and perspectives in the collective solving of particular problems.

### **Conclusion.**

Railside school offers an important case of an inner-city, low-income, comprehensive school that brought about high and equitable achievement. Our four-year, longitudinal study, in which we monitored students at this and two other schools, revealed the importance of the approach that the school employed in supporting mixed ability teaching and providing high level learning opportunities for a wide range of students. Railside school is not a perfect place - the teachers would like to achieve more in terms of student achievement and the elimination of inequities, and they rarely feel satisfied with the achievements they have made to date, despite the vast amounts of time they spend planning and working. But research on urban schools, and the experiences of maths students in particular, tells us that the achievements at Railside are extremely unusual. Teachers who have heard about the achievements of Railside's maths department have asked for their curriculum so that they may use it, but while the curriculum plays a central role in what is achieved at the school, it is only one part of a complex, interconnected system. At the heart of this system is the work of the teachers, and the many different equitable practices in which they engage.

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Additional Resources for Classroom Use.

<http://www.sussex.ac.uk/education/profile205572.html>

The website above includes 2 downloadable papers:

Boaler, J (2008). Promoting 'relational equity' and high mathematics achievement through an innovative mixed ability approach. *British Educational Research Journal*.

Boaler, J & Staples, M. (2008). Creating Mathematical Futures through an Equitable Teaching Approach: The Case of Railside School. *Teachers' College Record*.

These are longer versions of this paper with more evidence and details on the approach described.

**Complex Instruction:**

Website:

<http://cgi.stanford.edu/group/pci/cgi-bin/site.cgi>

Cohen, E. (1986) *Designing groupwork: strategies for heterogeneous classrooms* (New York, Teacher's College Press).

Cohen, E. & Lotan, R. (Eds.) (1997) *Working for equity in heterogeneous classrooms: Sociological Theory in Practice* (New York, Teachers College Press).