HOW TO BEGIN A NEW TOPIC IN MATHEMATICS: DOES IT MATTER TO STUDENTS' PERFORMANCE IN MATHEMATICS?

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Abstract

Canadian data from the Third International Mathematics and Science Study – Repeated (TIMSS-R) was used to examine six different instructional methods that teachers used to introduce new topics in mathematics, in relation to student performance in six mathematical areas. Results of hierarchical linear modeling (HLM) with students nested within schools showed that the instructional method in which the teacher explains rules and definitions had no instructional effect on student performance in any mathematical area across all schools. In contrast, the instructional method in which students work together in pairs or small groups on a problem project had the single largest positive instructional effect on student performance in each and every mathematical area. We suggest that student-centered cooperative learning is more appropriate than teacher-centered lecture instruction to set the stage for learning a new topic in mathematics.

BACKGROUND

In this study, we examined the way that mathematics teachers introduce new topics in mathematics as it relates to their students' mathematics performance. We asked three research questions. The first question asked whether certain instructional methods that are used to introduce new topics in mathematics will affect students' mathematics performance.

Based on our belief in differential teacher effectiveness, we formulated the second research question: Is there significant variation in terms of teachers' instructional methods on mathematics performance of their students? Finally, we believe that a school as a whole influences the instruction of mathematics teachers within the school (often referred to as "school effects"). Therefore, the third research question investigated whether there is a significant school mean instructional effect on students' mathematics performance.

Our motivation for posing these research questions was our recognition – and serious dissatisfaction – that the research literature pays scant attention to effective ways to introduce new topics in mathematics. By effective we mean effective in terms of facilitating and promoting students' mastery of mathematical topics and, as a result, effective in terms of improving student performance in mathematics. Most often, the choice of instructional method for introducing a new topic in mathematics is largely based on traditional wisdom or instructional convenience, rather than working knowledge derived from empirical evidence of research studies. We perceive a great potential in using this issue to influence instructional approaches of teachers to induce better mathematics performance in their students.

Referring to instruction as the way in which mathematics curriculum is enacted in classrooms, Secada (1992) classified instruction in mathematics into direct instruction, continuous progress, individualized instruction, and cognitively guided instruction. "Direct instruction is a highly structured form of teacher behaviors that are thought to support student engagement in and learning of mathematics" (Secada, 1992, p. 649). This instructional format carefully sequences teacher behaviors that guide students to learn mathematics in a structural manner. A classic example of direct instruction is Active Mathematics Teaching (AMT) (Good & Grouws, 1977, 1979).

"Continuous progress includes direct instruction as one of its features; in addition, students are to progress through a well-specified hierarchy of skills, and they should be grouped on the basis of their ongoing progress through that curriculum" (Secada, 1992, p. 648-649). This instructional format closely links teacher behaviors that ensure student progress with student outcomes (mathematical knowledge and skills).

Individualized instruction recognizes individual differences in the need and ability to learn mathematics. In addition, there is recognition that students learn mathematics in uniquely different ways. Individualized instruction therefore emphasizes that instructional methods need to be different from student to student in order to facilitate all students' learning.

Cognitively guided instruction (CGI) is "based on four interlocking principles: (a) teacher knowledge of how mathematical content is learned by their students, (b) problem solving as the focus of instruction, (c) teacher access to how students are thinking about specific problems, and (d) teacher decision-making based on teachers knowing how their students are thinking" (Secada, 1992, p. 649). Unlike direct instruction, CGI does not regulate instructional behaviors directly; instead, it allows teachers the flexibility to engage students in learning based on their knowledge of their students' thinking processes.

The student questionnaire used in the Third International Mathematics and Science Study (TIMSS) contains a scale that measured the different instructional practices that mathematics teachers employed to introduce new topics in mathematics. This made TIMSS data suitable to this study. Specifically, we used the Canadian sample from the latest data from the TIMSS-Repeated (TIMSS-R). There is no federal department of education in Canada (i.e., education is a provincial jurisdiction); Thus, in absence of national (unified) curricular and instructional standards, it is likely that different instructional formats are used to a greater degree in Canada. For this reason, we considered Canadian data as ideal to examine instructional effects on mathematics performance.

METHOD

Data

Data for our analysis came from the TIMSS-R. The target population was students who enrolled in the 8th grade in the 1998-1999 school year. The TIMSS-R employed a stratified sampling procedure in which schools were first selected, and then one 8th grade class was selected from each sampled school and all students in the selected class participated in the TIMSS-R. Sampled students had an average age of 14. Characteristics of social environment, particularly those at home and in school, tend to be most influential on students at this age. Participating students took achievement tests in mathematics and science and completed questionnaires on home and school experiences related to the learning of mathematics and science. School administrators and teachers also completed questionnaires regarding school operations and classroom practices. As mentioned earlier, our analysis focused on the Canadian sample that included 8,770 students from 385 schools.

Variables

In our analysis, dependent variables were mathematics performance scores derived from the achievement test in mathematics. We considered student performance in different mathematical areas as classified in the TIMSS-R, including (a) mathematics as a whole, (b) algebra, (c) data analysis, (d) fraction, (e) geometry, and (f) measurement. Major independent variables were the instructional methods used to begin a new topic in mathematics, which were derived from student questionnaires. These instructional methods included (a) having the teacher explain the rules and definitions, (b) discussing a practical or story problem related to everyday life, (c) working together in pairs or small groups on a problem project, (d) having the teacher ask students what they know related to the new topic, (e) looking at the textbook while the teacher talks about it, and (f) trying to solve an example related to the new topic. A dichotomous variable was created to represent each instructional method. Specifically, teachers who adopted a particular method were coded as 1, whereas those who did not employ that method were coded as 0.

Other independent variables were also derived from student and school questionnaires. We selected gender, age, mother's education, father's education, immigration status, mother's immigration status, and father's immigration status to describe individual and family characteristics; class size, school male enrollment, school female enrollment, school location, school mean mother's education, and school mean father's education to describe school characteristics. Gender, immigration status, mother's immigration status, and father's immigration status were coded as dichotomous variables. Other student characteristics were continuous variables.

Class size, school male enrollment, and school female enrollment were simply numbers of students. School location was coded into a series of dichotomous variables. School mean mother's education and school mean father's education were aggregated from the student level to the school level. Note that these independent variables were used mainly as control variables to derive "purer" teacher instructional effect on student performance in various mathematical areas.

Another group of school-level variables measured the average extent to which teachers practiced each instructional method in a school. These school-level variables were labeled as school mean or average instructional effects, and each was constructed by aggregating students' responses to a particular instructional method within each school. These school-level variables then represented school mean instructional effects on academic achievement over and above teacher (individual) instructional effects. For the purpose of data analysis, all student-level and school-level variables were either grand mean centered or standardized.

Analysis

Statistically, multilevel analysis techniques were used to address our research hypotheses (see Bryk & Raudenbush 1992). We developed a series of two-level models with students (level 1) nested within schools (level 2), resulting in separate analyses for various mathematical areas and instructional methods. Specifically, the level 1 model regressed academic achievement on each instructional method in the presence of statistically significant student-level variables. This procedure measured the effect of an instructional method on academic achievement. We also allowed this effect to vary at the school level, in an attempt to examine whether teacher instructional effect varies across schools. The level 2 model then focused on school mean instructional effect over and above teacher (individual) instructional effect (associated with a particular instructional method) with adjustment for school-level variables. In other words, each school mean instructional effect was estimated in the presence of school-level variables.

RESULTS

We analyzed the effect of each instructional method to begin a new topic in mathematics on academic achievement of students in a number of mathematical areas. Table 1 presents effects of different instructional methods on academic achievement in mathematics overall. Working together in pairs or small groups on a problem project, discussing a practical or story problem related to everyday life, having the teacher ask students what they know related to the new topic, and looking at the textbook while the teacher talks about it (in this order), showed statistically significant, positive effects on overall achievement in mathematics. Unexpectedly, trying to solve an example related to the new topic had a statistically significant, negative effect on overall achievement in mathematics. Having the teacher explain the rules and definitions turned out to have no impact on overall achievement in mathematics.

Table 1: Different Instructional Methods of Beginning a New Topic in Mathematics in relation to Student Performance in Mathematics

Instructional methods	*Teacher instructional effect*	*Variation in teacher instructional effect*	*School mean instructional effect*
Having the teacher explain the rules and definitions	-0.003	0.001	0.034
Discussing a practical or story problem related to everyday life	0.065***	0.002*	-0.072
Working together in pairs or small groups on a problem project	0.121***	0.005***	0.001
Having the teacher ask us what we know related to the new topic	0.046***	0.002***	0.096
Looking at the textbook while the teacher talks about it	0.033***	0.002***	-0.120
Trying to solve an example related to the new topic	-0.019**	0.001	-0.308*

Note. * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$. Teacher instructional effect measures the effect of an instructional method on academic achievement, estimated in the presence of age, mother's education, and father's education as statistically significant covariates. Variation in teacher instructional effect measures the extent to which teacher instructional effect varies across schools. School mean instructional effect measures whether the average degree to which teachers practice an instructional method in a school influences student academic achievement, estimated in the presence of school mean father's education and school male enrollment as statistically significant covariates. There are no statistically significant school-level variables that explain the significant variation across schools in teacher instructional effect associated with either discussing a practical or story problem related to everyday life or working together in pairs or small groups on a problem project. School male enrollment (one unit = 100 students) is statistically significant in explaining the significant variation across schools in teacher instructional effect associated with having the teacher ask us what we know related to the new topic (effect = -0.008, $p = 0.025$). Rural location is statistically significant in explaining the significant variation across schools in teacher instructional effect associated with looking at the textbook while the teacher talks about it (effect = -0.050, $p = 0.041$).

The four instructional methods with statistically significant (positive) effects on overall achievement in mathematics (working together in pairs or small groups on a problem project, discussing a practical or story problem related to everyday life, having the teacher ask students what they know related to the new topic, and looking at the textbook while the teacher talks about it) also showed statistically significant variation in teacher instructional effect across schools. There was no variation in teacher instructional effect across schools associated with trying to solve an example related to the new topic and having the teacher explain the rules and definitions. Finally, only one instructional method (trying to solve an example related to the new topic) showed a statistically significant, but again negative, school mean instructional effect over and above teacher instructional effect.

Results on effects of different instructional methods to begin a new topic in mathematics on academic achievement in other mathematical areas are presented in Tables 2 to 6. Using our interpretation of Table 1 as an illustration, results in Tables 2 to 6 can be similarly interpreted. In many cases, instructional methods showed similar effects on academic achievement in other mathematical areas in comparison to those on overall achievement in mathematics. For the sake of space, we provided a summary of results across Tables 2 to 6, with an emphasis on similarities and differences in results across those tables.

Table 2: Different Instructional Methods of Beginning a New Topic in Mathematics in relation to Student Performance in Algebra

Instructional methods	*Teacher instructional effect*	*Variation in teacher instructional effect*	*School mean instructional effect*
Having the teacher explain the rules and definitions	-0.006	0.002	0.083
Discussing a practical or story problem related to everyday life	0.058***	0.002**	-0.037
Working together in pairs or small groups on a problem project	0.105***	0.007***	-0.026
Having the teacher ask us what we know related to the new topic	0.033***	0.001	0.116
Looking at the textbook while the teacher talks about it	0.013	0.003***	-0.110
Trying to solve an example related to the new topic	-0.023**	0.001	-0.295*

Note. * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$. Teacher instructional effect measures the effect of an instructional method on academic achievement, estimated in the presence of age, mother's education, and father's education as statistically significant covariates. Variation in teacher instructional effect measures the extent to which teacher instructional effect varies across schools. School mean instructional effect measures whether the average degree to which teachers practice an instructional method in a school influences student academic achievement, estimated in the presence of school mean mother's education and school male enrollment as statistically significant covariates. There are no statistically significant school-level variables that explain the significant variation across schools in teacher instructional effect associated with discussing a practical or story problem related to everyday life, working together in pairs or small groups on a problem project, or looking at the textbook while the teacher talks about it.

Table 3: Different Instructional Methods of Beginning a New Topic in Mathematics in relation to Student Performance in Data Analysis

Instructional methods	*Teacher instructional effect*	*Variation in teacher instructional effect*	*School mean instructional effect*
Having the teacher explain the rules and definitions	-0.015	0.001	-0.008
Discussing a practical or story problem related to everyday life	0.063***	0.002*	-0.040
Working together in pairs or small groups on a problem project	0.084***	0.004***	0.020
Having the teacher ask us what we know related to the new topic	0.054***	0.001	0.089
Looking at the textbook while the teacher talks about it	0.049***	0.002*	-0.085
Trying to solve an example related to the new topic	-0.019**	0.001	-0.265*

Note. * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$. Teacher instructional effect measures the effect of an instructional method on academic achievement, estimated in the presence of age, immigration status, mother's immigration status, and father's education as statistically significant covariates. Variation in teacher instructional effect measures the extent to which teacher instructional effect varies across schools. School mean instructional effect measures whether the average degree to which teachers practice an instructional method in a school influences student academic achievement, estimated in the presence of school mean mother's education and school male enrollment as statistically significant covariates. There are no statistically significant school-level variables that explain the significant variation across schools in teacher instructional effect associated with discussing a practical or story problem related to everyday life, working together in pairs or small groups on a problem project, or looking at the textbook while the teacher talks about it.

Results in Tables 2 to 6 (in relation to those in Table 1) show that having the teacher explain the rules and definitions as an instructional method to begin a new topic in mathematics had no instructional effect on student mathematics performance in any mathematical area. There was no variation in teacher instructional effect across schools associated with this particular instructional method. School mean instructional effect (over and above teacher instructional effect) turned out to be null as well.

On the other hand, the instructional methods to begin a new topic in mathematics where teachers discuss a practical or story problem related to everyday life and where students work together in pairs or small groups on a problem project had statistically significant, positive effects on student mathematics performance in each and every mathematical area. Statistically, these teacher instructional effects also varied significantly across schools in each and every mathematical area. However, we did not find any school mean instructional effects over and above teacher instructional effects in any mathematical area for either of these two instructional methods.

Table 4: Different Instructional Methods of Beginning a New Topic in Mathematics in relation to Student Performance in Fraction

Instructional methods	*Teacher instructional effect*	*Variation in teacher instructional effect*	*School mean instructional effect*
Having the teacher explain the rules and definitions	0.008	0.002	0.031
Discussing a practical or story problem related to everyday life	0.076***	0.002***	-0.066
Working together in pairs or small groups on a problem project	0.123***	0.006***	0.013
Having the teacher ask us what we know related to the new topic	0.058***	0.002***	0.096
Looking at the textbook while the teacher talks about it	0.055***	0.004***	-0.113
Trying to solve an example related to the new topic	-0.013*	0.001	-0.312*

Note. * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$. Teacher instructional effect measures the effect of an instructional method on academic achievement, estimated in the presence of age and father's education as statistically significant covariates. Variation in teacher instructional effect measures the extent to which teacher instructional effect varies across schools. School mean instructional effect measures whether the average degree to which teachers practice an instructional method in a school influences student academic achievement, estimated in the presence of school mean mother's education and school male enrollment as statistically significant covariates. There are no statistically significant school-level variables that explain the significant variation across schools in teacher instructional effect associated with discussing a practical or story problem related to everyday life. Suburban location is statistically significant in explaining the significant variation across schools in teacher instructional effect associated with working together in pairs or small groups on a problem project (effect = -0.058, $p = 0.036$). School male enrollment and school female enrollment (both with one unit = 100 students) are statistically significant in explaining the significant variation across schools in teacher instructional effect associated with having the teacher ask us what we know related to the new topic (effect = -0.027, $p = 0.006$; effect = 0.019, $p = 0.049$). Rural location is statistically significant in explaining the significant variation across schools in teacher instructional effect associated with looking at the textbook while the teacher talks about it (effect = -0.049, $p = 0.038$).

Having the teacher ask students what they know related to the new topic as an instructional method to begin a new topic in mathematics had statistically significant, positive effects on student mathematics performance in all mathematical areas. Statistically, this teacher instructional effect varied significantly across schools in mathematics (as a whole) and in fractions, but not in algebra, data analysis, geometry, and measurement. There was no school mean instructional effect over and above teacher instructional effect.

Table 5: Different Instructional Methods of Beginning a New Topic in Mathematics in relation to Student Performance in Geometry

Instructional methods	*Teacher instructional effect*	*Variation in teacher instructional effect*	*School mean instructional effect*
Having the teacher explain the rules and definitions	0.002	0.001	0.072
Discussing a practical or story problem related to everyday life	0.078***	0.002***	-0.153
Working together in pairs or small groups on a problem project	0.123***	0.007***	-0.067
Having the teacher ask us what we know related to the new topic	0.054***	0.001	0.066
Looking at the textbook while the teacher talks about it	0.072***	0.005***	-0.152*
Trying to solve an example related to the new topic	-0.005	0.001	-0.307**

Note. * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$. Teacher instructional effect measures the effect of an instructional method on academic achievement, estimated in the presence of age, gender, and father's education as statistically significant covariates. Variation in teacher instructional effect measures the extent to which teacher instructional effect varies across schools. School mean instructional effect measures whether the average degree to which teachers practice an instructional method in a school influences student academic achievement, estimated in the presence of school mean father's education and school female enrollment as statistically significant covariates. There are no statistically significant school-level variables that explain the significant variation across schools in teacher instructional effect associated with discussing a practical or story problem related to everyday life. Class size is statistically significant in explaining the significant variation across schools in teacher instructional effect associated with working together in pairs or small groups on a problem project (effect = 0.005, $p = 0.023$). Rural location is statistically significant in explaining the significant variation across schools in teacher instructional effect associated with looking at the textbook while the teacher talks about it (effect = -0.071, $p = 0.010$).

Looking at the textbook while the teacher talks about it as an instructional method to begin a new topic in mathematics had statistically significant, positive effects on student mathematics performance in all mathematical areas except algebra. Statistically, this teacher instructional effect also varied significantly across schools in all mathematical areas. We did find one statistically significant, positive school mean instructional effect over and above teacher instructional effect in geometry.

The instructional method to begin a new topic in mathematics in which teachers try to solve an example related to the new topic had statistically significant, negative effects on student mathematics performance in each and every mathematical area. In addition, this instructional method was the only one that had statistically significant school mean instructional effects over and above teacher instructional effects in all mathematical areas. These effects, however, were all negative. Finally, teacher instructional effect associated with this particular instructional method did not vary across schools.

Table 6: Different Instructional Methods of Beginning a New Topic in Mathematics in relation to Student Performance in Measurement

Instructional methods	*Teacher instructional effect*	*Variation in teacher instructional effect*	*School mean instructional effect*
Having the teacher explain the rules and definitions	-0.004	0.001	0.012
Discussing a practical or story problem related to everyday life	0.043***	0.002***	-0.121
Working together in pairs or small groups on a problem project	0.099***	0.004***	0.001
Having the teacher ask us what we know related to the new topic	0.030***	0.001	0.082
Looking at the textbook while the teacher talks about it	0.024*	0.004***	-0.109
Trying to solve an example related to the new topic	-0.020**	0.001	-0.341**

Note. * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$. Teacher instructional effect measures the effect of an instructional method on academic achievement, estimated in the presence of age, immigration status, mother's education, and father's education as statistically significant covariates. Variation in teacher instructional effect measures the extent to which teacher instructional effect varies across schools. School mean instructional effect measures whether the average degree to which teachers practice an instructional method in a school influences student academic achievement, estimated in the presence of school mean mother's education and school male enrollment as statistically significant covariates. There are no statistically significant school-level variables that explain the significant variation across schools in teacher instructional effect associated with either discussing a practical or story problem related to everyday life or working together in pairs or small groups on a problem project. Rural location is statistically significant in explaining the significant variation across schools in teacher instructional effect associated with looking at the textbook while the teacher talks about it (effect = -0.076, $p = 0.005$).

DISCUSSION

Our analysis of the effects of different instructional methods to begin a new topic in mathematics on student mathematics performance has important implications for classroom mathematics instruction. Several patterns have clearly emerged from our analysis, which has identified the most and the least effective instructional methods to introduce new topics in mathematics in relation to student mathematics performance. Overall, our findings indicate that different instructional methods to begin a new topic in mathematics do have different impacts on student mathematics performance. In other words, the way that mathematics teachers introduce a new topic in mathematics contributes to student learning and, therefore, achievement.

Results for the method having the teacher explain the rules and definitions as an instructional method to begin a new topic in mathematics are interesting in two respects. First, there was no impact of this instructional method on student mathematics performance in any mathematical area across all 385 schools. Second, the average extent to which teachers practiced this instructional method in a school had no impact on student mathematics performance in any mathematical area across all 385 schools. We suggest that these findings are a good indication of the total ineffectiveness of having mathematics teachers explain the rules and definitions as an instructional method to begin a new topic in mathematics.

In contrast, the instructional method to begin a new topic in mathematics in which students work together in pairs or small groups on a problem project stood out on two accounts. First, among all instructional methods to begin a new topic in mathematics, this instructional method had the single largest positive instructional effect on student mathematics performance in each and every mathematical area. In fact, this instructional method had an effect several times larger than other instructional methods that showed statistically significant, positive instructional effects including discussing a practical or story problem related to everyday life, having the teacher ask students what they know related to the new topic, and looking at the textbook while the teacher talks about it. We conclude that working together in pairs or small groups on a problem project was the most effective instructional method to begin a new topic in mathematics, as far as student mathematics performance is concerned.

Second, working together in pairs or small groups on a problem project as an instructional method to begin a new topic in mathematics showed the largest variation across schools in teacher instructional effect on student mathematics performance in each and every mathematical area. This finding indicates that in some schools, this instructional method had much larger effects on student mathematics performance, whereas in other schools, it had much smaller effects. Based on this finding, we conclude that there were schools considerably successful in using this instructional method to promote student mathematics performance. Further investigations into why working together in pairs or small groups on a problem project (as an instructional method to begin a new topic in mathematics) was so successful in promoting student mathematics performance in some schools may inform mathematics educators about, for example, the classroom condition that facilitates the effective use of this instructional method.

Other instructional methods to being a new topic in mathematics including discussing a practical or story problem related to everyday life, having the teacher ask students what they know related to the new topic, and looking at the textbook while the teacher talks about it are in between the most effective and the least effective instructional methods in terms of student mathematics performance (as discussed above). Specifically, these instructional methods can be characterized as much more effective than having the teacher explain the rules and definitions but much less effective than working together in pairs or small groups on a problem project. Among these three instructional methods to being a new topic in mathematics, discussing a practical or story problem related to everyday life showed the largest positive impact on student mathematics performance in each and every mathematical area. In this sense, this instructional method was more effective than having the teacher ask students what they know related to the new topic and looking at the textbook while the teacher talks about it.

Discussing a practical or story problem related to everyday life as an instructional method to being a new topic in mathematics showed the smallest variation in teacher instructional effect on student mathematics performance in each and every mathematical area among instructional methods with statistically significant variation in teacher instructional effect. To some extent, this finding implies that discussing a practical or story problem related to everyday life had relatively more homogeneous effects (than other instructional methods) on student mathematics performance across schools. Unlike working together in pairs or small groups on a problem project that had much larger teacher instructional effects in some schools than other schools, students benefited to a more equivalent extent in mathematics performance across schools from their teachers' discussing a practical or story problem related to everyday life as an instructional method to introduce new topics in mathematics.

We found an unexpected result regarding trying to solve an example related to the new topic as an instructional method to being a new topic in mathematics. This instructional method demonstrated a statically significant, negative effect on student mathematics performance in each and every mathematical area. In terms of the average extent to which teachers in a school practiced this instructional method, students in schools where teachers in general practiced more on trying to solve an example related to the new topic as the way to introduce new topics in mathematics demonstrated poorer mathematics performance in each and every mathematical area. We note that this school-level disadvantage was over and above the disadvantage associated with teacher instructional effect of this method. This means double disadvantages for students whose mathematics teachers adopted this instructional method. Therefore, trying to solve an example related to the new topic as an instructional method to begin a new topic in mathematics actually harmed students in mathematics performance.

To some extent, the negative instructional effect associated with trying to solve an example related to the new topic is even less preferable than the absence of any instructional effect associated with having the teacher explain the rules and definitions. With data from the TIMSS-R, we were unable to account for this unexpected finding associated with trying to solve an example related to the new topic as an instructional method to begin a new topic in mathematics. We can only speculate. In using this instructional method, mathematics teachers often attempt to foreshadow the use of concepts and principles to be learned in solving problems. It is then possible that inappropriate examples may actually confuse students and create incorrect perceptions among them about a new topic that interfere later on with the actual learning of the new topic. Again, this explanation is our speculation. We do not have empirical data to examine this hypothesis which we offer to researchers for further investigations.

Finally, we want to touch on the debate between teacher-centered lecture instruction and student-centered cooperative learning. Among the six instructional methods to begin a new topic in mathematics that we have examined in this study, some clearly lean towards traditional teacher-centered instructional practice. Having the teacher explain the rules and definitions is one such typical teacher-centered lecture instruction. On the other hand, some other instructional methods are clearly more related to student-centered cooperative learning. Working together in pairs or small groups on a problem project is one such typical student-centered instructional practice.

Although our study is neither aimed nor equipped to evaluate the effectiveness of these two general types of instructional practices, it has offered some (indirect) insights into this debate. Findings in our study certainly lean towards supporting student-centered cooperative learning rather than teacher-centered lecture instruction, as far as student mathematics performance in relation to how mathematics teachers begin a new topic is concerned. As a matter of fact, our analysis has revealed findings in sharp contrast. Recall that having the teacher explain the rules and definitions failed to show any instructional effect on student mathematics performance in any mathematical area across all (385) schools, whereas working together in pairs or small groups on a problem project showed the single largest positive instructional effect in each and every mathematical area among all (six) instructional methods that we examined.

In addition, among all (four) instructional methods with statistically significant, positive instructional effects on student mathematics performance, looking at the textbook while the teacher talks about it, another typical teacher-centered instructional practice, was the least effective in five out of six mathematical areas. It appears that working together in pairs or small groups on a problem project is able to lay a substantially better foundation to facilitate student learning in mathematics than both having the teacher explain the rules and definitions and looking at the textbook while the teacher talks about it. Therefore, we suggest that student-centered cooperative learning is more appropriate than teacher-centered lecture instruction to set the stage for the learning of a new topic in mathematics.

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