

A CONCEPTUAL FRAMEWORK FOR STUDYING CURRICULAR EFFECTS ON STUDENTS' LEARNING: CONCEPTUALIZATION AND DESIGN IN THE LIECAL PROJECT

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In the United States, the debate about how to conduct studies that yield adequate information about the effect of curricula on students' learning has been as heated as the debate about how well Standards-based curricula promote achievement for all students. In this paper, we present a conceptual framework for studying curricular effects on students' learning by discussing the conceptualization and design of a U.S. National Science Foundation-funded project called the LieCal Project. This longitudinal project is to investigate whether the Connected Mathematics Program (CMP) can effectively enhance student learning in algebra.

INTRODUCTION

Advocates of mathematics education reform often attempt to influence classroom practice, and hence, students' learning, by means of changes in curricula. In the late 1980s and early 1990s, the National Council of Teachers of Mathematics (NCTM) in the United States published its *Standards* documents, which provided recommendations for improving K-12 school mathematics (NCTM, 1989, 1991). Then, a number of *Standards*-based school mathematics curricula were developed and implemented to align with the recommendations in the *Standards*.

The implementation of *Standards*-based instructional materials requires change not only in how mathematics is viewed but also in how mathematics is taught and learned. Thus, teachers and school districts face challenges when trying to implement *Standards*-based curricula. Moreover, because the *Standards*-based curricula claim to have different learning goals, and because they also look very different than traditional mathematical curricula, some parents, professionals, and school communities challenge both the new goals and the efficacy of these new curricula. In the past several years, there have been heated debates over the mathematics education reform movement in general and *Standards*-based curricula in particular in the United States (Senk, & Thompson, 2003). As the debates continue, there is an increasing demand for data that show the extent to which *Standards*-based curricula promote achievement for all students (Kilpatrick, 2003; NRC, 2004). Unfortunately, the debate about how to conduct studies that yield adequate information about the effect of curricula on students' learning has been as heated as the debate about how well *Standards*-based curricula promote achievement for all students.

The purpose of this paper is to provide a conceptual framework for studying curricular effects on students' learning by discussing the conceptualization and design of the LieCal Project (Longitudinal Investigation of the Effect of Curricula on

Algebra Learning). We first provide a brief description of the project, and then present the conceptualization and design of the Project.

DESCRIPTION OF THE LIECAL PROJECT

The LieCal Project investigates whether the Connected Mathematics Program (CMP) can effectively enhance student learning in algebra. This is a complete, *Standards*-based, middle school program (Lappan et al., 2002). The LieCal Project investigates not only the ways and circumstances under which the CMP curriculum can or cannot enhance student learning, but also the characteristics of the curriculum and implementation that lead to student achievement gains. We are conducting the project in 16 middle schools of an urban school district in the United States. Eight of the participating schools have adopted the CMP curriculum and the other eight use a non-CMP curriculum. All the mathematics teachers in each school and all their students participate in the project, beginning with the 6th grade. During the first year of the project, 25 CMP classes (about 700 students) and 24 non-CMP classes (about 700 students) participated in the project. All these 6th-grade students will be closely followed for three years as they move to 7th and 8th grade within the same schools. In addition, about 100 of the CMP students and 100 of the non-CMP students will be closely followed as they move into 9th grade in the district’s high schools.

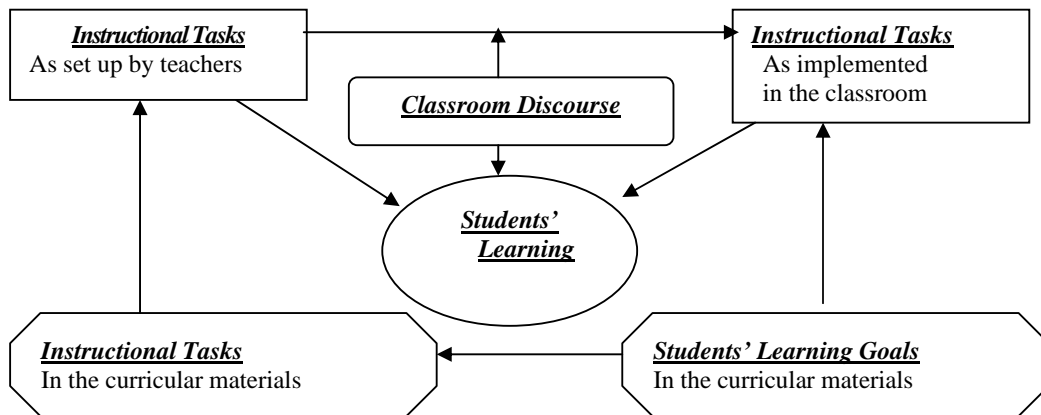


Figure 1: LieCal Research Framework

CONCEPTUALIZATION AND DESIGN IN THE LIECAL PROJECT

Figure 1 above shows the framework for conceptualizing and designing the LieCal Project. In the figure, the center is students’ learning since the central goal of curriculum reform is to improve learning opportunities for all students. Although the curriculum itself provides the foundation for student learning in the classroom, the implementation of the curriculum is the ultimate arbiter of student learning. Therefore, the bottom level of the framework illustrates the foundational role played by the intended curriculum, while the placement of the implemented curriculum at the top level illustrates the decisive role played by the teacher.

Assessing Students' Learning. In order to examine the effect of curricula, we need to investigate its impact on students' learning. Studies of mathematics learning over the years have often focused on identifying the ways that students' actions demonstrate a propensity to "think mathematically" (e.g., Burton, 1984; Kieran and Pirie, 1991; Krutetskii, 1976). These studies suggest that we need to be very broad in assessing the mathematical thinking of students. For example, while we know that students need to have algorithmic knowledge to solve many kinds of problems, we also know that algorithmic knowledge does not ensure that students have the conceptual knowledge needed to solve non-routine or novel problems (Cai, 1995; NRC, 2001a; Steen, 1999). Hence, it is crucial that studies of learning include tasks that measure students' high-level thinking skills as well as their routine problem-solving skills. Obviously, higher-order thinking skills are important, as is fluency in computation and symbolic manipulations. However, having higher-order thinking skills does not necessarily imply that students possess basic computational skills or vice versa. In the LieCal Project, students' learning is assessed in a multi-dimensional manner, beyond symbol manipulation and correctness.

Beyond symbol manipulation. Learning mathematics is much more than just doing computations and solving equations. The heart of measuring students' learning is the set of tasks on which achievement is to be assessed (Mislevy, 1995; NRC, 2001b). In the LieCal Project, a combination of multiple-choice and open-ended assessment tasks is used to measure students' performance. Because of their potential for broad content coverage and objective scoring, their highly reliable format, and their low cost, multiple-choice questions are used to assess whether students have learned the basic knowledge required to perform competently in algebra. However, multiple-choice questions are more appropriate for measuring procedural knowledge and basic skills than conceptual understanding (Magone et al., 1994). Also, it is difficult to infer students' cognitive processes from their responses to multiple-choice items. Thus, in addition to multiple-choice questions, open-ended tasks are included in assessing student performance in the LieCal project. Such open-ended tasks provide a better window into the thinking and reasoning processes involved in students' problem solving. In responding to open-ended tasks, students are required to show their solution processes and provide justifications for their answers. Since performing open-ended tasks is time-consuming, and since only a small number of these tasks can be administered to students within a testing period, and also, since grading students' responses to such items is labor-intensive, therefore a matrix sampling design of open-ended tasks is used in the LieCal Project to assess student performance. The use of a combination of multiple-choice and open-ended tasks provides information to answer questions such as "Does the curricular emphasis on conceptual understanding come at the expense of fluency with basic skills?"

Beyond Correctness. It is useful to know the differences between the performance mean scores on various types of tasks of students using a variety of curricula. However, such simple comparisons do not provide a complete profile of what CMP

and non-CMP students can and cannot do. Indeed, comparing the performance of students from different mathematical programs on correctness of individual tasks is not particularly revealing without some exploration of the thinking and methods that led students to their answers. For example, two students may receive the same mean score, but use very different solution strategies. Also, two students may receive the same mean score, but may make very different errors. The ways that students represent their solutions reflect the ways they process a problem and thus provide insight into their mathematical ideas and thinking processes. The use of open-ended assessment tasks makes it possible not only to measure students' higher-order thinking skills and conceptual understanding, but also to analyze students' solution strategies, representations, and mathematical justifications (Cai, 1997).

In the LieCal Project, we use both state and researcher-administered tests to measure the learning outcomes of students using CMP and Non-CMP curricula. The state tests assess a broad spectrum of mathematical thinking, as well as reading and writing skills. The two PI-administered tests assess students' thinking and reasoning skills in both pre-algebra and algebra. The reading and writing scores are used both as covariates (examining the growth in math achievement) and dependent variables (examining the growth in reading and writing) in our analyses. We regard reading and writing as dependent variables to examine whether the CMP curriculum impacts students' learning in language arts. Because of its increased emphasis on reading and writing, CMP could conceivably enhance students' reading and writing scores.

Examining the Fidelity of Implementation. To understand the impact of curricula on students' learning, it is important to examine the relationship between the degree of curriculum implementation and student achievement (Cohen & Hill, 2000). It is possible that teachers vary widely in their commitment to a curriculum. Teachers using the CMP curriculum may supplement widely, present the new content in a lecture mode, or continue to use the old program (Kilpatrick, 2003). On the other hand, teachers using a non-CMP curriculum may supplement widely with CMP-type curricular materials. Since the effectiveness of curricula depends critically on how well teachers understand and implement them, studies on the effectiveness of school curricula must gather data on how the teachers use the curricula (Kilpatrick, 2003; NRC, 2004). Therefore, to study the effects of curriculum on students' learning, it is critical to examine the fidelity of curricular implementation, as well as the experiences students undergo in the classrooms using different curricula.

To track the fidelity of curricular implementation in the LieCal Project, four types of data are collected from the participating teachers: teacher logs, classroom observations, assigned homework, and pre- and post-instruction interviews. Each teacher participant is asked to keep a log that records the major instructional activities conducted each week and the supplementary materials used. The teacher logs are analyzed to determine the number of units and number of activities taught each semester as well as the kinds of supplementary materials used during the semester. Each semester, trained research specialists observe two consecutive lessons taught by

each participating teacher, and they conduct pre- and post-observation interviews. We have developed a protocol to guide the classroom observations. The observation protocol helps us focus on the critical features of classroom instruction illustrated in the LieCal framework shown in Figure 1 above: (1) learning goals; (2) mathematical tasks; and (3) classroom discourse. The goal of our classroom observations is not just to describe each of these features. Rather, our goal is to provide a profile of what CMP and non-CMP classroom instruction looks like, and to identify teachers' levels of implementation in their classrooms.

Learning Goals. There are important connections between the goals for learning and the teaching practices that amplify students' abilities to accomplish these goals (Bransford et al., 2000; NAE, 1999). In the complex enterprise of teaching, teachers encounter many unexpected events. Although a teacher has an overall plan, she/he cannot follow exactly a detailed script for action. With clear learning goals for a lesson, the teacher can make immediate decisions to address the unexpected and guide students toward the learning goals. Therefore, we examine the kinds of learning goals CMP and non-CMP teachers set. We also analyze how the teachers set learning goals for each lesson and how they use them to guide each lesson.

Mathematical tasks. Mathematical tasks govern not only students' attention to particular aspects of content, but also their ways of processing information (Doyle, 1983; NCTM, 1991; Stein et al., 1996). However, only "worthwhile problems" give students the chance to solidify and extend what they know and stimulate learning (NCTM, 1991). Regardless of the context, worthwhile tasks should be intriguing, with a level of challenge that invites speculation and hard work. Tasks that are truly problematic, can promote students' conceptual understanding, foster their ability to reason and communicate mathematically, and capture their interest and curiosity (NCTM, 1991). In the LieCal project we examine both *what* mathematical tasks CMP and non-CMP teachers select and *how* they use these tasks to maximize students' opportunities in classrooms.

Classroom discourse. Worthwhile mathematical tasks alone do not guarantee students' learning. They are important, but not sufficient, for effective mathematics instruction because worthwhile tasks may not be implemented as intended. Stein et al. (1996) found that only about 50% of the tasks that were set up to require students to apply procedures with meaningful connections were implemented effectively. In the classroom, students' actual opportunities to learn depend not only on the type of mathematical tasks that teachers present, but also on the kind of discourse that teachers orchestrate to implement the tasks toward learning goals (Cazden, 1986). In the LieCal project we examine how CMP and non-CMP teachers decide what aspects of a task to highlight, how they organize and integrate students' work, and what questions they ask to challenge those with varied levels of expertise.

Level of Implementation. We analyze teacher logs, pre- and post-observation interviews, assigned homework and classroom observations to ascertain the level of

each teacher's implementation of the CMP or non-CMP curriculum. Using the data, we determine an implementation level (High, Medium, or Low) according to (1) the extent of coverage of the curricular materials, (2) the consistency between the intended and implemented curricular goals, (3) the congruence between instruction and curriculum design of the textbooks, and (4) the length of the use of the curriculum (NRC, 2004).

Level of Conceptual Understanding. Using a non-CMP curriculum does not imply traditional pedagogy. When a teacher uses a non-CMP curriculum, it is possible that the teacher is teaching in such a way that she/he fosters students' conceptual understanding of algebraic ideas at a Low, Medium, or High level. For example, to foster a *High level* of conceptual understanding, the teacher would guide students to develop procedures with understanding, apply prior knowledge to a new situation, use mathematics known to establish and extend new knowledge, and pose problem situations to explore new mathematical ideas. To foster a *Low level* of conceptual understanding, the teacher would teach discrete concepts and skills without making connections to prior knowledge.

In our data analysis, we compare the learning outcomes of CMP classrooms having High, Medium, or Low implementation levels to the learning outcomes of non-CMP classrooms (regardless of conceptual understanding level). We also compare the learning outcomes of CMP classrooms having High, Medium, or Low implementation levels respectively to the learning outcomes of the non-CMP classrooms having High, Medium, or Low conceptual understanding.

Analyzing the CMP and Non-CMP Curricula. Research consistently has shown that student achievement is highly correlated with intended curricular treatment (Schmid et al., 2002). To understand the differential effects of a curriculum on students' learning, it is necessary to identify the unique features of the curriculum that were designed specifically to foster students' learning with understanding (NRC, 2004). In the LieCal project, the algebra strands in both the CMP and non-CMP curricula are being analyzed from three inter-related perspectives: (1) goal specification, (2) content coverage, and (3) process coverage. We developed and successfully used this framework to analyze several elementary school curricula.

Goal Specification. We first identify the algebraic thinking goals in the CMP and non-CMP curricula. In this dimension of the analysis, we not only are identifying algebra-related goals in each curriculum, but we are also identifying a set of specific mathematics problems in each curriculum that can be assigned by teachers to determine whether their students have reached the goals.

Content Coverage. For our second perspective, we are identifying the BIG IDEAS of algebraic thinking in each of the CMP and non-CMP curricula. A big idea of algebra is an essential concept or technique for reasoning about quantitative conditions and relationships. In our analysis, we focus on the following commonly accepted algebraic ideas: variables, patterns and relationships, proportional reasoning,

equivalence of expressions, equation and equation solving, representation and modeling. In our analysis, we also examine how each of the big ideas develops throughout each of the CMP and non-CMP curricula.

Process Coverage. Algebra is much more than just solving for x and y ; it is also a way of thinking. When people think algebraically to solve problems, various habits of thinking come into play. Curricula can serve to demystify algebra by providing activities that foster these sorts of thinking in students. Therefore, while we are examining the development of each of the big ideas of algebraic thinking, we are also examining how CMP and non-CMP curricula help students make the connection between the way these habits of thinking are employed in their pre-algebra experience, and the way they are employed when doing formal algebra.

CONCLUSION

In the United States, the debate about how to conduct studies that yield adequate information about the effect of curricula on students' learning has been as heated as the debate about how well Standards-based curricula promote achievement for all students. In this paper, we have presented a conceptual framework for studying curricular effects on students' learning by discussing the conceptualization and design of the LieCal Project. The framework emphasizes the assessment of students' learning in a multi-dimensional manner (beyond both symbol manipulation and correctness), examining the fidelity of curricular implementation, and identifying important features of the curricula being studied. We hope that this framework can be used by researchers to design and conduct studies that provide compelling data about the relative effectiveness of different types of curricula.

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