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A STUDY OF THE INSTRUCTIONAL EFFECTIVENESS OF Math Expressions Common Core © 2013

Report Number 473

July 2014

Contents

ABSTRACT

To help school students develop knowledge, understanding, and skills of mathematics. ***Houghton Mifflin Harcourt*** has published, ***Math Expressions Common Core © 2013*** for students in grades K to 6***. Math Expressions Common Core © 2013*** combines elements of standards-based instruction with traditional approaches. Through drawings, conceptual language, and real-world examples, it is designed to help students make sense of mathematics.

Houghton Mifflin Harcourt contracted with the ***Educational Research Institute of America*** (ERIA) to conduct an academic year-long study to test the effectiveness of the program. The study was conducted with students in grades 2 and 4 during the 2013/2014 academic year.

The Iowa Test of Basic Skills: Mathematics © 2012 published by Riverside Press was used for pretesting and post-testing. At grade 2 the Form E, Level 8 was used and at grade 4 Form E, Level 10 was used.

The results showed that the ***Math Expressions Common Core*** classes made statistically significant gains at both grades 2 and 4 over the course of the year. The increases at both grades were greater than a one year grade equivalent increase and the effect sizes were large. The results also showed the ***Math Expressions Common Core*** program proved effective with both higher and lower pretest scoring students. Descriptive analyses of the grade equivalent scores showed very positive increases at both grade 2 and grade 4.

Overview of the Study

This report describes a 2013-2014 academic year study with students in grade 2 and 4 to determine the impact of the ***Math Expressions Common Core © 2013*** program for elementary grade level students. ***Math Expressions Common Core*** reflects the most recent research on effective math instruction and fits the learning progressions, the core grade-level goals, and the dual focus on understanding and fluency of the Common Core State Standards.

Houghton Mifflin Harcourt school publishers contracted with the *Educational Research Institute of America* (ERIA) to conduct a full academic year study to determine the program's effectiveness. The ***Math Expressions Common Core © 2013*** was the primary instructional program in the tryout classes.

The program is described by the publisher on the Houghton Mifflin Harcourt web site as follows:

> *Math Expressions Common Core focuses on the priority core concepts at each grade level, identified by the Common Core State Standards, to build in-depth understanding of major mathematical ideas. The Standards for Mathematical Practice are incorporated into all of the lessons in the Math Expressions program, and the Learning Progressions are referenced throughout the Teacher's Edition. Based on the NSF-funded* Children's Math World project and over ten years of research, Math Expressions Common Core is proven to be effective in raising student achievement. Hands-on and inquiry driven, Math Expressions Common Core teaches students how to represent solutions and explain their answers. This approach helps develop problem-solving and reasoning skills. The strong emphasis in Math Expressions Common Core on representation and discussion opens up the world of mathematics to all learners. Every lesson includes intervention, on-level, and challenge differentiation to support classroom needs. Math Expression Common Core is the only U.S. curriculum developed using the methods of learning science design research. It is based on the research results of the Children's Math Worlds (CMW) NSF-funded research project. Both the program and the research have a focus on conceptual understanding intertwined with the other components of math proficiency.*
>
> ** This material is based upon work supported by the National Science Foundation under grant numbers ESI-9816320, REC-9806020, and RED-935373. Any opinions, findings, and conclusions or recommendations in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.*

Research Questions

The following research questions guided the design of the study and the data analyses:

1. Is ***Math Expressions Common Core*** effective in improving the mathematics knowledge, skills, and understanding of grade 2 and grade 4 students?
2. Is ***Math Expressions Common Core*** effective in improving the mathematics knowledge, skills, and understanding of lower performing as well as higher performing grade 2 and grade 4 students?

Design of the Study

The program's efficacy was evaluated using a pretest/posttest design. The study took place during the 2013/2014 academic year in four different states in eight different schools. The program was used by a total of 30 different teachers at grade 2 and 24 different teachers at grade 4.

Pre-tests and post-tests were administered at the beginning and end of the academic year. The test was the ***Iowa Tests of Basic Skills: Mathematics*** published by *Riverside Press*. The publisher describes the mathematics test as follows:

> *In accordance with the Curriculum and Evaluation Standards for School Mathematics of the National Council of Teachers of Mathematics (NCTM), the Math tests at all levels do much more than assess skill in solving numerical problems. The tests emphasize the ability to do quantitative reasoning and to think mathematically in a wide variety of contexts.*

Pretest and post-test administration was under the direction of the classroom teacher. The tests were scored by *Riverside Press* and all tests were returned to ERIA for analyses.

Timeline and Program Use

The teachers used the ***Math Expressions Common Core*** text as their primary instructional program. The teachers reported using the program 5 days per week and for an average of over 55 minutes per day over the entire academic year. Pretests were administered the middle of September, 2013 and posttests were administered the end of May, 2014.

Description of the Research Sample

Tables 1 and 2 provide the demographic characteristics of the schools included at each grade level. Some of the schools were the same for both grade levels and some were just grade 2 or just grade 4 for other schools. It is important to note that the school data does not provide a description of the make-up of the classes that participated in the study. However, the data does provide a general description of the school and, thereby, an estimate of the make-up of the classes included in the study.

Table 1

Grade 2 Schools Included in the Study: Demographic Characteristics

School	State	Location	Grades	Enrollment	% Minority	% Free/Reduced Lunch
1	WI	Suburban	PK-5	723	20%	17%
2	WI	Rural	PK-2	450	5%	46%
3	IL	Rural	PK-12	500	0	13%
4	MI	Suburban	PK-5	550	9%	30%
5	AZ	Suburban	PK-5	747	33%	39%
6	AZ	Suburban	K-6	637	33%	30%
7	AZ	Suburban	PK-5	705	31%	25%
Average				*616*	*19%*	*29%*

Table 2

Grade 4 Schools Included in the Study: Demographic Characteristics

School	State	Location	Grades	Enrollment	% Minority	% Free/Reduced Lunch
1	WI	Suburban	PK-5	723	20%	17%
2	WI	Rural	3-5	360	5%	13%
3	IL	Rural	PK-12	500	0	13%
4	MI	Suburban	PK-5	550	13%	30%
5	AZ	Suburban	PK-5	747	33%	39%
6	AZ	Suburban	K-6	637	33%	30%
7	AZ	Suburban	PK-5	705	31%	25%
Average				*603*	*19%*	*24%*

Description of the Assessment

The pretest and posttest used in the study were the Iowa Tests of Basic Skills: Mathematics. The descriptions of each of the two tests as reported in the test manual are as follows:

LEVEL 8 (GRADE 2)

The test is administered in two separate sessions and all 46 questions are read aloud to the students by the teacher.

In Part 1, the response options for each question are either pictorial or numerical. Students are required to demonstrate their understanding of, and ability to apply, a variety of concepts in the areas of:

- number sense and operations
- geometry
- measurement
- number sentences

In Part 2, some questions involve the interpretation of data presented in graphs or tables: students locate data, compare amounts, or develop generalizations.

For some other questions, brief word problems are presented, students solve the problems, and then record their answers according to the choices provided. One choice in each set is N, meaning that the problem's solution is not given among the choices presented. For some other questions, students select a number sentence that could be used to solve the problem.

LEVEL 10 (GRADE 4)

The test includes two parts.

Mathematics: Students must demonstrate an understanding of mathematics concepts, relationships, visual representations, and problem solving.

Computation: Most problems in the Computation test require the use of one arithmetic operation—addition, subtraction, multiplication, or division. The problems require operations with whole numbers, fractions, decimals, or various combinations of these. Students must solve a problem and compare their answer with the choices given. The fourth option in each question is "N," meaning the correct answer is not given among the choices provided.

The 50 questions cover:

- number sense and operations
- algebraic patterns and connections
- data analysis

Data Analyses

Data analyses were conducted separately for each grade. The primary scores used were the standard scores provided by the test publisher. These scores are basically a linear transformation of the raw scores and the scale goes across all grade levels. In addition, descriptive analyses were used to assess the grade equivalent (GE) score for each student. The GE scores were provided for each student by *Riverside Press*.

Data analyses and descriptive statistics were computed for the standard scores from the ***Iowa Tests of Basic Skills: Mathematics*** assessments. The ≤.05 level of significance was used as the level at which increases would be considered statistically significant for all of the statistical tests.

The following statistical analyses were conducted to compare students' pretest scores to posttest scores:

- A paired comparison *t*-test was used to compare the pretest mean standard scores with the posttest mean standard scores for all students.
- The students were split into two groups based on pretest scores. Paired comparison *t*-tests were used with the group that scored higher and the group that scored lower on the pretest to determine if the program was equally effective with students who had lower and higher pretest scores.

Descriptive statistics were also used to compare pretest and post-test grade equivalent scores for the total group as well as the higher and lower pretest score groups.

An effect-size analysis was computed for each of the paired *t*-tests. Cohen's *d* statistic was used to determine the effect size. This statistic provides an indication of the strength of the effect of the treatment regardless of the statistical significance. Cohen's *d* statistic is interpreted as follows:

.2 = small effect
.5 = medium effect
.8 = large effect

Analysis Results

Grade 2 Analyses

Researchers at ERIA conducted a paired c**o**mparison *t*-test to determine if the difference from pretest standard scores to posttest standard scores was statistically significant. For this analysis, researchers were able to match the pretest and posttest scores for 579 students. Students who did not take both the pretest and the posttest were not included.

Table 3 shows that the average standard score on the pretest was 156, and the average standard score on the posttest was 176. The increase was statistically significant (≤.0001). The effect size was large.

Table 3
Paired Comparison *t*-test Results
Pretest/Posttest Comparison of Standards Scores

Test	*Number Students*	*Mean Standard Score*	*SD*	*t-test*	*Significance*	*Effect Size*
Pretest	579	156	14.7	41.665	≤.0001	1.30
Posttest	579	176	16.1			

Higher and Lower Scoring Students

An additional analysis was conducted to determine if students who scored lower on the pretest made gains as great as those students who scored higher on the pretest. For this analysis students were ranked in order on the basis of their pretest standard scores. The group of 579 students was divided into two approximately equal sized groups of 289 and 290 students. The first group included those students who scored lower on the pretest with a mean of 144 with scores ranging from 118 to 154. The higher scoring group scored an average standard score on the pretest of 167 with scores ranging from 154 to 210.

Pretest-to-posttest comparisons are shown in Table 4 for the lower and higher pretest scoring students. Scores were analyzed using a paired comparison *t*-test to determine if both groups made significant gains.

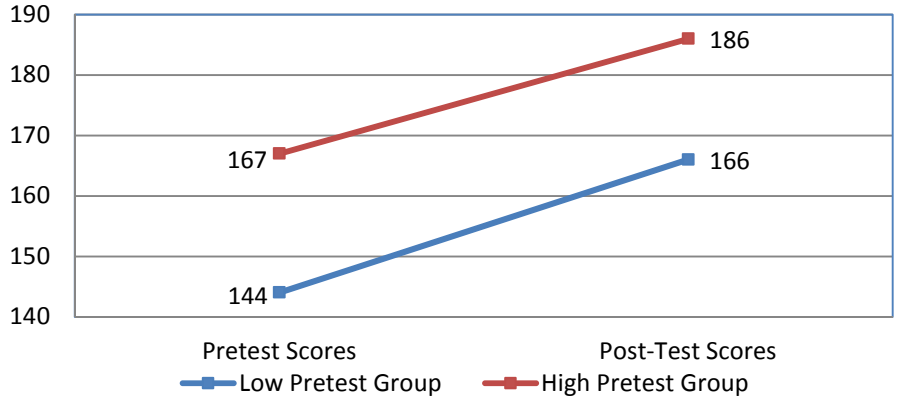
For both the higher and the lower scoring groups, the average scores increased statistically significantly (≤.0001). The effect size for both the lower scoring and higher pretest scoring groups was large. In line with those results, the data shows that the lower pretest group increased 22 standard score points and the higher pretest scoring group increased 19 standard score points.

Table 4
Paired Comparison *t*-test Results for Pretest/Posttest Standard Scores for the High- and Low-Scoring Pretest Groups

Test Form	*Number Students*	*Standard Score*	*SD*	*t-test*	*Significance*	*Effect Size*
Lower Scoring Group						
Pretest	289	144	6.7	31.545	≤.0001	2.23
Posttest	289	166	12.2			
Higher Scoring Group						
Pretest	290	167	11.0	27.773	≤.0001	1.59
Posttest	290	186	12.8			

Figure 1 provides a pretest-to-posttest comparison of the standard scores of lower and higher scoring pretest students. The lower scoring pretest group increased their scores more than the higher scoring pretest group resulting in scores that showed a 23 point difference at the beginning of the academic year and a 20 point difference by the end of the academic year.

Figure 1
Standard Score Increases for Lower and Higher Pretest Score Students



Changes in Grade Equivalent Scores

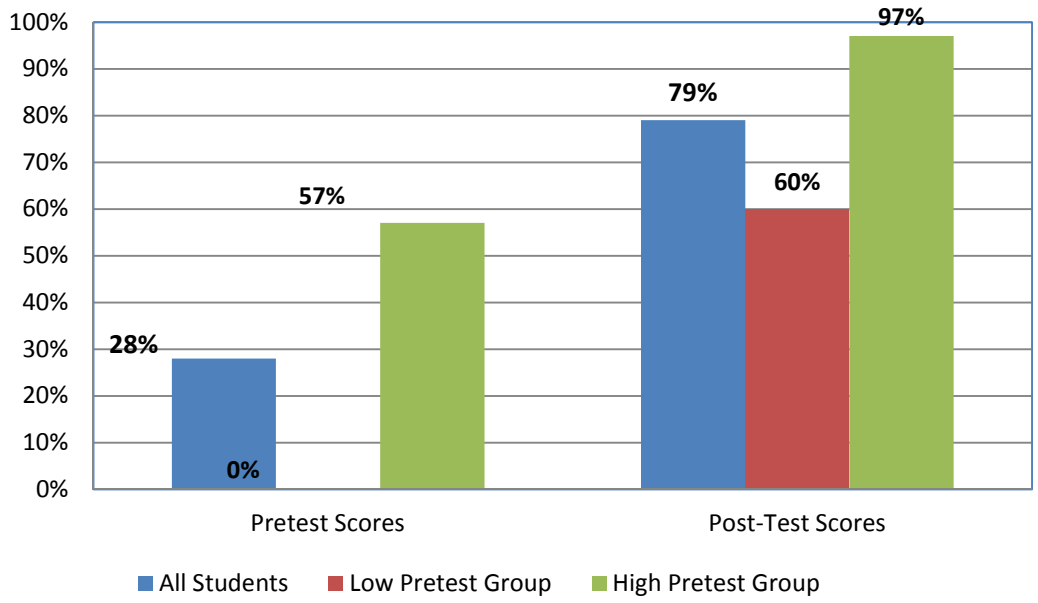
The Iowa Test of Basic Skills provides grade equivalent scores based on how the student scores on the test. These grade equivalent scores are norm-referenced scores and provides a basis for comparing student performance to students at the same grade levels. For example, a grade equivalent score of 2.5 indicates that any student getting that score is similar to those students in the norm population who are in the 5th month of grade 2. This is based on a 10 month academic year.

To determine how the students improved their scores in grade equivalent levels, the score of 2.5 was chosen as the comparison grade. This is the mid-point of the grade in which the students were enrolled. A frequency count in percentages was computed to determine the percentage of students who scored at or above a grade equivalent score of 2.5 at the beginning of the academic year and what percentage scored below 2.5 on the post-tests. This was done for all students, the high pretest scoring students and the low pretest scoring students.

The percentage of students scoring at or above a grade equivalent score of 2.5 from the beginning of the year to the end of the year is shown in Figure 2. For the total group of grade 2 students 28% scored at a grade equivalent score of 2.5 at the beginning of the academic year and 79% scored at the level or higher at the end of the year.

The score change for the low pretest scoring group is very positive. At the beginning of the year, none of the students in the low scoring group scored at the 2.5 level. By the end of the year, the low scoring group had 60% scoring at a grade equivalent score of 2.5 or higher.

Figure 2
Percent of Students Scoring a Grade Equivalent Score At or Above 2.5 From Pretesting to Posttesting



Grade 4 Analyses

Researchers at ERIA conducted a paired c**o**mparison *t*-test to determine if the difference from pretest standard scores to posttest standard scores was statistically significant. For this analysis, researchers were able to match the pretest and posttest scores for 503 students. Students who did not take both the pretest and the posttest were not included.

Table 5 shows that the average standard score on the pretest was 191, and the average standard score on the posttest was 210. The increase was statistically significant (≤.0001). The effect size was large.

Table 5
Paired Comparison *t*-test Results
Pretest/Posttest Comparison of Standards Scores

Test	*Number Students*	*Mean Standard Score*	*SD*	*t-test*	*Significance*	*Effect Size*
Pretest	503	191	19.9	31.890	≤.0001	.91
Posttest	503	210	22.0			

Higher and Lower Scoring Students

An additional analysis was conducted to determine if students who scored lower on the pretest made gains as great as those students who scored higher on the pretest. For this analysis students were ranked in order on the basis of their pretest standard scores. The group of 503 students was divided into two approximately equal sized groups of 252 and 251 students. The first group included those students who scored lower on the pretest with a mean of 175 with scores ranging from 142 to 191. The higher scoring group scored an average standard score on the pretest of 207 with scores ranging from 191 to 260.

Pretest-to-posttest comparisons are shown in Table 6 for the lower and higher pretest scoring students. Scores were analyzed using a paired comparison *t*-test to determine if both groups made significant gains.

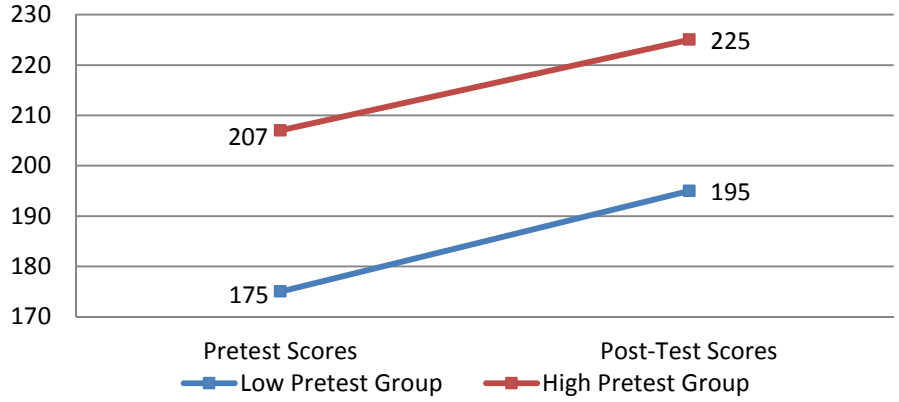
For both the higher and the lower scoring groups, the average scores increased statistically significantly (≤.0001). The effect size for both the lower scoring and higher pretest scoring groups was large. In line with those results, the data shows that the lower pretest group increased 20 standard score points and the higher pretest scoring group increased 18 standard score points.

Table 6
Paired Comparison *t*-test Results for Pretest/Posttest Standard Scores for the High- and Low-Scoring Pretest Groups

Test Form	*Number Students*	*Standard Score*	*SD*	*t-test*	*Significance*	*Effect Size*
Lower Scoring Group						
Pretest	252	175	10.5	22.462	≤.0001	1.44
Posttest	252	195	16.6			
Higher Scoring Group						
Pretest	251	207	13.1	22.732	≤.0001	1.27
Posttest	251	225	15.1			

Figure 3 provides a pretest-to-posttest comparison of the standard scores of lower and higher scoring pretest students. The lower scoring pretest group increased their scores more than the higher scoring pretest group resulting in scores that showed a 32 point difference at the beginning of the academic year and a 30 point difference by the end of the academic year.

Figure 3
Standard Score Increases for Lower and Higher Pretest Score Students



Changes in Grade Equivalent Scores

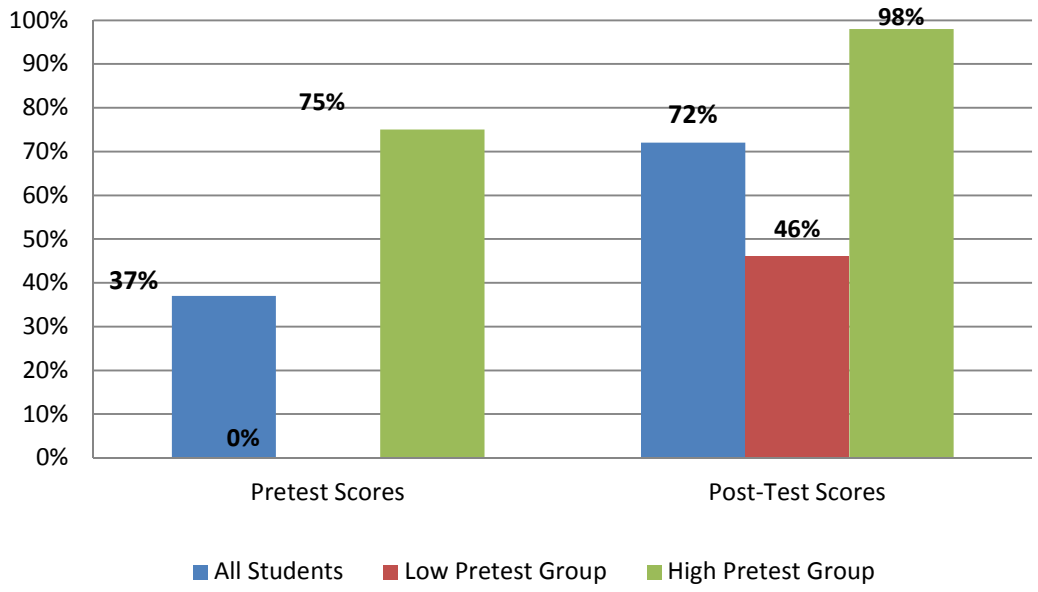
The Iowa Test of Basic Skills provides grade equivalent scores based on how the student scores on the test. These grade equivalent scores are norm-referenced scores and provides a basis for comparing student performance to students at the same grade levels. For example, a grade equivalent score of 4.5 indicates that any student getting that score is similar to those students in the norm population who are in the 5th month of grade 4. This is based on a 10 month academic year.

To determine how the students improved their scores in grade equivalent levels, the score of 4.5 was chosen as the comparison grade. This is the mid-point of the grade in which the students were enrolled. A frequency count in percentages was computed to determine the percentage of students who scored at or above a grade equivalent score of 4.5 at the beginning of the academic year and what percentage scored below 4.5 on the post-tests. This was done for all students, the high pretest scoring students and the low pretest scoring students.

The percentage of students scoring at or above a grade equivalent score of 4.5 from the beginning of the year to the end of the year is shown in Figure 4. For the total group of grade 4 students 37% scored at a grade equivalent score of 4.5 at the beginning of the year and 72% scored at that level or higher at the end of the year.

The score change for the low pretest scoring group is very positive. At the beginning of the year, the low scoring group had 0% students scoring at the 4.5 level or higher. By the end of the year, the low scoring group had 46% scoring at the 4.5 level or higher.

Figure 4
Percent of Students Scoring a Grade Equivalent Score At or Above 4.5 From Pretesting to Posttesting



Conclusions

This study sought to determine the effectiveness of ***Math Expressions Common Core © 2013,*** an elementary level mathematics program published by Houghton Mifflin Harcourt. The study was carried out with classes at grades 2 and 4.

Two research questions guided the study:

1. Is ***Math Expressions Common Core*** effective in improving the mathematics knowledge, skills, and understanding of grade 2 and grade 4 students?
2. Is ***Math Expressions Common Core*** effective in improving the mathematics knowledge, skills, and understanding of lower performing as well as higher performing grade 2 and grade 4 students?

Question 1: Is ***Math Expressions Common Core*** effective in improving the mathematics knowledge, skills, and understanding of grade 2 and grade 4 students?

The *Iowa Test of Basic Skills: Mathematics* was used to assess the mathematic knowledge and skills at the beginning and end of the school year. Statistical analyses of students' scores showed that the students increased their scores statistically significantly on the assessment. The effect size was large.

A descriptive analysis of the grade equivalent scores of the grade 2 and grade 4 students showed very large increases from the beginning to the end of the study.

Question 2: Is ***Math Expressions Common Core*** effective in improving the mathematics knowledge, skills, and understanding of lower performing as well as higher performing grade 2 and grade 4 students?

Statistical analyses of higher and lower pretest scoring students' scores showed that for both the lower and higher pretest scoring students the increase was statistically significant. For both the higher and lower pretest scoring students the effect size was large.

A descriptive analysis of the grade equivalent scores of the grade 2 and grade 4 students lower and higher pretest scoring students showed very large increases from the beginning to the end of the study.

On the basis of this study, both research questions can be answered positively.

- ***The Math Expressions Common Core program is effective in improving the mathematics knowledge, skills, and understanding of grade 2 and grade 4 students.***
- ***The Math Expressions Common Core program is effective in improving the mathematics knowledge, skills, and understanding of lower performing as well as higher performing grade 2 and grade 4 students.***