The effectiveness of the rocket math program for improving basic multiplication fact fluency in fifth grade students: a case study

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Introduction

Current Standing of Mathematics in the United States

In the United States, mathematics has long been an area of focus for improvement in the educational system. On the Trends in International Mathematics and Science Study, conducted by the National Center for Education Statistics (NCES; 2007), the United States ranked eleventh out of 35 countries among fourth grade students, and ninth out of 47 countries among eighth graders in mathematics achievement. Studies conducted in 1999 and 2003 had the U.S. ranked as low as sixteenth in comparison to international peers. Historically, the interpretation of these rankings by educational leaders has been that the United States underachieves when compared to other industrialized countries in the world. According to the National Mathematics Advisory Panel (NMAP) Final Report published by the U.S. Department of Education (2008), "American students achieve in mathematics at a mediocre level by comparison to peers worldwide." (p. xii). According to the National Center for Education Statistics (NCES; 2010), though math assessment scores have more recently shown improvement at the fourth and eighth grade levels, the level of proficiency drops off as students progress through school. In 2009, 40% of fourth graders demonstrated proficiency on standardized assessments, only 32% of eighth graders demonstrated proficiency, and only 23% of 12th graders were at a proficient level (NCES; 2009, 2010). 12th graders were not assessed in 2011. The 2008 NMAP report stated, "The sharp falloff in mathematics achievement in the US begins as students reach late middle school, where, for more and more students, algebra coursework begins (p. xiii). In the NMAP (2008) report, one of the areas most frequently identified by surveyed algebra teachers as needing improvement was knowledge for basic concepts and skills. This included students being over-reliant on calculators for basic calculations (NMAP, 2008). Further, comparison studies between US children and children in countries with higher mathematics achievement suggested that, "contemporary US children do not reach the point of fast and efficient solving of single digit addition, subtraction, multiplication, and division with whole numbers much less fluent execution of more complex algorithms as early as children in many other countries." In fact, "many never gain such proficiency" (NMAP, 2008, p. 26). Not surprisingly, the NMAP (2008) report called for improvement and greater emphasis on "the mutually reinforcing benefits of conceptual understanding, procedural fluency, and automatic (i.e. quick and effortless) recall of facts" (NMAP, 2008, p. xiv). Fluency with whole numbers was the first item listed as a recommended area of focus in critical foundations for algebra. This includes proficiency in addition, subtraction, multiplication, and division.

Translating Recommendations into Pedagogy Though achieving competency in mathematics is an important goal in our educational system, the fact remains that relative to reading, little research is available to suggest what best practices are or should be (e. g., Clarke, Baker, & Chard, 2008; Gersten, Beckmann, Clarke, Foegen, Marsh, Star, & Witzel, 2009). Students' weaknesses in basic facts, particularly fluency, impact their ability to efficiently acquire and retain higher order math skills (Ashcraft, 1989; Dehaene, 1999; Hunt & Ellis, 2004; NMAP, 2008). Lack of fluency can impact the ability of a student to acquire more

complex skills and conceptual understanding by increasing the amount of time consumed in learning (Wong & Evans, 2007), the potential for error (Pellegrino & Goldman, 1987), and the overall cognitive load utilized (Dehaene, 1999; Delazer, Domahs, Bartha, Brenneis, Lochy, Trieb, & Benke, 2003; Pellegrino & Goldman, 1987; Skinner, 1998). To address these issues, it is important to ensure that sufficient practice in the classroom is devoted to fluency development. Fluency can be taught in conjunction with a larger curriculum of conceptualized math rather than in isolation (Baroody, 2006; Gersten et al., 2009; Kilpatrick, Swafford, & Findell, 2001; Wu, 1999), or it can be used as a stand-alone intervention (Gersten et al., 2009). Devoting a small portion of instructional time (i.e., 10 minutes or so per session) to fluency exercises is recommended for students in all grades who need extra assistance with math, to maintain facts that have already been acquired and to develop automaticity as new facts are learned (Clarke et al., 2008; Gersten et al., 2009).

The Interrelationship between Fluency and Automaticity

Fluency in calculation has received support within the literature as a tenable precursor to higher order skill development (Berch, 2005; Clarke et al., 2008; Geary, 2004; Hanich, Jordan, Kaplan, & Dick, 2001; Shapiro, 2010). Development of fluency means that as more efficient calculation strategies are introduced, they supplant older, slower methods (Lemaire & Sigler, 1995). Fluency is generally acquired in a three phase process: simple counting, critical thinking and calculation, and finally, automatic retrieval of responses (Baroody, 2006). Since skill proficiency and conceptual knowledge are linked, fluency then facilitates the development of subsequent skills (Binder, 1996; Bucklin, Dickinson, & Brethower, 2000; Cowan, Donlan, Shepherd, Cole-Fletcher, Saxton, & Hurry, 2011; Haughton, 1972; Wong & Evans, 2007; Wu, 1999). Kelley (2008) asserted that basic fact fluency is as central to higher level mathematics as decoding is to reading. Furthermore, for students who have not achieved fluent automaticity of basic facts by the end of fifth grade, there will likely not be frequent, structured, opportunities to adequately develop that automaticity in later grades (Steel & Funnell, 2001).

Step-wise Development of Fluency

In developing fluency, accuracy must be adequately developed before automaticity becomes the goal (Haring & Eaton, 1978; Kelley, 2008). The use of immediate peer-provided feedback has been shown to increase rates of accurate retrieval of basic math facts (Fantuzzo, King, & Heller, 1992; Kilpatrick etal., 2001; Maheady & Gard, 2010; Rhymer, Dittmer, Skinner, & Jackson, 2000; Skinner & Smith, 1992). Once accuracy is well established, the use of an explicit timing component can increase accuracy and can ultimately facilitate production of automatic responses (Rhymer, Skinner, Henington, D'Reaux, & Sims, 1998; Rhymer, Henington, Skinner, & Looby, 1999).

Keeping Students Engaged

Motivation is an important factor in learning, and the 'drill' aspect of this type of direct instruction means that activities could become dull and potentially aversive to students. Simply having a timing component in a program may be enough to improve the learning and effort of students in a variety of areas (Van Houten, Morrison, Jarves, & McDonald, 1974; Van Houten & Thompson, 1976). Allowing students to track their own progress, in addition to provision of frequent feedback regarding students' performance levels are suggested best practices to maintain motivation and develop self-regulated learning (Clarke et al., 2008; Fuchs, Fuchs, Kams,

Hamlett, Katzaroff, & Dutka, 1997; Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, et al., 2003; Fuchs, Seethaler et al., 2008; Gersten et al., 2009).

The Use of Rocket Math as a Fluency Intervention

Only one study of the Rocket Math (Crawford, 2009) program was identified during review of the available literature. Smith Marchand-Martella & Martella (2011) tracked the effectiveness of Rocket Math with a first-grade student from a suburban elementary school in eastern Washington. The participant was diagnosed with Attention Deficit Hyperactivity Disorder and had a special education classification of Developmental Delay with social/adaptive deficits. He was selected for the study based on low math assessment scores (62% on the district math assessment) despite average cognitive abilities as well as difficulties with fluency and an inability to attend to specific math tasks.

The study was a single-case pretest posttest non-experimental design and was conducted in a classroom setting where all students completed the program, though the researchers only tracked the subject's results. Each student was given a one-minute placement test to determine their individual goal for problems correct on future one-minute monitoring tests. The participant's target goal was 26 problems correct. The participant was also given an additional, independent curriculum based measure (CBM) where he completed as many addition problems as he could in one minute. This CBM was repeated at the end of the study as well.

Sessions occurred three times per week for approximately 15 minutes per day. Progress was tracked across four months. Each session started with students practicing addition problems arranged in a circle around the outside of a program-provided worksheet. The students whispered problems and answers to themselves for one minute while the teacher circulated and listened for accuracy. Immediately following the practice time, students then had one minute to complete as many problems as possible from the middle of the same worksheet. The teacher then collected the worksheets and checked the answers. She also noted any consistently missed problems for the students to target with additional practice prior to the next one-minute worksheet. If a student met their target goal for problems correct, they moved to the next level worksheet (worksheets are leveled by difficulty from A-Z). If a student did not achieve their goal, they attempted the same worksheet during the next session.

Results were measured by the rate per minute for problems completed correctly. On the CBM, the participant increased his problems completed correctly from 10 to 21 by the end of the program. He did not have any errors on either the pre or posttest. At the beginning of the program, the participant started on level A. He had progressed to level M by the end of the study. He averaged 2.6 attempts to pass a level. By the end of the study, he was completing problems at grade level mastery (Shapiro, 2010).

The results of the study support Rocket Math (Crawford, 2009) as a potentially effective tool in developing and improving fluency skills for basic math facts. However, it was noted that the single subject design as well as the use of a single instructor were limitations as far as generalizability of the results to larger populations. It was also noted that the subject did not entirely complete the program and was engaged in additional math instruction simultaneous to the treatment condition. Results may have differed had the subject continued through the entire program. Further, positive impact may have been confounded by reinforcement from regular math instruction.

Rationale for the Current Study

One intervention for basic math fact fluency that incorporates peer feedback and correction as well as explicit timing is Rocket Math (Crawford, 2009). Rocket Math is a commercially available math fluency program designed to promote both accuracy and fluency for addition, subtraction, multiplication and division. The assessment process is relatively easy to accomplish in the regular classroom, and takes minimal time away from conceptual instruction. Though the Rocket Math program incorporates much of what is known in terms of current best practices in fluency instruction, there is scant evidence to support its use in schools. At the time the current study was conducted, (in academic year 2012-2013), only one published study using the program could be located. Smith Marchand-Martella & Martella's (2011) study demonstrated that the program was effective for a single subject; however, even though it is a popular program in many districts in the area, to date no studies have looked at its impact on a larger scale.

Further information regarding the effectiveness of Rocket Math is needed to determine if the program is a useful way to promote fluency for basic math skills in elementary age students. Since the program was designed for use on a classroom-wide scale, it seems logical that the next step of research should consider how the program functions in its intended capacity. This study aims to contribute to the literature by examining the effectiveness of the Rocket Math program in improving the multiplication fluency in three classrooms of fifth grade students.

Method

Participants

This study was completed using data obtained from 44 students in three fifth grade classrooms in a rural central Pennsylvania public school district. Students were between 10 and 11 years of age. Each class was part of a team of rotating classrooms, so the same math teacher taught math content for all participants. The classrooms were selected based on teacher willingness to participate and mathematical level being taught. The fifth grade classrooms were slated to start Rocket Math at the multiplication level whereas the other grades were starting at the addition or subtraction levels.

As of the 2012-2013 school year, the school district student population was 2,274 pupils in Kindergarten through 12th grade. The elementary school was 3rd grade to fifth grade and had a student population of 555 pupils. Approximately 3% of the students identified as Asian/Pacific Islander, 3% identified as Black, 3% identified as Hispanic, and 2% identified as Multiple Races. All others identified as White.

The fifth grade population was 187 students. 47% were female and 53% were male. 39% were eligible for free or reduced lunch. There were 37 fifth grade students (20%) identified for special education services. Of those, 19 had a primary classification of Specific Learning Disability, 11 had a primary classification of Other Health Impairment. The remaining students had primary classifications of Speech and Language Impairment (3), Emotional Disturbance (2), Orthopedic Impairment (1), and Intellectual Disability (1).

The participant group was comprised of 23 (52%) females and 21 (48%) males. In the participant group, 33 students (75%) were in regular education programming. Eleven students (25%) were receiving special education services in the fonn of Learning Support from a special education teacher. Of the 11 special education students whose data were used, eight were classified as having a Specific Learning Disability (SLD) in reading and/or math. One student had a classification of Other Health Impairment (OHI), due to executive functioning deficits. The remaining two students had dual classifications of SLD and OHI.

This particular 'team' of fifth grade classrooms was where the students placed in Learning Support were concentrated to facilitate co-teaching and inclusion with the special education teacher. Classroom 1 had six students (40%) and Classroom 2 had five students (36%) identified for special education services. Classroom 3 was comprised entirely of regular education students.

Materials

All materials utilized were part of the published Rocket Math program. These items included a writing baseline test, a placement probe, leveled practice and answer sheets, leveled one-minute advancement tests, and two-minute progress monitoring tests. A veteran teacher with prior experience using the Rocket Math program administered all parts of the program in her classroom. The researcher supervised administration of all items to ensure that each component of the program was implemented as intended.

Design

This study was conducted as a pretest-posttest non-experimental design. Each student served as his or her own control. This design was used to replicate and extend findings from Smith et al. (2011). Baseline data were gathered using the writing and placement probes prior to implementation of the intervention. All students were leveled and given an initial problem completion goal based on their performance on the two probes. The practice sessions took place 2-5 times per week for 9 weeks. A total of 28 sessions occurred.

Procedure

Students were initially administered a pre-intervention writing probe where they were asked to copy as many numbers as possible in one minute. Depending on how many numbers they were able to write, a corresponding goal was set for the number of problems they should be able to complete on the placement probes and one-minute tests. The students circled their individual goal number on a provided goal sheet. Students were then also administered 15-second placement probes. If the goal for the first placement probe was met, students continued taking additional probes up to a maximum of four or until they were unable to meet their goal on a probe. Based on number of probes passed, each student was placed at his or her recommended starting fluency level. The 26 levels ranged from A-Z with four potential starting points (A, G, M or division) corresponding to the four placement probes. Each of the 26 levels added one to two additional facts and their corresponding reversals (for example, 2x4 and 4x2) in a predetermined sequence.

Each day in class students practiced in pairs for two minutes each. One student, the "learner" sat with the practice sheet for their current level in front of him/her. The problems for practice were in a circle around the outside of the page and did not have the answers written in. Out loud, the learner read each fact and provided their answer. The other student, the "checker" had the answer key and listened for a hesitation or an error on one of the facts. If an error or hesitation occurred, the checker provided the answer and waited while the learner repeated the problem and the answer three times. The learner then backed up three problems and began reciting facts and answers again. After the first two minutes were done, the students switched roles and repeated the process. The students completed as many problems as they could in their allotted practice time. If a student completed all the practice problems with time remaining, he or she started over and continued until time expired.

Each day, immediately after practicing, the students took a one-minute probe (located in the center of their practice sheet). If a student met or exceeded their individual total problems correct goal, he or she moved on to the next level in the sequence (i.e. move from level A to level B). If a student's goal was not met, he or she continued to practice on the same level sheet and took the same probe the next day. If a student failed to pass a level after five attempts, he or she dropped back to the previous level until that was passed and then moved forward again. As students passed levels, they filled in corresponding bars on their 'Rocket Chart' to visually track their own progress.

Approximately once every two weeks, a two-minute progress-monitoring test was given. Students had two minutes to complete a sheet of multiplication problems that were not based on level. Upon completion, of the test, students were instructed to switch papers with a peer in another part of the room and grade one another's work. The total number of problems correct was recorded and graphed by the students. Data from performance on the daily and bi-weekly probes was collected by the researcher, aggregated, and graphed to analyze overall progress and determine effectiveness of the program.

Results

Forty-four total students' data were included in the study results. Thirteen students' data were omitted. Of those omitted, two students left the district before the end of the study. The remaining omitted students (four special education, and seven regular education) did not follow the given instructions or guidelines for grading their own one-minute probes and progressing through the levels. Errors included failure to omit incorrect responses from the total correct, failure to meet the required goal before progressing to the next level, and failure to use the correct goal consistently. These problems were unique to the one-minute probes because students checked their own work and maintained their own progress. The two-minute probes were peer-checked and therefore were not subject to the types of errors mentioned above.

Level Advancement

For each student, the total number of levels passed was counted and totaled. The mean number of levels passed for the group as a whole was $M=15.25$. For the special education students, $M=12.55$. For the regular education students, $M=16.15$. An independent samples t-test was used to determine that in mean number of levels progressed, the difference between groups was not significant ($p=.155$).

The mean number of levels progressed was also calculated for each of the three classrooms in the study. A one-way analysis of variance (ANOVA) was used to compare classroom means. Results indicated that in mean number of levels progressed, no significant differences existed between classrooms ($p = .422$).

Percentage Advancement

Each two-minute probe score was converted to a percentage correct score by dividing the number of responses correct by the two-minute goal for the individual student and then multiplying by 100. The percentage correct score for the first probe was subtracted from the percentage correct score on the last probe to determine a total percentage correct increase. For all participants combined, the mean percentage increase during the study was M=22.98%. A paired samples t-test was used to determine the significance of the mean increase for all students. Results indicated the performance increase was significant (p =.000). The effect size was calculated to be 1.61.

For students identified as special education, the percentage increase was M=21.09% with an effect size of 1.53. For regular education students, total percentage increase was M=23.61% with an effect size of 2.04. An independent samples t-test was run to determine if there was a significant difference between the percentage increase for regular education students and special education students. Results indicated that there was no significant difference in the overall increase in performance between the two groups (p=.617).

The mean percentage increase overall was also calculated for each of the three classrooms. An ANOVA was used to compare classroom means. Results indicated that in mean percentage increase, there were no significant differences between classrooms (p=.753).

Discussion

Assessment of Effectiveness

Based on the results of the study, the Rocket Math program appears to have been an effective intervention for improving the multiplication fluency skills of the students. By the end of nine weeks, 93% (n=41) of students had made positive advancement in the number of problems they could accurately complete in two minutes. Three students (7%) had regression in their percentage of progress meaning they failed to meet or exceed their baseline results in the final two-minute probe. These students were not identified as having any special education programming. One of the three students exceeded their two-minute goal on the first try and then only matched it on the fourth try indicating that they had already achieved mastery and were therefore not as able to demonstrate positive improvement as other students. For the remaining two students who had regression, there may have been insufficient practice for those particular individuals to achieve the accuracy needed to develop rapid responses. Haring and Eaton (1978) stated that accuracy in response must be the primary, initial focus for students learning basic skills. The two students who showed a negative outcome in their progress may have been demonstrating the same effect shown in the Rhymer et al. (1998) study wherein students experienced a drop-off in accurate output once a timing component was introduced. The researchers theorized that because the study did not include a component to measure general accuracy levels before introducing their intervention, some of the subjects may have not had sufficient practice and accuracy with basic math facts needed in order to effectively increase fluency using timing. For the two students in the present study, the amount of practice time allotted may have been insufficient to address their accuracy deficits. As a result, the timing component may not have been effective in increasing overall fluency.

Program Implementation Issues

In practice, Rocket Math did have some shortcomings based on classroom use. Rocket Math is intended to be largely student driven so as to increase motivation as well as decrease overall load on the teacher. This was particularly true for the study classrooms where independence and responsibility were emphasized expectations in preparing the students for middle school. Most issues had to do with the prospect of having students run much of the intervention on their own. A few students were caught cheating while others seemed to simply misunderstanding fundamental features of the Rocket Math program. None of those students received special education services. Failure to comply with or follow instructions was also a problem indicated in the Rhymer et al. (1999) study. In that study and the current study, students who exhibited those issues had their data omitted from the results. For the most part, problems with instructions fell into two categories: cheating and confusion.

Cheating. A few students were caught cheating in some form. Some were not omitting incorrect responses from the total correct and instead were passing themselves to the next level based solely on number of problems completed rather than number of problems correct. Other students simply wrote the number correct on their paper to match or exceed their goal regardless of the number of problems they had actually completed. These cases were generally evident when tests were reviewed for accuracy by the researcher. Cheating was curbed on the two-minute test by having peers grade one another's paper. No instances of cheating were discovered on any of the two-minute tests indicating that this may have been an effective way to prevent the issues that were occurring with the one-minute tests.

Confusion. Though students were walked through the instructional procedures for the initial stages and subsequent daily routines for Rocket Math, some still struggled to remember and/or understand how certain elements of the system worked. For example, some students seemed to struggle with the concept of the individual goal for problems correct needed to pass to the next level. These students were noted to have changed their goal based on the number of problems correct on a prior test. For example, they might start with a goal of 45, get 35 correct on an attempt and then change their goal for the subsequent test to 35. The cases of this occurring did not seem to be to intentionally manipulate the system as the students adjusted their goals to be both easier and more difficult from test to test. It may have been helpful to remind students about how the goals worked on multiple occasions while reinforcing the daily procedure periodically. It seemed that students were following protocol well in the initial days and weeks, but then moved away from the routine over time. A refresher of the instructions could help mediate some of the confusion related errors.

Another area of confusion for some students was in simply tracking their level. Despite maintaining records on their 'rocket sheet' as well as having the prior passed test in their folders, some students reverted back to a previously passed level needlessly before moving on again. Conversely, some students with no prior history of cheating randomly skipped a level altogether. This seemed to be the result of simply not paying close attention to their correct level when obtaining the next worksheet in the sequence. This was a more difficult problem to mediate since the students were already tracking their progress on their graphs as well as retaining their prior tests. It seemed that the issues were mostly related to less developed self-monitoring and organizational skills which were areas already being emphasized in the classroom.

One way to address many of the issues involving cheating and confusion could be to have peers monitor one another. On the two-minute probes, peers exchanged papers and graded one another. The results were much more reliable and accurate. No two-minute probes were identified as being improperly graded. This process could also be used to check one-minute probes and daily progress. Peers could exchange one-minute probes for grading and record the current level for one another. Time is already allotted for students to check their own work, so it would not create an additional time constraint if the students simply switched papers before completing the grading process. It would also not add to the work of the teacher as far as grading or monitoring students, preserving the ease of use in a classroom environment as well.

Finally, though the program used peers as a means to provide immediate feedback for accuracy, the students did not undergo any formal training on how to tutor one another. In both the prior studies mentioned that utilized peer tutoring, students participated in training sessions prior on how to properly implement the tutoring materials (Fantuzzo et al., 1992; Rhymer et al., 2000). The students who participated in Rocket Math were given explicit instructions on how to tutor one another and were given examples, however, there was no formal training that emphasized the important skills and aspects of effectively and efficiently monitoring and providing feedback. Peer partners were monitored informally in the classroom, but there was no way to monitor each pair during every practice session. If students were not vigilant in their tutoring roles, their peer may have inadvertently practiced a problem incorrectly and reinforced a wrong answer in memory.

Limitations of the Current Study and Implications for Future Study

In the current study, progress was tracked over a total of one nine-week marking period. Though this allowed for a substantial amount of data to be collected, it was not sufficient time for most students to complete all levels of the program. This was a weakness also indicated in the previous Rocket Math study conducted by Smith et al. (2011). It would be prudent for future studies to track progress over the course of longer period of time (perhaps even a whole school year) to determine the pattern of progress as more students moved into increasingly difficult levels. This could also illuminate potential plateaus in performance or potential patterns in progression through each set of facts.

Additionally, the study did not have any follow-up to determine long-term retention of facts. Though the data demonstrated a positive impact in the immediate performance of facts, there is no way to know if students are able to maintain their knowledge and fluency for learned facts once they have completed the multiplication series.

Finally, this study was limited to the development of multiplication math facts; however, the Rocket Math program also addresses numeral writing, addition, subtraction, and division. While this study provided positive support for the use of the program for multiplication fluency, it did not explore the effectiveness of the same strategies for other basic math facts and skills.

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Table 1
Means and Standard Deviations for Total Levels Progressed Overall and by Group

	N	M	SD
Overall	44	15.25	7.24
Regular Education	33	16.15	7.27
Special Education	11	12.55	6.76

Table 2
Means and Standard Deviations for Total Levels Progressed by Classroom

	N	M	SD
Classroom 1 (40% special education)	15	13.27	6.77
Classroom 2 (36% special education)	14	15.93	7.60
Classroom 3 (regular education only)	15	16.60	7.41

Table 3
Means, Standard Deviations, and Effect Sizes for Percentage Increase from Two-Minute Probe #1 to #4 Overall and by Group

	N	M	SD	d
Overall	44	22.98	14.23	1.61

Regular Education	33	23.61	15.40	1.53
Special Education	11	21.09	10.35	2.04

Table 4
Means and Standard Deviations for Percentage Increase by Classroom

	N	M	SD
Classroom 1 (40% special education)	15	25.26	16.15
Classroom 2 (36% special education)	14	22.03	14.16
Classroom 3 (regular education only)	15	21.59	12.91