Theoretical Frameworks for Math Fact Fluency

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Abstract

Recent education statistics indicate persistent low math scores for our nation's students. This drop in math proficiency includes deficits in basic number sense and automaticity of math facts. The decrease has been recorded across all grade levels with the elementary levels showing the greatest loss (National Center for Education Statistics, 2009). The purpose of this paper is to use Vygotsky's sociocultural theory as a framework to discuss the benefits of peer assisted drill and practice for math fact fluency. One basic aspect of this theory centers on the contention that cognitive growth and development can be promoted in less capable peers if they are given opportunities to interact with more capable peers (Vygotsky, 1978). In addition, the delivery and effectiveness of computer assisted drill and practice will be discussed within the context of the Information Processing Theory. These theories are based on the assumption that cognitive manipulation of input must precede its release as output (Miller, 2011). The theory is based on a model much like a computer. Through a review of literature and current research, the two methods of math practice will be compared and contrasted.

Theoretical Frameworks for Math Fact Fluency

Reflecting national trends, many school districts have seen a drop in math proficiency, especially with number sense and automaticity of math facts. To address this situation, systems are investing in research based, computerized drill and practice math remediation programs, such as those developed by iLEARN, called Think Fast(iLEARN, 2011). This program is a diagnostic instructional tool meant to provide practice in identified math skill deficits to those students lacking proficient math skills. General education as well as special education often uses programs such as this to increase math fact fluency, and special education and general education teachers have used various methods and strategies to provide drill and practice opportunities to students with deficient skills in math facts.

This paper will focus on the current research examining the effects of computer assisted drill and practice as a method to address deficits in math fact fluency. Research will also be reviewed which investigates the effectiveness of peer assisted math fact drill and practice. Specific elements of the sociocultural theory are used to discuss peer assisted drill and practice and the information processing theory is used to discuss computer assisted drill and practice. The literature discussed will provide additional information about the effectiveness of each method in providing opportunities for remediation and to increase math fact fluency. This paper concludes with a personal view on whether or not there is a difference between the effectiveness of computer assisted drill and practice and peer assisted drill and practice

Review of the Literature and Current Research in the Field

Findings from the National Center for Education Statistics (2009) indicate that many students in the elementary grades have not mastered basic math facts fluently. An important issue for teachers is finding ways to help their students memorize and utilize math facts with fluency, a skill which requires students to respond quickly and correctly. Not only is fluency necessary but automaticity in generating these facts is critical to effective problem solving. Another consideration for teachers is determining which students would benefit from drill and practice strategies to increase fluency and which strategy would show the greatest gains and be most effective. Teachers must also ensure that time with drill and practice is spent productively.

Vygotsky and other sociocultural theorists (Vygotsky, 1978) believe that more competent students paired with less competent students can increase the development of their less competent peers. Research does indicate that when drill and practice is configured after this model, the less competent students are able to increase their fluency rate of math fact retrieval. Rhymer, K., Skinner, C., Jackson, S., McNeill, S., Smith, T., and Jackson, B. (2002) examined strategies such as peer tutoring using flashcard procedures for drill and practice and found that these procedures did improve fluency and were effective, but also required an inordinate amount of time and, therefore, may not be an efficient use of time. When students engaged in this type of collaborative peer tutoring using unmatched peers, the potential development for each could be enhanced. According to Vygotsky, (1978) these peers are operating in the zone of proximal development. While more able peers help them to proceed through the zone, they reach a higher level of competence and this increased competence further develops their readiness to learn new concepts. Through repeated trials of drill and practice, students become more agile in retrieving math facts and are ready to apply the learned math facts into problem solving which, ultimately, is the goal.

Vygotsky (1978) defined schools as cultures where students interact with the teacher and their peers in the instructional setting. These peers and adults all interact through a process which helps children learn how to use the tools of the culture, namely math facts. This is clearly shown when requisite skills such as fluency of math facts are developed and competence is demonstrated by the students who are ready to move on to more complex mathematics and problem solving. Vygotsky (2011) believed that as students become more adept at recall of math facts, they can advance their own thinking in the area of problem solving with or without the scaffolding assistance from peers and become efficient in recall of math facts.

According to Woodward (2006) complex mathematics and problem solving objectives require skill and competence in basic computation. However, those students who devote too much time to basic computations may not have sufficient capacity to apply cognitive processes toward the acquisition of complex math operations. In this respect, a needed corollary of fluency in facts is the automatization of these facts.

Researchers such as Nist and Joseph (2008) have used the term automaticity to describe a student's ability to respond rapidly and accurately with minimal cognitive effort. Working at this level is most efficient and developing automaticity is an important first step in successful problem solving. Poncy, B., Skinner, C., and O'Mara, T., (2006), developed the Detect, Practice, Repair strategy as a class wide procedure that focuses on increasing fluency by allowing students to practice only those math facts that are not developed to the point of automaticity. Axtell, P., McCallum, S., Bell, S., and Poncy, B., (2009) expanded this research and found when deficits were detected by the teacher and peer assisted drill and practice was implemented, students were able to repair the gap in skills and increase their fluency. This allowed teachers to use peers to remedy skill deficits while applying instructional time only to target those skills in need of remediation. Both peer mediated strategies were very effective in increasing fluency and automaticity of math facts. Use of these, and other, strategies appear to allow what Rogoff (1990) termed guided participation: those students who have developed and demonstrated math fact fluency skills were now ready to apply those skills to problem solving through a gradual decrease in their dependency on peer assistance.

Vygotsky (1978) labeled this mutually beneficial collaboration intersubjectivity: states of shared understanding where both students are focused and share a common goal: Namely, the practice of known facts for the more able peers and provision of opportunities to increase fluency skills for the less competent peers.

Aspects of the sociocultural approach to development of cognitive skills and studies supported by the literature, indicate that peer assisted drill and practice of math facts appears to be an effective strategy to increase fact fluency to the point of automaticity. In addition, the collaborative nature of the remediation appears to be beneficial to the child in need of remediation as well as the more capable peer.

Human information processing theorists focus less on the steps in problem solving but more on the specific mental processes that must be developed and used prior to reaching a problem solution (Andre, 1996). Theorists from the information processing orientation would therefore, focus on how students acquire, process and remember information. According to Miller (2011), the information processing researchers examine the flow of information through the cognitive system. For purposes of this paper, the process begins with some input, such as a math problem, into the human information processing system and ends with the output, which can be viewed as the student's response or answer. When students are using a computer assisted program to drill and practice math facts, they are taking in information through their senses in the form of a software application and providing output by quickly calling the answer from memory. The relevant issue for information processing theorists is in the processing of information once it has been input. Or, in this context, what does the student do with the image of the math fact?

The visuospatial sketchpad processes and retains visual information. Here it is stored briefly in the episodic buffer before being sent to long term memory (Miller, 2011). Research provided by iLearn (2011) points to the need for students to develop strategies prior to the development of math fluency. These strategies need to be activated in the episodic buffer so the visual information can be coded before it is sent to storage.

Siegler's (2006) research on microgenetic methods centered on how children develop strategies over several problems and sessions. Programs such as ThinkFast (2011) provide explicit instruction in rules and a variety of strategies to use when problem solving, in the hope that children begin to use these strategies automatically when encountering novel problems. Information processing models also rely on rules as a basis for children to problem solve. Siegler's (1996) important overlapping waves model represents a theory in which children would use a certain strategy to learn the math fact but would retain the use of that strategy until a newer or more efficient strategy is fully developed and can be used in its place as well as with other problems calling for novel solutions.

According to Miller (2011) another important feature of the information processing theory is the child's use of encoding. How a child labels information is critical for future recall. Through the use of strategies, children can modify the mathematical information before it is stored in long term memory. Once the data has been manipulated, the child can store it for future retrieval. Drill and practice strengthens the learning and makes it more enduring because the more frequently the math fact data is recalled from memory the stronger the learning. The computer provides the drill and practice for these stored facts. Children become fluent in the recollection of facts and this leads to automaticity. Information processing theorists (Miller 2011) identify this process as automatization or the condition when the recall of math facts no longer requires conscious awareness. The recall becomes second nature.

Lynch (2006) used another area of computer assisted math fact drill and practice methods to combine strategy instruction which focused on errorless learning, as well as clearer understanding of the processes of computation. Programs which combine extended practice and looping back to any missed facts ensure that students do not have the opportunity to practice incorrect answers which is believed to be a weakness of peer mediated drill and practice. Teachers should also ensure that while students are using the computer for drill and practice that the time spent is productive and their attention is focused and consistently applied to repetitive aspects of the strategy. A study completed by Cates (2005) investigated the use of computer-assisted math programs and concluded that while such programs did increase active student engagement, simple engagement may be insufficient for effective learning. Their research indicated that many times the facts were not encoded sufficiently to be stored for future retrieval.

There is a great body of research available on the efficacy of computer assisted drill and practice as a method to increase fluency and ensure automaticity of math fact retrieval.

Conclusion

Both theories are feasible when discussing a model of how children can learn math facts to the point of automaticity. Both theories consider developmental stages and when a child would be developmentally capable of recalling facts fluently and applying them in problem solving. While both theories recognize the cognitive manipulation of information that is necessary to problem solve, the socioculturalists see it as an extrinsic exercise while interacting within a culture, such as a school, with peers or adults. Evidence of learning is demonstrated by a change in behavior such as an increase in math fact fluency as peers interact with one another. The information processing theorists, on the other hand, view this as an intrinsic exercise happening internally with effectiveness demonstrated by the presentation of correct output or math facts. Clearly students should have enough computational fluency to automatically recall a fact and apply it to a problem. Perhaps the most important point is that students practice facts with an understanding of the applications. If students can directly apply the facts, the procedures will be less likely to be forgotten or confused. In the classroom, the most effective application of either theory to the practice of math facts would involve a teacher who is knowledgeable of the students in class and know their learning styles. Both methods, peer assisted drill and practice and computer assisted drill and practice, have a place in the classroom. The wise teacher would differentiate and use both depending upon the needs of the students. The issue of motivation is an important consideration as well. A child interacting with the computer may need to be more self directed and motivated to remain on task and interested in the lesson, while the interaction with peers may be motivating enough for others. Reinforcement is overt when in a social context; it may not be so when interacting with a computer.

As with most research, this topic also raises more questions. For example, which method is more effective in retention of math facts? Which method is more motivating and engaging to students? Which method maintains a student's level of motivation and self direction more consistently? It is clearly evident that learning does not happen by chance but, rather, through a complex and cumulative process.

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