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Learning Math in Second Grade: An Application of Cognitive Apprenticeship

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ABSTRACT

This paper provides a description of the concept of cognitive apprenticeship and outlines this instructional paradigm as one way to support young students' learning of mathematics. The teaching of mathematics was embedded in the context of the cognitive apprenticeship (2nd grade store) where tasks, aligned with the school district's content standards, became meaningful and motivational for the students. Data analyses indicated that the students who studied math in the framework of a cognitive apprenticeship had higher math scores on the state's standardized achievement test than those students who studied math in a traditional way.

Keywords: cognitive apprenticeship, authentic learning, elementary school, mathematics

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Introduction

How can teachers promote young diverse students' conceptual understanding and skill acquisition? Numerous models in specific subject areas are available to educators for teaching thinking skills, such as Feuerstein et al.'s Instrumental Enrichment program, Adey and Shayer's Cognitive Acceleration through Science Education program and their Cognitive Acceleration through Maths Education program, Leat's thinking through Geography, and Lipman's Philosophy for Children (Robson, 2006). A growing body of research seems to indicate that thinking skills approaches can be used or integrated to establish effective learning context for students (De Corte, 1990). In order to gain expertise in an area, however, thinking skills need to be supplemented by subject matter knowledge and an understanding of when and how to use particular knowledge and skills.

Cognitive apprenticeship is gaining popularity as a student-centered teaching method in elementary schools besides other commonly used approaches, such as inquiry and problem-based learning as well as dialogue and instructional conversations

(Woolfolk, 2010). Researchers propose that effective instruction should focus on problem solving, analysis, reasoning, and other higher-order thinking skills. Since cognitive apprenticeship models are effective contexts for expert-like problem solving and reasoning activities, this model is highly recommended (Perkins, Jay, and Tishman, 1993) for any subject matter as a meaningful, authentic, and effective method (Collins, Brown, & Newman, 1989). This paper describes in detail the concept of cognitive apprenticeship and demonstrates how this powerful instructional methodology has the potential to increase student learning of mathematics.

Description of Cognitive Apprenticeships

The apprenticeship model has been used for learning since the later part of the Middle Ages. The idea that young apprentices can learn the skills and knowledge of their trade from a master craftsman in exchange for their labor has been successfully transmitted to our modern times as the school context enables a teacher, mentor, or an experienced peer to assist in the learning of a less experienced student. According to Collins, Brown, and Newman (1987), learning in school has become more fragmented and decontextualized as students learn information often inapplicable to their lives and are engaged in activities that necessitate regurgitating information and focusing on getting the right answer only. Collins et al. (1987) claim that this inert knowledge is not available for real problem solving. Instead they recommend using the concept of apprenticeship for learning various subjects, such as language arts, mathematics, and science.

The concept of cognitive apprenticeship originates from social constructivist theory based on the work of Vygotsky (1978) and Bakthin (1981). The concept of apprenticeship – learning knowledge and skills from a competent master or a more knowledgeable peer – is applied to the cognitive domain (thus "cognitive apprenticeship") where academic learning takes place within a school context. In this instructional paradigm the apprentices learn from a master academic knowledge and skills identified in the school curriculum. Though there are many similarities between traditional and cognitive apprenticeships, there are also differences (Collins, Brown, & Newman, 1989). The following section summarizes these features.

Similarities Between Traditional and Cognitive Apprenticeships

In both contexts the tasks are genuine, the goals are realistic, the activities are purposeful, the process is authentic, and the assessment is embedded in the production and learning process. While working with the master (and possibly other peers), the apprentices observe others during task completion and get actively engaged instantaneously at their own developmental level. The learners understand that they have to participate in the activities to contribute to the well-being of their community.

During learning the master models the task purposefully and provides appropriate prompts, reminders, and scaffolding to assist the learners in becoming more competent.

The concept of scaffolding simply means that the master provides assistance in the learners' zone of proximal development (ZPD), which is the distance between the "actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978, p. 86). The degree and type of assistance depends on the apprentices' experience, prior knowledge, and skill set. As the apprentices gain more knowledge and their skills get more refined, the master 'raises the bar' by providing less help and expecting more complex products. The master evaluates the apprentices' final product and performance by giving specific and timely feedback. This assessment information is then built into the learning cycle as the apprentices are expected to advance their practice based on identified areas of improvement.

Differences Between Traditional and Cognitive Apprenticeships

Apprentices in the traditional model are mostly engaged in physical activities and learn skills that are generally visible (e.g., carving wood). Cognitive apprentices, however, learn thinking skills, problem solving, and other abstract academic knowledge and skills that are not necessarily visible by their nature (e.g., using the commutative and associative rules for addition to simplify mental calculations). Thus the tasks involved in a cognitive apprenticeship are intellectually more challenging and tend to be based on more complex problems.

Another difference is related to the learning context. Learners in a traditional apprenticeship usually work on their own or with a few other apprentices hired by the same master. Cognitive apprentices, however, usually share a classroom with a higher number of peers who share similar learning goals, and aid and challenge one another during learning.

While both traditional and cognitive apprentices learn from observing the master and more competent peers, cognitive apprentices also engage in thinking tasks by reasoning, diagnosing problems, and explaining their thought processes. Masters teach traditional apprentices by modeling, coaching, and gradually diminishing the amount of their assistance; teachers in cognitive apprenticeship use a wider variety of instructional strategies that include modeling, coaching, scaffolding and encouraging reflection, articulation, and exploration of new ideas. These methods are briefly described in the next section.

Components of Cognitive Apprenticeships

More specifically, the cognitive apprenticeship model has been described by using the following features (Collins, Brown, & Newman, 1989; Kellogg, 2008; and Woolfolk, 2010):

1. Novices observe an expert who models the activity and demonstrates how and why a task is completed in a particular way.

2. Novices are assisted in their learning through coaching that includes hints, feedback, reminders, checklists, etc. Having a positive interpersonal relationship with the expert provides motivation for the novices to succeed.
3. Novices receive scaffolding (Vygotsky, 1978), assistance, which is appropriate for their skill level and gradually fades as learning occurs.
4. The complexity and diversity of tasks increase as novices become more competent.
5. Novices regularly articulate their understanding of the content and processes they learned in order to perfect, extend, and challenge their own thinking and that of their peers through discussion, presentation, demonstration, or writing.
6. Novices reflect on their own learning by comparing their performance to their own previous accomplishment and that of an expert, and explore how they can further improve their knowledge and fine-tune their skills.
7. Novices are constantly supported to explore new ways of applying their newly acquired knowledge and skills in other contexts.

Modeling

According to Bandura's social cognitive learning theory (1997), we all learn from observing others. We learn academic and non-academic skills by first observing, then imitating experts, and intentionally practicing skills. During learning novices gradually increase their participation in tasks, processes, products, and interactions until they fine-tune their knowledge and refine their skills. Observation allows novices to create a conceptual 'map' of the target behavior, the nature of the task, and the effectiveness of possible solution strategies. When the master explains the purpose of the task, and the skills are explicitly described, the apprentices are able to understand the goal-subgoal structure of the problem. This learning context also permits the apprentices to learn what knowledge to use when, how, and why. Apprentices also have an opportunity to witness how experts set goals, plan their activities, monitor and evaluate their performance, deal with obstacles, troubleshoot, and revise their strategies when they face difficulties. This mental model that novices create may assist in a deeper conceptual understanding (Collins, Brown, & Newman, 1989).

Some tasks (e.g., washing the car) lend themselves more easily to imitation, but more complex, cognitive skills (e.g., working with fractions in 2nd grade) are much more challenging to acquire based on only observation because these skills and the rules of the discipline are hard to see or access by the learners. Acquisition of these tacit skills requires more extended time, more explanation, and appropriate assistance. As cognitive performance is mostly imperceptible or silent, experts may support novices by thinking out loud. Think-alouds (Ericsson & Simon, 1980) allow experts to verbalize their thought processes as they conceptualize tasks, utilize problem-solving strategies, cope with unexpected events, and attack problems in different contexts. As experts reveal their reasons for taking particular steps and selecting some approaches rather than others, learners gain an insight into experts' thinking and a deeper conceptual understanding of the structure and nature of the task. By gaining more experience, novices' knowledge deepens, their skills become more refined, and their metacognition develops (Collins, Brown, & Newman, 1989; Collins, 1991). Learning in authentic environments also allows apprentices to see how their newly acquired knowledge and skills are applicable to other contexts. In a cognitive apprenticeship model novices are treated as able members of a community who need more learning experiences to become experts themselves.

Coaching and Scaffolding

Through the process of coaching the master provides appropriate and timely assistance for the novices. The one-on-one tutoring experience is especially effective as the master can tailor instruction according to the novices' unique academic and emotional needs. The master knows how much can be expected of the apprentices and encourages them towards increasingly independent practice whenever possible. The master also assists the novices by answering questions and providing prompts, hints, reminders, and help when needed.

Through the process of successive approximations (Skinner, 1953) the novices practice skills until those skills become refined and resemble those of a master. This skill development can also be characterized by stages of skill acquisition (Anderson, 1983), i.e., the cognitive stage, the associative stage, and the autonomous stage. In the cognitive stage, novices use declarative knowledge to perform the skill. At this level the learners complete the task slowly, paying attention to all the details and steps in the sequence. Rather than only getting the right answer without real learning, apprentices confront situations in which errors and misconceptions are revealed and addressed systematically. In the associative stage, the learners string more steps together, performing the task with more ease and understanding. In the autonomous stage, all the steps are linked, and the performance becomes refined and executed without much conscious effort or attention. Skill performance at this stage is smooth, errorless, and expert-like.

While apprentices engage in the practice of a new skill, they receive an appropriate amount and kind of assistance, 'scaffolding,' from their master. By observing and diagnosing their novices' skill level and prior knowledge, masters know what expectations are suitable and what tasks can be completed by the novices. The master assigns tasks that the learners can complete with assistance within their zone of proximal development (Vygotsky, 1978). By completing some parts of the task, the master allows novices to participate in *legitimate peripheral participation* (Lave and Wenger, 1991), which allows learners to engage in the practice of an expert and take on as much of the task as they are capable with assistance from the master or a more knowledgeable peer. Practicing the target skills with scaffolding (like training wheels) is motivational because it allows novices to complete meaningful tasks in authentic contexts. This try-out reveals for the novices the overall goal structure of the task, which provides further understanding of how the subtasks fit together in the complex target activity. In this learning environment the apprentices learn what the expected final product looks like, what knowledge and skills need to be learned, and how to use strategic planning to reach their goal.

During practice the master assists the novices in monitoring their own performance and fine-tune the skill practiced. Besides self-correction, the learners are encouraged to engage in self-monitoring and self-regulation – characteristics of expert-like performance. Apprentices need to ask questions, such as, What are you doing and why? How will success in what you're doing help you find a solution to the problem? (Schoenfeld, 1985). Thoughtful responses to these questions may lead to an increase in metacognitive awareness and help students think like real mathematicians.

As the learners develop, the master 'fades' or gradually removes her assistance in order to support the learners' independent practice. As novices develop, the master expects faster execution, more refined skills, more elaborate schemas, and more automated skills. The master also assigns a higher number of more diverse problems that are increasingly more complex in their structures. As masters coach their apprentices, they also evaluate the novices' performance and provide feedback to promote further engagement, improvement, and motivation.

Articulation

Learners are encouraged to articulate their thinking related to the task and its performance. Making their knowledge explicit uncovers learners' understanding and misconceptions. When apprentices are expected to verbalize their problem solving and reasoning, they tend to refine their conceptual understanding.

Reflection

During the reflective process, novices examine their own practice, skill level, and knowledge by comparing them to those of an expert. This analysis indicates areas of improvement and how knowledge and skills need to be integrated to achieve expertise. The outcomes of reflection allow the learners to diagnose their own difficulties, seek out help if necessary, and incrementally adjust their performance to achieve the level of an expert.

Exploration

Once learners have reached a certain level of proficiency, the master recommends guided learning experiences to explore other areas where the students can apply their newly acquired skills and obtain additional knowledge. Collins, Brown, and Newman (1989) recommend that learners identify and solve their own problems. By teaching general exploration strategies, the master can encourage students to become independent learners who set their own learning goals, explore areas of their interests, create and test their hypotheses, identify rules, amass data, solve problems they have identified, and attempt to implement different solution strategies that may even lead to new discoveries (Collins, 1991). By setting personal goals, novices have an impetus to extend their understanding and apply their skills to new problems. However, masters continue to provide (and fade) scaffolding when needed even as learners explore new materials independently, articulate and reflect.

When the deep structure of authentic classroom tasks resemble that of real-life activities, transfer between in-school and out-of-school learning is more possible. Since activities in a cognitive apprenticeship are embedded in authentic learning environments, this constructivist approach increases the chances that learners can transfer their knowledge and skills to other academic disciplines and non-school tasks.

Application of Cognitive Apprenticeship in Teaching and Learning

How can the concept of cognitive apprenticeship be applied in a school setting? How can teachers and more skilled peers scaffold learning? This section describes an instantiation of a cognitive apprenticeship model in an elementary classroom. Features of the cognitive apprenticeship formed the core of this effective instructional model where the teacher utilized problem-based activities in the classroom characterized by 1) teacher-student and student-student interactions, 2) scaffolding to accommodate the children's increasingly sophisticated processing capabilities, and 3) systematic communication about the nature and purpose of the problems to be solved.

The learning context was designed to be effective and responsive to the students' needs, and it capitalized on the nature of human learning and interaction. The teacher tailored learning experiences to meet the unique needs of all students and included authentic, goal-directed activities with the goal of engaging students and promoting their conceptual understanding.

Students worked individually, in pairs, and in different size groups. Sometimes they were required to be self-regulated when, for example, the children decided how to set up the store as a business. To a large degree various forms of collaborative learning were the norm. Students helped one another in natural ways to become more competent and productive members of the classroom store. The teacher had opportunities for direct instruction in the form of mini-lessons, but the nature of the store activities made the students more active and inquisitive as they worked toward the classroom goal. This community of practice with its authentic activities and social interaction (McLellan, 1994) was designed to make learning meaningful.

The next part of this paper introduces how the 2nd graders learned mathematics in the context of a cognitive apprenticeship as they 'played store' in their class.

Cognitive Apprenticeship in the 2nd Grade Store

The math activities in the second grade store were based on state learning standards that addressed 1) number sense and operations, such counting, reading, writing, comparing, and ordering numbers; identifying place value; representing numbers using words and models; and working with money and even/odd numbers; 2) commonly used fractions, such as ½ and ¾, 3) computation and operations, such as knowing multiplication facts and using algorithms for 2- and 3-digit addition and subtraction; 4) estimation, such as completing simple repeating patterns, using commutative and associative rules for addition when doing mental math, and calculating and solving problems involving estimation; 5) basic geometry, such as identifying, describing, and comparing 2- and 3-dimensional shapes; and matching and creating congruent and symmetric shapes; 6) measurement, such as telling time, measuring and comparing objects, and using estimates of measurement; and 7) data analysis, statistics, and probability, such as gathering, representing, organizing, and discussing data using tallies, graphs, diagrams, and charts; and formulating inferences based on data.

Detailed planning and organization lead to the design of the ‘store’ that included authentic and meaningful mathematical problem-solving activities. The learning context and the engagement of students were carefully planned prior to the beginning of the school year. When the school year began, the teacher held an information session for the children and guided the discussion in terms of creating a ‘business’ for the second graders. Enthusiasm ensued, and the classroom community decided to have a field trip to the neighborhood grocery store where staff members and managers created a meaningful learning experience for the students. The field trip to the local grocery store was a great success and enabled the students to relate “in-school learning” to “out-of-school learning”. The context of the store increased the children’s excitement who - upon returning to the classroom - decided to open up their own little store in their classroom.

To keep the momentum up, the teacher had to move fast to allow the children to start ‘playing store’ in math class within a few days. As a matter of fact, the children wanted to do nothing but play store (do math) all the time! The classroom was equipped quickly with all the necessary tools and instruments for the store, such as cash registers, note pads, receipts, pencils, and inventory lists. Visual guidelines were available and accessible to the apprentices in order to perform their assigned tasks independently (e.g., pictures, labels, and a binder on a job: *How to be a cashier*.) In writing class the children filled out application forms (with scaffolding) to apply for jobs, such as cashiers, sales associates, security guards, inventory personnel, stock clerks, and managers. All the students were encouraged to apply for any jobs. Once a person was hired, the teacher and peers trained the individual for the job. The merchandise (previously obtained from donations and garage sales) was put on display and priced by the children. The students soon learned the tasks and responsibilities that opening the store required. As apprentices in the store, the children observed the teacher complete tasks and practiced skills before the customers arrived.

The store was open twice a week. The days when the store was closed were spent practicing skills the apprentices needed for their improved performance on the job. All the apprentices had equal opportunities for participation in the various activities: together they prepared merchandise for sale, set up the store twice a week, and took care of the sales and transactions. The apprentices ran the store with assistance from the teacher, who gradually removed scaffolding as the children’s proficiency increased. The children approached the teacher to ask for help when they needed, and making mistakes was considered part of learning on the job. The focus was on meaningful learning, increasing proficiency, and discussing misconceptions rather than only getting the right answers. The students always had to explain their thinking and their problem solving strategies. The children and the teacher collaborated in this environment, and their roles were complementary. Rather than simply completing exercises in a textbook and correcting the wrong answers, the teacher assisted children in refining their learning outcomes by providing meaningful practice and feedback on their performance.

Modeling

Instead of the traditional approach to teaching mathematics where the teacher presents the material, and the children practice strictly prescribed skills by following detailed and specific instructions, the teacher engaged the students in learning math by involving them in all activities of running the store. In this dynamic and real-life context the teacher functioned as a facilitator and expert who guided students in their everyday activities and jobs. Rather than giving lectures and long presentations, the teacher broke up tasks into meaningful chunks related to specific jobs and collaborated with the children who imitated her.

The store activities were integrated into everyday math instruction as the business was an ongoing, overarching theme for learning math. The context provided the comprehensive goal for the students to learn math skills that were inevitable for operating a store. Soon after the store opened, the children were able to explain the nature of the store, their job description, the purpose of the activities, and ways of doing their jobs better. The 2nd graders could give very elaborate descriptions of what they did and were planning to do. References in the classroom (such as artifacts, posters, banners, and student work) reminded the children of the overarching goal of their activities.

When the teacher modeled a skill, for example, how to make inferences based on customer satisfaction survey data, she described and explained what she was doing, modeled the execution of the task, used manipulates for new knowledge representation, and presented the material in various ways (tactile, visual, and auditory) to encourage children with various preferences for representation to integrate the new material into their prior knowledge. The teacher also modeled critical thinking and used questions, cues, and prompts to encourage children to use higher order thinking skills. Because the context of the store lent itself well to all the math standards in the curriculum, the teacher was able to meet all the students' learning. She could easily modify the store activities for struggling mathematicians - novices who needed 'training' in first grade math. For instance, struggling students practiced how to find out whether a customer had enough money to buy three products (adding three 1-digit whole numbers) and how much money would be left after the transaction.

Each activity in the store was aligned with learning standards and provided a meaningful context for learning skills that are usually taught in mostly decontextualized settings. For instance, the children learned to alphabetize by creating an inventory list for their classroom store, and once the list was made, it became a computerized spreadsheet used for real inventory and accounting purposes. The context of the store created natural opportunities for comparing quantities, counting, using fractions, adding numbers, and rounding – skills for 1st and 2nd graders to practice.

The teacher utilized technology to provide additional modeling to the students. Various software of different difficulty levels provided practice opportunities for all children within their zone of proximal development. Those who struggled with math were 'trainees' who received help from their peers and the teacher on the computer. The math games and other computer activities provided practice in skill acquisition closely related to the standards and the classroom role. Technology also provided assessment opportunities for the teacher in a game-like environment to gain insight into what knowledge and skills the children acquired and still needed to practice. Based on this information, the teacher sometimes guided children in their job application process to ensure that they were placed in situations where they needed to use some skills that needed additional practice. Some shy students needed to be sales representatives to practice talking to customers and struggling mathematicians needed to be cashiers to work with money. Naturally, some children did not want to apply for challenging jobs because they were not comfortable in situations where they lacked some skills. However, the teacher encouraged them, expressed her confidence in their ability to learn the new skills, and made herself available to help.

The children's tasks gradually and regularly became more comprehensive, complex, and challenging based on their zone of proximal development. Learning gains were visible in the level of sophistication in the students' products and execution of particular tasks, such as counting money using fractions and giving back change.

Coaching and Scaffolding

Instead of requiring mere memorization of math facts, the teacher placed focus on conceptual understanding as she asked her students to explain their answers. Group work allowed all the students to discuss their thinking processes and results, and it also encouraged struggling students to get help from their more knowledgeable peers. The teacher asked questions to elicit longer responses and explanations that revealed students' thinking and misconceptions. Class discussions also provided opportunities for the children to talk about the material, different ways of doing things, and what they learned from the activities.

The teacher scaffolded children's verbalization by asking open-ended questions rather than using the prescribed questions in the textbook or other yes-no questions that fail to promote higher order thinking. The types of goals, questions, assistance, feedback, and assessment methods the teacher utilized seemed to indicate that she wanted her 2nd graders to think deeply about the material and hopefully transfer their newly acquired knowledge to other areas. The teacher set very clear and explicit learning goals *with* her students: "learn math to run the store successfully and take very good care of our customers." This overarching goal permeated all math activities that were considered to be essential for good business and excellent customer service.

Because the teacher's goal for her students focused on conceptual understanding of basic math concepts and processes rather than simple memorization of math facts in isolation, the learning activities required more, higher-level thinking of second graders, for instance, role-playing in the store, analyzing trends in profit, organizing various activities and responsibilities for each job in the store, and making inferences about customers' preferences, and summarizing store activities.

Coaching was provided by the teacher, peers, and also technology. The students used the computers to practice math skills, such as adding, subtracting, and using fractions – skills they needed to run the store. Coaching allowed the teacher to get an insight into her students' thinking and see that even a correct answer does not guarantee clear understanding at all times. The children were encouraged to work in groups or individually without her constant presence; however, she was always available for assistance if the children needed her. Her feedback was extensive, focused on process as well as product, and included feedback on good performance or errors rather than merely pointing out whether the answer was correct or not. The children, who often worked independently, seemed to be very engaged in all the tasks, for example, creating an inventory, counting money, accepting payment and making change, filling out forms, and verifying that the payments were made. These same activities provided authentic opportunities for assessing children's skill acquisition and knowledge retention. Once the children's autonomy rose in the activities, and they were able to complete tasks independently, the teacher faded her scaffolding in those areas and introduced more complex activities that the children were able to complete only with some assistance.

The children internalized the new knowledge and skills and were able to transfer them to new situations successfully, for instance, when the school-wide doughnut sale needed sales people. Several 2nd graders volunteered and completed the tasks efficiently because they were already accustomed to the context of a real store.

Articulation

The process of articulation allows apprentices to exchange with their peers and the teacher the knowledge they obtained in the activities. The children demonstrated how they completed their tasks and solved problems, for example, how they figured out what merchandise would result in the highest profit margin for the classroom. (The students recognized that upper classmen preferred used DVDs to kindergartener art creations. The store employees calculated that it was more profitable to sell used DVDs of children's movies with a profit margin of 50 cents each than to create laborious art designs and make only 25 cents on each. When kindergartners visited the store, the art designs were much more popular and ensured higher income for the store personnel.)

Instead of using predetermined questions at the end of each chapter of their textbook that provided drill practice of these skills in decontextualized contexts, the teacher created authentic opportunities for the students to explain their thinking. For example, the children gave a presentation based on survey data of what merchandise other classes would like to buy in the store and how much profit they think the store would make. Elaborate mathematical calculations were included in these presentations that were created by groups of children and assisted by the teacher. These presentations proved to be wonderful teaching opportunities as many children had to confront their misconceptions and ineffective strategies and had the motivation to change because of their desire to run the store more successfully. Eventually, all children discussed their successes and difficulties that lead to a refined conceptual understanding beyond memorization of discrete facts and superficial treatment of math processes.

Reflection

The teacher enhanced the students' reflection by asking them to think about how well they completed their tasks and what their difficulties were, for example, what was challenging about putting the store inventory together? Children were asked to think about how they could do their jobs better, for example, what skills they would need to practice to be better cashiers. The teacher also asked the students to create their own questions to which they wanted to find answers, for instance, what questions they would need to ask on their customer satisfaction survey, and how their job descriptions would have to change to run the business more efficiently. These personally meaningful questions increased the apprentices' engagement and activities – all tied together by a shared focus and goal.

During the course of the academic year, the class returned to the supermarket to see how real professionals completed their jobs so that the apprentices could compare their performance to that of experts. The reflective discussions highlighted what skills were challenging and why more practice was essential. Reflection about their performance in the context of an overarching goal seemed very motivation for the children who further engaged in math activities that did not necessarily appeal to them. The desire to achieve expertise propelled the students to engage in practice and make meaning from their activities. In this context reflection became meaningful and resulted in conversations that signaled in-depth thinking. These reflective activities provided additional opportunities for the teacher to assess her students' content mastery and skill acquisition.

Exploration

Cognitive apprenticeships support problem solving and student autonomy in learning. The hope is that children continue exploring their interests, playing with math even outside of the classroom, and transfer their knowledge and skills to other areas. The teacher encouraged the children to be independent learners who identify problems they want to solve and find ways to solve them. The teacher encouraged the second graders to come up with their own hypotheses about trends and profits, collect data, and come up with their own conclusions. When the teacher invited other guests from other cultures to show how they handle numbers, the children became very interested in the use of the abacus! Exploring what the students want to learn rather than what the teacher and the curriculum prescribe is a powerful and motivating tool. If student interest determines learning goals, children stay engaged longer, focus better, and persist at tasks even in the face of obstacles.

Methods

Subjects and Setting

The participants in this study were 30 second grade students in the first academic year and 36 in the second academic year in an inner city public school in the Mid-Atlantic region. The student population at the school was 100% African-American. More than 97% of the children qualified for free breakfast and/or lunch. Approximately 90% of the students lived in the housing complexes that surrounded the school, and most children were raised by a single parent or a grandparent.

The community where the school is located is considered the most dangerous part of the city that is plagued by a high level of violence, rampant crime, and unbridled drug use. The annual count of homicide in the whole city has ranged between 143 and 472, and the annual number of firearm recoveries has been between 1,982 and 2,534. Since the part of the city where the school is located is considered the most dangerous section, a majority of the crimes occur there.

The area of the school lacks retail shops, restaurants, libraries, and small businesses. Most of the shops are liquor stores that determine the kinds of customers who frequent that area. Many homes seem decaying and unsafe, and the community seems literacy-barren with the exception of a few large ads on the street. The lots are occupied mostly by used car repair shops and empty lots that are homes to trash receptors and abandoned cars. In sum, the community looks dangerous and in need of a renovation and renewal.

Measuring Instrument and Data Collection

The school district used the Stanford Achievement Test, Ninth Edition (SAT-9) to assess student learning in the area of mathematics. This test was administered to all children from 1st to 6th grades. Each year the test was administered in October to obtain pre-test measures and April to amass post-test measures. The administration schedule of SAT-9 allowed for a test-retest format to calculate growth for each student and compare performance between the end of first grade and the end of second grade. This approach helped address possible initial differences between the two classes at the beginning of the school year.

This study examined data from two cohorts of students in two consecutive academic years. In both years the students were assigned non-randomly to the two 2nd grade classes by the principal prior to the beginning of the school year. In the 2nd Grade Store, the teacher set up the environment to teach mathematics in the context of a cognitive apprenticeship while the teacher in the other second grade class taught mathematics using traditional methods.

The data analysis utilized Grade Equivalent Scores (GES) as the school system reported student learning in terms of GES. GES offers an estimation of students' tested performance in a subject area based on grade level and month in a given school year. For example, a GES score of 2.2 indicates performance that is expected of a second grader in the 2nd month of the academic year, i.e., in October. GES scores can be used to track development or growth in student achievement.

Data Analysis

Table 1 displays the growth results for the cognitive apprenticeship (CA) classroom in the 2nd grade store and a traditional 2nd grade classroom.

The table presents the average growth of the children in the two classrooms measured in GES in the area of mathematics at the beginning of first grade and second grade. The results indicate gain in the area of math computation, which shows .9 years of additional benefit for the CA classroom, and Math Total showed a .5 year effect. These results seem to provide validation to the idea that naturally emphasized, authentic activities lead to increased learning. Since a substantial amount of store activity involved math (e.g., pricing, making change, calculating credits), it would make sense that computation math skills improved as a result of store activities.

Table 1

Comparison Between a Cognitive Apprenticeship Classroom and a Traditional Classroom in Terms of Growth in Math from 1st to 2nd Grade as Measured by Standardized Testing*

Standardized Test Scores	**2nd Grade Store - CA (n=15)**			**Traditional (n=15)**		
	1st	**2nd**	**Growth**	**1st**	**2nd**	**Growth**
Computation	1.1	3.49	**2.39**	.75	2.24	**1.49**
Application	1.09	2.54	**1.45**	1.43	2.90	**1.47**
Total	1.06	2.84	**1.78**	1.12	2.42	**1.30**

Table 2 presents standardized achievement data in GES for the CA and traditional classes in the second academic year. Due to reliability problems with data collection in the second year, it was not possible to obtain data for these groups of students at the end of their first grade. However, growth data from the beginning and end of the school year in Table 2 illustrate the same pattern as the data in the previous year. Students in the CA classroom showed superior performance in computation when compared to the students in the traditional class. Math Computation showed a 1.4 year effect, and Math Total showed a .8 year benefit. Thus, the data analysis indicates consistent effects of improved performance and selectively large effects for areas that were naturally emphasized by the authentic activities in the CA store.

Table 2

Comparison of Posttest Data in Terms of Grade Equivalent Scores for the 2nd Grade CA Classroom with a 2nd Grade Traditional Classroom

CTBS Subtests	**2nd Grade Store - CA (n=16)**	**Traditional (n=20)**
Mathematics		
Computation	**3.0**	**1.6**
Application	1.8	1.4
Total	**2.4**	**1.6**

In short, the implementation of a cognitive apprenticeship model in 2nd grade was successful. The growth results of the 2nd grade store were inspiring.

Conclusion

Cognitive apprenticeships (see Brown, Collins, & Duguid, 1989) are authentic instructional environments in which one or more students (apprentices) study a domain, discipline, or profession under the mentorship of someone more skilled, with the stated intention of developing expertise in that particular area.

Cognitive apprenticeships have several features that make them useful instructional models. First, the expert-apprentices relation allows for intensive one-on-one tutoring. The expert "scaffolds" for the apprentices thereby (1) exposing the internal representation of a problem, (2) guiding the apprentices through the problem space of the problem, and (3) acting as a model problem solver (thereby demonstrating the goal-subgoal structure of the problem and the strategy for solving it). In subsequent interactions, the expert points out similarities and differences between and among problems. All the while the expert monitors and assesses the progress of the apprentices. This process is akin to keeping the apprentices in their zone of proximal development (Vygotsky, 1987). Together, these tutoring activities help the apprentices build an organized, elaborated, and systematic understanding of the domain, an understanding that is personally meaningful.

Cognitive apprenticeships are situated in problem-based learning activities, which are authentic or real rather than decontextualized or artificial problems often found in classrooms. The assumption is that authentically acquired and used knowledge is more likely to transfer to other real-world situations (Robson, 2006). In problem-based learning environments, students acquire cognitive competence by working on real problems that challenge their current level of thinking, rather than working solely on isolated parts of a problem or on problems they will never encounter outside of school. As the students' processing capabilities become more sophisticated, the level of problem difficulty and the students' level of responsibility for solving the problem increase accordingly. One integral result of working on real problems is that students have many natural opportunities to practice small, specialized, sets of cognitive activities in context. Eventually, automated basic skills develop as subroutines within the goal structure of larger problem-solving procedures.

Cognitive apprenticeships posses a social character of the learning environment (e.g., Vygotsky, 1987). By design the environment creates a high degree of interaction rather than having an individual work in isolation. This interaction may take the form of collaborative problem solving, direct instruction, informal assessment, or coaching. Through these interactions, the roles of the members are defined. One prerequisite for successful maintenance of the apprentices' relationship is legitimate contribution by all apprentices according to their role, knowledge, and skill set. These interpersonal relationships and the accompanying expectations are very motivational for engagement.

The literature indicates that cognitive apprenticeship is a powerful tool to facilitate student learning (Collins, Brown, & Newman, 1989). Cognitive apprenticeship engages and motivates learners with the use of authentic, meaningful, and expert-like learning activities in a culture of expert practice. By the nature of learning tasks and assessment, it may promote retention and transfer (Resnick, 1989) as well as higher order reasoning (Hogan & Tudge, 1999) – important outcomes for all learners.

References

Anderson, J.R. (1983). *The architecture of cognition.* Cambridge, MA: Harvard University Press.

Bakhtin, M.M. (1981). *The dialogical imagination: Four essays by M.M. Bakhtin* (Trans. C. Emerson & M. Holquist). Austin, TX: University of Texas Press.

Bandura, A. (1997). *Social learning theory*. Englewood Cliffs, NJ: Prentice-Hall.

Brown, J.S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*, 32-42.

Collins, A. (1991). Cognitive apprenticeship and instructional technology. In L. Idol & B.F. Jones (Eds.), *Educational values and cognitive instruction: Implication for reform* (pp. 121-138). Hillsdale, NJ: Lawrence Erlbaum Associates.

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the craft of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 453-494). Hillsdale, NJ: Lawrence Erlbaum Associates.

De Corte, E. (1990). Towards powerful learning environments for the acquisition of problem solving skills. *European Journal of Psychology in Education, 5*(1), 5-19.

Ericsson, K., & Simon, H. (1980). Verbal reports as data. *Psychological Review, 87*(3), 215- 251. doi: 10.1037/0033-295X.87.3.215.

Hogan, D. M., & Tudge, J. R. H. (1999). Implications of Vygotsky's theory for peer learning. In A. M. O'Donnell & A. King (Eds.), *Cognitive perspectives on peer learning* (pp. 39-65). Mahwah, New Jersey: Lawrence Erlbaum.

Kellogg, R.T. (2008). Training writing skills: A cognitive developmental perspective. *Journal of Writing Research, 1*(1), 1-26.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation.* New York, NY: Cambridge University Press.

McLellan, H. (1994). Situated learning: Continuing the conversation. *Educational Technology 34*, 7-8.

Perkins, D.N., Jay, E., & Tishman, S. (1993). New conceptions of thinking: From ontology to education. *Educational Psychologist, 28,* 67-85.

Resnick, L.B. (Ed.). (1989). *Knowing, learning, and instruction: Essays in honor of Robert Glaser.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Robson, S. (2006). Frameworks for thinking: Supporting successful thinking and learning. *Transylvanian Journal of Psychology, 2*(1), 77-88.

Schoenfeld, A.H. (1985). *Mathematical problem solving*. New York, NY: Academic Press.

Skinner, B. F. (1953). *Science and human behavior*. Oxford, England: Macmillan.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Woolfolk, A. (2010). *Educational psychology* (11th ed.). Upper Saddle River, NJ: Merrill.