Prerequisite Skills and Mathematics Learning: Role of Games in Learning Mathematics

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Prerequisite Skills and Mathematics Learning[1]

Toys and games are synonymous with play, pleasure, and relaxation. Almost everyone likes to play and, in one form or other, this continues throughout one's life. Play is not just a filling in of an empty period or a relaxation or leisure activity, it is also an important learning experience—an essential ingredient for growth and development for children and adults alike. For example, babies play with their fingers and toes and in so doing bring about a social interaction with adults who join in their game. As the baby explores this form of play, the child acquires numeracy. In many countries, parents often chant a rhyme such as the one below while touching each of the child's toes:

one, two, three, four, five,
once I caught a fish alive:
six, seven, eight, nine, ten,
then I let him go again.

This is the beginning of parents' efforts towards assisting the child to learn to count.

In addition to the commonly accepted means of relaxation, play is seen as a means to work off aggression, to learn basic survival skills (as is also observable in the animal kingdom), and to learn social behavior (competitive and cooperative). But more importantly, the role of play is to engage in learning and to gain interest in learning.

Simple activities such as exploring patterns around the house and in nature with games, sound, color, objects and movement are ways by which children can develop many skills that prepare them for formal mathematics learning. At first, children need help to recognize patterns (a pattern is a relationship between many pieces of information—numbers, letters, shapes, sounds, etc. that is ongoing, predictable, and can be expressed explicitly or implicitly). Then they need to understand how a pattern can be copied, extended, and applied. Finally, with practice, children are able to make predictions about patterns. It is this predictable nature of patterns that teaches the most. Outside the home, children can find patterns easily with a crayon and paper. Creating rubbings they can find patterns in leaves, rocks, and tree bark. Parents should help children create a pattern album drawing pictures of shells, flowers, waves on a shore, or animal coats at the zoo.

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[1]Excerpted from
Games and Their Uses in Mathematics Learning (Sharma, 2008/2012)

Fun is a great motivator for learning any subject, even mathematics. Unfortunately, many in our society feel inadequate even when it comes to mundane, everyday calculations, and they view mathematics as an anxiety-provoking task. That feeling makes it difficult for teachers to teach mathematics and for students to invest interest, time, and energy to learn mathematics. Fortunately, through games and toys, our motivation and fun can advance learning.

In the information and Internet age, smart-phones, computers, and web-based games have become a major source of play among children. They rapidly learn how to operate these devices because they are motivated to explore. Children's sense of adventure through computer and web-based games supports learning in the classroom and laboratory when youngsters progress to other subjects, for example, science in secondary school. These games provide opportunities for acquiring many skills for learning (visuo-spatial, sequencing, and spatial sense). For a fuller development of the brain, though, and for broader learning and sociolinguistic skills, multi-sensory games are essential because they develop and integrate tactile/kinesthetic, visual, auditory, socio-linguistic, and executive functioning skills.

These days, board games are not limited to play dates and family game nights. Classic games like Scrabble, Candy Land and Sorry are finding their way into classrooms as educators creatively use the games to reinforce mathematics, language and critical thinking skills. Numerous research studies support the assertion that playing board games helps students improve mathematics and thinking skills. For example, in one study, disadvantaged preschool students played a simple numeric board game four times for 15-20 minutes at a time over a two-week period. At the end of the two weeks, researchers found students' knowledge of math greatly increased in several different areas related to quantitative thinking and number sense. Numbersense is a form of quantitative thinking—knowing what a collection representing 5 looks like and knowing that 5 is less than 8 and is made up of 5 and 3. Numbersense depends on counting, learning quantitative language, and spatial representation and distribution of objects in the representation, but counting is only a part of the number conceptualization process—it is just the beginning. Several developmental steps are necessary to attach a number value to collections and amounts and to give meaning to numbers, and then to understand the interrelationships of numbers.

Number concept is the integration of several prerequisite skills: sequencing, one-to-one correspondence, visual clustering—arrangement of objects, and decomposition/ re-composition of visual clusters

(numbers)—can the child instantly break the number (from 2 to 10) into its component sub-clusters (smaller numbers) as needed (e.g., 10 is made up of 1 and 9; 2 and 8; 3 and 7; 4 and 6; and 5 and 5).

Number conceptualization is easily achieved by games and toys. For example, games involving playing cards, dominoes, and dice integrate the skills—sequencing, one-to-one correspondence, visual clustering, and decomposition/recomposition. Many card and board games reinforce numbersense and help children learn one-to-one correspondence, sequencing and visual clustering, but most importantly logical reasoning and communication of ideas.

The benefits of using board games are not limited to mathematics. They can be used to build vocabulary, spelling, and logical reasoning skills. Basically any game can be adapted to help learn. For example, the card game ***Go Fish*** can be modified into a game ***Go Make Ten***. It is played in the same way as Go Fish, but here children make as many pairs of two cards that add to ten. In a short time, children learn the most important arithmetic facts clusters: what two numbers make ten? Children who have not mastered this family of addition facts have great difficulty in mastering other addition facts (a non-negotiable skill at first grade). The game can further be modified to other number facts: ***Go Make Nine***, ***Eight***, or any other number. Because of their intrinsic entertainment value, games provide educators with an effective tool for engaging students because students think they're just having fun.

Many parents want to work with their children to help them in mathematics, but they may feel that they have limited mathematics training and understanding of mathematical concepts, particularly the "modern math" or "new ways" of teaching mathematics. Other parents may be impatient with children having problems because they have high expectations of their children. While working with their children, they may also mix the roles of parenting and teaching, which can cause difficulties both in learning and personal relationships. To avoid transferring their own anxieties or setting unrealistic expectations, parents should work on mathematics only if they feel comfortable with mathematics and have realistic goals for their children. Children of parents who show an interest in and enthusiasm for mathematics around the home are more likely to develop that enthusiasm themselves.

Despite these possible limitations, there is a great deal parents can do to help children in learning mathematics. For example, they can help children acquire prerequisite skills. Prerequisite skills help us learn, retain, and master formal concepts, skills, and procedures in mathematics. In any instructional or remedial program, whether the

student is eight years old, fifteen, or an adult, we need to devote a portion of the teaching time in helping the student acquire prerequisite skills such as:

- Classification/class inclusion
- Matching/one-to-one correspondence
- Visual clustering
- Ordering and sequencing
- Visualization
- Ability to follow sequential directions
- Spatial orientation and space organization
- Estimation
- Pattern recognition, extension, and its application
- Deductive and inductive thinking

With exposure and practice, these skills can be easily learned. Collecting patterns, playing with spatial reasoning and numbersense games are all methods by which parents can encourage positive attitudes toward mathematics. Because mathematics is the study of patterns in quantity (number), space, and their integration, the emphasis in mathematics related games should be on quantitative (numbersense) and spatial (space, shapes, etc.) reasoning.

Spatial reasoning: Spatial reasoning is the back-bone of mathematics. Playing with Blocks, cubes, Lincoln Logs®, Legos®, Tinker Toys®, puzzles, Jenga® cubes and tangrams all help develop the skills of early spatial reasoning—a foundation for mathematical understanding. With practice manipulating objects a child gains an awareness of shapes and how they relate to each other. For example, a family project using wood, nails and instructions how to make a box can encourage spatial reasoning.

Numbersense: First, children need an awareness of numbers. This can happen throughout the day by pointing out numbers on clocks, houses, phones, calendars, any number a parent sees. Children need to learn the concept of what the symbol of a particular number means. So, as they see the number three on a clock, count out three blocks together. When they find a number two, together count two apples, pointing and moving each apple as you count. Count socks, cars, cookies, simple daily objects. Then, move objects into sets…two socks, three carrots, four spoons. Play board games that require a child to count numbers on dice, then count spaces on a board.

To develop prerequisite skills, games and toys should have certain characteristics:

1. Games should be based on strategies. In other words, to be proficient

in a game should mean proficiency in the strategies. This means that each encounter with the game or toy helps the child discover something more about the game, i.e., a strategy, a perspective, or a relationship between moves. Such games are interesting to novice and expert alike and help children improve their cognition, inquisitiveness, perseverance, visualization, and executive functions.

2. In general, a game should last on average ten to fifteen minutes so that children can see the end of the game in a fairly short period of time and so that they can understand the relationship between a strategy and its impact on the game. This teaches children the foundation of deductive thinking or what can be understood as cause and effect. Only when a child has more interest and maturity and is able to handle delayed gratification are complex strategy games such as chess meaningful. For some children, games like chess may become ends in themselves, which is fine, but then they no longer serve the same purpose that I advocate—preparation for prerequisite skills for mathematics learning.
3. Each game we select should develop at least one prerequisite mathematics skill either directly or indirectly. For example, the commercially available game Master Mind is an excellent means for developing pattern recognition and visual memory and a good vehicle for developing deductive thinking in children as well as adults.

Every teacher and parent has a favorite list of games. Some games might be for a specific purpose—reinforcing a skill, teaching a concept, strengthening a process, or just offer entertainment.

Following is a list of games and toys I have used extensively with children and adults to develop prerequisite skills and mathematics concepts and thinking. Most of these games and toys are commercial. They are highly motivational and can break formal instructional routines. These games:

- have educational value
- are and should be fun
- are a natural activity in children's visual/perceptual development
- further their cognitive, affective and psycho-motoric development
- are useful assessment tools

Games (including prerequisite skills):

- **Battleships** (spatial orientation, visualization, visual memory)
- **Black-Box** (logical deduction)
- **Blink** (pattern recognition, visual memory, classification, inductive reasoning)
- **British Squares** (spatial orientation, pattern recognition)
- **Card Games** (visual clustering, pattern recognition, number

concept—visual clustering, decomposition/recomposition of number, number facts) (see Number War Games)

- **Checkers (**sequencing, patterns, spatial orientation/space organization)
- **Chinese Checkers** (patterns, spatial orientation/space organization)
- **Concentration** (visualization, pattern recognition, visual memory)
- **Cribbage (**number relationships, patterns, visual clusters)
- **Cross Number Puzzles** (number concepts, number facts)
- **Dominos (**visual clusters, pattern recognition, number concept and facts, decomposition/recomposition, number) (Number War Games)
- **Four Sight** (spatial orientation, pattern recognition, logical deduction)
- **Go Muko** (pattern recognition, spatial organization)
- **Go Make Ten** (**Go Fish Ten** or **Big Ten**) (number concept, decomposition/recomposition)
- **Hex** (pattern recognition)
- **In One Ear and Out the Other** (number relationships, number facts, additive reasoning)
- **Kalah**, **Mankalah,** or **Chhonka** (sequencing, counting, estimation, visual clustering, deductive reasoning)
- **Krypto** (number sense, basic arithmetical facts)
- **Math Bingo Games** (number facts)
- **Master Mind** (sequencing, logical deduction, pattern recognition)
- **Number Master Mind** (number concept, place value, properties of numbers)
- **Number Safari** (number facts, additive and multiplicative reasoning, equations, a paper/pencil game)
- **Number War Games** (visual clustering, arithmetic facts, mathematics concepts, deductive reasoning, fluency of facts)
- **Othello (**pattern recognition, spatial orientation, visual clustering, focus on more than one aspect, variable or concept at a time)
- **Parcheesi** (sequencing, patterns, number relationships)
- **Pinball Wizard** (number facts, a paper/pencil game)
- **Pyraos** (spatial orientation/space organization)
- **Quarto** (spatial orientation/space organization, patterns, classification)
- **Qubic** (pattern recognition, spatial orientation, visualization, geometrical patterns)
- **Reckon** (number facts, estimation, basic operations)

- **Score Four** or **Connect Four** (pattern recognition, spatial orientation, visual clustering, geometrical patterns)
- **Simon** or **Mini Wizard** (sequencing, following multi-step directions, visual and auditory memory)
- **Snakes and Ladders** (sequencing, following multi-step directions, visualization, number facts)
- **Stratego** (spatial orientation, logical deduction, graphing)

Games should not simply be used to occupy children's time. Rather, as mathematics learning tools, games should be used purposefully. Initially, all activities, games, software, or equipment must be teacher/parent directed and goal oriented. The involvement of the teacher/parent is essential for success and progress. Engaging all children in a single game assumes that there are no individual differences among children, parents, or teachers. The key to the wise use of games and toys is first to determine what prerequisite skills the child needs and then to select the appropriate games and toys.

The **Number War Games**, a collection of games, which I designed based on the popular ***Game of War*** using ordinary deck of cards to teach number and number relationships, is useful for developing arithmetic skills. These games use ordinary decks of playing cards and dominos—a versatile set of tools for teaching mathematics from number conceptualization to introductory algebra. For children to develop number concepts, it is better to play these games with cards that do not have numbers on them (instead, the cluster on the card represents the number). *Cards without numbers (Visual Cluster Cards) are available from my Center: www.mathematicsforall.org*.

Number War Games begin in the same way as the Game of War. They are played essentially the same way and are easy to learn. To avoid the word war, you can call it by some other name such as: "beat it" or "top it." Children love to play these games. I have successfully used them for initial as well as remedial instruction, particularly for learning number arithmetic facts, comparison of fractions, and operations on integers (treating club and spade cards as positive numbers and heart and diamond cards as negative numbers, for example, five of spades is $^{+}5$, and six of diamonds as $^{-}6$ and assign any value to face cards). Once they master arithmetic with these cards, one should extend the idea to algebra (e.g., in this game, one with bigger value for $P = 2x + 3y$, where x is the value of the red card and y is the value of the black card. The expression for P changes ($P = x^2 + y^2$, $P = 2x/3y$, $P = |x| - 3|y|$, *etc.)* with each game (See my text *Number War Games* for detailed instructions).

In addition to developing prerequisite skills, manipulative devices

and games may be used in other ways:

- as a help in demonstrating the mathematical process,
- by children as they practice a process for ease in computation,
- by children as they practice to gain speed and accuracy in recall.

Furthermore, games and play provide good opportunities for discussions of strategies, outcomes, and feedback to improve strategies. Regular discussions invite children to communicate concepts while sharpening their thinking skills such as their ability to make inferences, to support their arguments with reasons, and to make analogies—skills essential to learning and applying mathematical skills.

Math through literature: Reading to children is a treasured activity in many homes. What better way to integrate mathematics into the lives of children than to read them stories that bring mathematical ideas to life? Children's books related to mathematics can be separated into four categories: counting books, number books, storybooks, and concept books. Have a representation of these kinds of books when you read to your child. Some titles to get started:

- It Spot by Lucille Recht Penner
- The 512 Ants On Sullican Street by Carol A. Lossi
- Pieces = Part = Portion by Scott Gifford (Fractions, Decimals, Percents)
- Pizza Counting by Christina Dobson
- The Purse by Kathy Caple
- The M &M Counting Book by Barbara McGrath

Reading mathematics related books to children helps parents communicate the importance of mathematics to children and become more involved in their children's mathematical education. An important objective of these readings is to become aware of fun activities that parents can use with children from preschool age through grade 5 to strengthen their math skills and build positive attitudes toward math.

In an environment where discussions are encouraged, children begin to ask questions not only of their classmates and siblings but also of parents. They learn to evaluate answers, draw conclusions, and follow up with more questions both of convergent (a question that calls for a yes, no, or a short answer) and of divergent (a question that calls for an answer with explanation) types, which strengthen facility in reasoning. Development and use of reasoning is the core of mathematics learning.

Without discussions, children become procedurally oriented. Too much procedural or ‘recipe’ learning eventually leads to boredom in mathematics. In contrast, an environment, whether in home or school that inculcates and emphasizes language and reasoning and develops these

skills first in informal settings and then in formally prepares children better for formal mathematics learning. These experiences are forerunners of formal mathematical thinking.

In conclusion, to the uninitiated, mathematical objects are abstract, unreal, but for those who enjoy mathematics they are real, almost concrete objects. Doing real mathematics is like playing a game; it is thinking about and acting upon mathematical objects and the relationships among them, using the same mental abilities that we use to think about physical space, other people, or games and toys. To engage children in mathematics and excite them about mathematics learning, they need to see mathematics as a collection of interesting games.

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	arithmetic facts	basic operations	classification.	concept of Time	counting	estimation	focus on many concepts	following multistep directions	geometrical patterns	graphing	logical deduction	mathematics concepts	number facts	number relationships	number sense	paper/pencil	pattern recognition	patterns	sequencing	space organization	spatial orientation	visual and auditory memory	**visual clusters**	**visual memory**	**visualization**
Simon or Mini Wizard								◙											◙			◙		◙	
Battleships																			◙					◙	◙
Cribbage			◙															◙		◙	◙				
Quarto																	◙								◙
Concentration																		◙						◙	◙
Chinese Checkers																		◙		◙	◙				
Pachisi														◙				◙	◙						
Checkers																		◙	◙	◙	◙				
Othello				◙			◙										◙			◙			◙		
Score Four/Connect Four									◙								◙				◙		◙		
Qubic									◙									◙			◙				◙
Pyraos																				◙	◙				
Krypto	◙														◙										
Go Muko																	◙			◙					
Kalah or Mankalah					◙	◙													◙				◙		
Master Mind											◙						◙		◙						
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Stratego										◙	◙										◙				
Number Safari													◙			◙									
Pinball Wizard													◙			◙									
In One Ear & Out the Other													◙			◙									
Number War Games	◙											◙												◙	

Center for Teaching/Learning of Mathematics

CT/LM has programs and materials to assist teachers, parents, tutors, and diagnosticians to help children/adults with their learning difficulties in mathematics. We conduct regular **workshops, seminars,** and **lectures** on topics such as:

1. How does one learn mathematics? This workshop focuses on psychology and processes of learning mathematics—concepts, skills, and procedures. The role of factors such as: Cognitive development, language, mathematics learning personality, pre-requisite skills, conceptual models, and key developmental milestones (number conceptualization, place value, fractions, integers, algebraic thinking, and spatial sense) in mathematics learning. Participants learn strategies to teach their students more effectively.

2. What are the nature and causes of learning problems in mathematics? This workshop focuses on understanding the nature and causes of learning problems in mathematics. We examine existing research on diagnosis, remedial and instructional techniques in dealing with these problems. Participants become familiar with diagnostic and assessment instruments for learning problems in mathematics. They learn strategies for working more effectively with children and adults with learning problems in mathematics such as: dyscalculia and math anxiety.

3. Content workshops. These workshops are focused on teaching key mathematics milestone concepts and procedures. For example, **How to teach arithmetic facts easily and effectively. How to teach fractions more effectively. How to develop the concepts of algebra easily. Mathematics As a Second Language.** In these workshops, we use a new approach called **Vertical Acceleration.** In this approach, we begin with a simple concept from arithmetic and take it to the algebraic level.

4. What to look for in a results-oriented mathematics classroom: This is a workshop for administrators and teachers to understand the key elements necessary for an effective mathematics classroom.

We offer **individual diagnosis** and **tutoring services** for children and adults to help them with their mathematics learning difficulties, general learning problems, and dyscalculia. We provide:

1. Consultation with and training for parents and teachers to help their children cope with and overcome their anxieties and difficulties in learning mathematics, including dyscalculia.
2. Consultation services to schools and individual classroom teachers to help them evaluate their mathematics programs and teaching and help design new programs or supplement existing ones in order to minimize the incidence of learning problems in mathematics.
3. Assistance for the **adult student** who is returning to college and has anxiety about his/her mathematics.
4. Assistance in test preparation **(SSAT, SAT, GRE, GMAT, MCAS**, etc.)
5. Extensive array of mathematics publications to help teachers and parents to understand how children learn mathematics, why learning problems occur and how to help them learn mathematics better.

Publications

Dyslexia and Mathematics Language Difficulties	**$15.00**
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Guide for an Effective Mathematics Lesson	**$15.00**
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6. **Professional development: Teachers' questions**

Most children have difficulty in mathematics when they have not mastered the key mathematics milestones in mathematics. The key milestones for elementary grades are: Number conceptualization and arithmetic facts (addition and multiplication), place value, fractions and its correlates—decimal, percent, ratio and proportion. These videos and DVDs present strategies for teaching these key mathematics milestone concepts. They apply Prof. Sharma's approach to teaching numeracy. These were videotaped in actual classrooms in the UK.

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Professor Mahesh Sharma is the founder and President of the Center for Teaching/Learning of Mathematics, Inc., Framingham, Massachusetts, and Berkshire Mathematics in England. Berkshire Mathematics facilitates his work in the UK and Europe.

He is the former President and Professor of Mathematics Education at Cambridge College, where for more than thirty-five years, he taught mathematics and mathematics education to undergraduate and graduate students.

He is internationally known for his groundbreaking work in mathematics learning problems and mathematics education, particularly dyscalculia and other specific learning disabilities in mathematics. He is an author, teacher and teacher-trainer, researcher, consultant to public and private schools, as well as a public lecturer.

Professor Sharma was the Chief Editor and Publisher of *Focus on Learning Problems in Mathematic*s, an international, interdisciplinary research journal with readership in more than 90 countries, and the Editor of *The Math Notebook*, a practical source of information for parents and teachers devoted to improving teaching and learning for all children.

Professor Sharma provides direct services of evaluation and tutoring for students (children as well as adults) who have learning disabilities such as dyscalculia or face difficulties in learning mathematics and gifted/talented children to ehlp them reach their potential. He works with teachers and school administrators to design strategies to improve mathematics curriculum and instruction for all. He has been a consultant to many educational organizations, many school systems, states and provinces in North America, and countries in Asia and Europe.

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