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EXECUTIVE FUNCTIONS: IMPLICATIONS TO MATHEMATICAL SKILLS AMONG PRESCHOOLERS

Ma. Raniella M. Ardiente

Ma. Raniella M. Ardiente is currently pursuing her Doctor of Educationa major in Early Childhood Education in Cebu Normal University, Cebu City, Philippines.
Contact No.: 0910-559-2149
E-mail: mrmardiente@nemsu.edu.ph

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ABSTRACT

Mathematical skills are vital to the children's life because it will be used in making decisions in almost every area of their lives, in their studies and in other learning situations. The study investigated the relationship of executive functions: inhibitory control and working memory of the preschoolers to their mathematical skills. Descriptive research design was used. The participants were one hundred preschoolers of the three schools in Cagayan de Oro City. The researcher-made test was used to determine the preschooler's mathematical skills which include classification, seriation, counting and comparing, one to one correspondence, number and number words, and addition and subtraction. Various assessments were employed to measure the pupils' extent of demonstration of executive functions. The study found that the pupils' mathematical skills were not significantly related to working memory but were found to have significant negative correlation with inhibitory control. Within the components, positive and negative correlations were found. The study concludes that the use of executive functions does not necessarily ensure the manifestation of good mathematical skills.

The early development of mathematical skills, along with other skills (such as reading), is related to the development of the children's executive functions. Executive functions are the "cognitive processes that regulate learning and control distractions" (Miyake, Friedman, Emerson, Witzki, Howerter & Wager, 2000). The most primary time in the progress of executive function is early childhood, particularly around 5 years old, when the central components of executive functions start to take a more central purpose in cognitive function (Garon, Bryson, & Smith, 2008).

Studies were made in relation to preschoolers' executive function skills (Dike-Ugwu, 2013) and about the infancy predictors of preschool and post-kindergarten executive functions (Kraybill and Bell, 2012). However, only few studied the relationship of executive functions to the pre-academic skills of the children. This current study hopes to contribute to education by linking executive functions with the children's pre academic skills particularly their mathematical skills.

Among the academic skills of preschoolers, mathematics was chosen as a variable in this study in relation to executive function because the researcher is interested to know how these functions relate to the pupils' mathematical skills. In mathematics, children need more attention, thinking skills and focus to understand the concepts and procedures inherent in this discipline.

The preschool provides opportunities for the development of these skills to enhance learning. Considering that executive functions are vital to learning at this stage, there is a need for early childhood teachers to be aware of these functions in the children and its possible link to academic achievements so they may help facilitate the learning process of the children.

Children lack attention and easily get distracted and tempted with other activities and things around that they could hardly focus their learning processes especially in mathematics. They are expected to remember and follow multi-step instructions, avoid distractions, control responses, adjust when rules change, persist at problem solving, and manage long-term assignments.

It is very helpful to have early attention to develop efficient skills, such as doing math calculations. The child has to hold onto the numbers while working with it. Children are using working memory skills when expected to follow a set of oral instructions. But if there's a weakness, they may not be able to keep the instructions in mind. Thus, there is a need to develop these executive skills in children. These skills will develop by practice and are made stronger by the experience through which they are used and sharpened.

To provide opportunities for the development of these skills, there is a need to conduct this study so teachers know the extent to which children demonstrate the use of their executive functions and how they are related to the development of mathematical skills.

FRAMEWORK

This study assumes that executive functions have an implication on preschoolers' pre-academic skills. That pupils' working memory and inhibitory control skills would have great part in the development of the mathematical skills. This assumption implies that pupils who have high extent in their executive functions are likely to have high level of mathematical skills.

Executive Function. The general concept of the executive function (EF) includes the separate but related thinking, understanding, learning and remembering; and the control of information of working memory, and cognitive inhibitory control (Carlson & Moses, 2001; Diamond, Barnett, Thomas, & Munro, 2007; Zelazo, 2004), which constitutes the ability to grasp on and work with information. It consists of working memory, reasoning, task flexibility, problem solving, planning and inhibitory control (Miyake, Friedman, Emerson, Witzki, Howerter & Wager, 2000). These are the skills of the children that are important for school attainment, adapting future activities and are contributory to children's mathematical skills (Monette et al. 2011). Cited by Monette, the EF skills contribute to the development and enhancement of mathematical skills of the children. The core skills of executive functions are working memory and inhibitory control (Magrabi, 2010).

Inhibitory Control. Children have the skills to refuse distractions and habits and to think before doing. It is the capacity that keeps the children from doing impulsive reactions on whatever comes to mind. It is ability to respond effectively and have careful attention as well as behavioral and cognitive inhibition (Zelazo, 2014).

Studies show that inhibitory skills were found to be significantly associated with math skills at the primary level (Monette et al, 2011). However, other studies also found that children with mathematical problems experiences no difficulties with inhibition (Van der Sluis et al., 2007) as cited by Toll (2013).

Working Memory. Children are able to remember and follow several instructions, connect information from one setting to another, and remember numbers. These are the abilities of the children to keep and control information in mind in a short period of time, to be used when needed. This is called working memory. It involves keeping information in mind and mentally operating on it.

Studies show that executive function influences mathematical thinking, with working memory and inhibition separately predicting achievement in math (Diamond et al., 2007; Espy et al., 2004). Thus, executive functions are important to academic achievement. However, there are times when the working and latent memory conflicts, in the case of perseveration. According to the theory of competing memory system, (Morton &Munakata, 2002; Munakata, 1998), perseveration comes when there is a competition between these two distinct memory systems. The theory explains that the latent memory system builds up memories in posterior cortical and subcortical regions as a behaviour that has been repeated over time. This system leads to a bias to repeating that behaviour (for example, sorting cards by shape), whereas the working memory system actively holds information that is currently being processed. Working memory and latent memory may compete when currently relevant information conflicts with previously relevant information. This theory posits that perseveration occurs when the latent memory wins the competition; whereas flexible switching occurs when working memory prevails.

Mathematical Skills. Children begin to learn and recognize numbers, shapes and colors and begin in counting, naming colors and shapes. For example, activities like working puzzles and building with blocks help children develop skills such as rote counting, and understanding one-to-one correspondence. Components of the mathematical skills included in the study were classification, seriation, counting and comparing, one to one correspondence, number and number words, and addition and subtraction. Classification shows the ability of the children to group things according to its class. Children who can arrange and sort things or objects by size, more or less showed the ability in seriation. Recognizing how many objects are there and comparing it with more or less show the ability in counting and comparing. The ability to know that one means only one object and three mean three things is one to one correspondence.

The child has the ability about numbers when able to identify and write the number name. Addition is the process to put together sets of things or objects together and subtraction means taking away objects from the set.Mathematic knowledge are the skills before learning how to read and write words and numbers and a process of becoming literate. It is a gradual process that happens over time from birth - until a child can read, write and count.

The ability to recognize numbers and counting is one of the important skills of the children. Children contact with numbers always in the daily basis. The math of child's early years comes from activities: they compare numbers, make copy objects, make and build something from blocks. This mathematical ability helps children and make up the hard basis for their achievement in school (National Association for the Education and Young Children, NAEYC, 2002). Children develop a variety of math skills informally even from ages 4-5 (Coates & Thompson, 1999), and the success of the child to develop self-control is important in developing this skill.

METHODOLOGY

The research used the descriptive correlational design. A correlational research design is conducted to explore "the extent to which two or more variables co-vary, that is, where changes in one variable are reflected to changes in the other" (Creswell, 2008).

The participants of the study were one hundred (100) 5–6 years old senior kinder preschoolers wherein 50 of them were from School A, 25 were from School B and another 25 were from School C, School Year 2014–2015. There were two (2) sets of instruments used in this study. The first set consists of the researcher-made tests used to measure the level of pupils' mathematical skills specifically classification, seriation, counting and comparing, one to one correspondence, number and number words, and addition and subtraction. The second set was adapted from the Administering Measures from the PRI Learning-Related Cognitive Self- Regulation Study by Meador, Turner, Lipsey, and Farran (September 2013). There were three tasks used to test the pupils' working memory namely the Stick Tapping Task (Luria, 1966; Diamond & Taylor (1996); Dimensional Change Cards Sort (DCCS) (Rogers & Monsell, 1995) that requires the children to sort things to one dimensions and then to other dimensions using color test and shape game, Kansas Reflection-Impulsivity Scale for Preschoolers (KRISP) (Wright, 1971) that assess the attentiveness, reflexive processing, and sustained focus. There were two tasks used to test the pupils' inhibitory control namely the Head Toes Knees Shoulders or HTKS (Ponitz, et al., 2008) that measures inhibitory control; Statue test (NEPSY,1998) that examines the child's inhibition ability. Permission to conduct the study was first sought from the Division Office and the Principal. After approval was granted, the letter of permission was also given to the class advisers and the parents of the Preschoolers who were involved in the study. Then the researcher gathered the tests that were individually administered to the participants according to the allowed time schedule given by the teachers, which were the morning sessions of each day.

The tests were made within three consecutive days in the second week of December 2014 for School A, three consecutive days in the third week of January 2015 for School B and another three consecutive days in the last week of the January 2015 for School C. Each child was called to respond to the tests and exercises. The researcher read the instructions for the child to understand what to do in each test and task, and explained the instructions further when needed, using the language intelligible to the pupil concerned.

Descriptive statistics such as frequency count, percentage, mean and standard deviation were used in describing the data on each of the variables in the study, and Spearman's rho was used to determine the relationship between the executive functions and the mathematical skills of the pupils.

RESULTS AND DISCUSSION

Table 1. Summary table of indicators of working memory

Indicators of Working Memory	Mean	SD	Perfect Score	Description
Color Test	5.99	0.1	6	Great Extent
Shape Game	5.93	0.26	6	Great Extent
Stick Tapping	4.82	1.92	8	Moderate Extent
KRISP	24.42	3.84	30	Great Extent
Overall	41.16	4.35	50	Great Extent

Table 1 from page 5 shows the summary of the pupils' indicators of working memory. It reveals that pupils are good at almost all of the indicators. Their means are closer to the perfect score except the stick tapping.

Zelazo (e.g, Zelazo & Frye, 1997; Zelazo, Muller, Frye &Marcovitch, 2003; Zelazo, 2006), in his theory of Cognitive Complexity and Control (CCC), described that the control of the behavior of the child increases as s/he able to integrate pairs of rules into a single rule pattern. Children had the control of the rules given to them and demonstration it well.

Table 2. Summary table of indicators of inhibitory control

Indicators of Inhibitory Control	DESCRIPTIVE STATISTICS					
	Mean	Median	SD	Minimum	Maximum	Perfect score
HTKS	20.29	19	9.149	0	40	40
Statue Test	7.8	8	2.118	2	10	10
Overall	28.09	26.5	9.306	10	48	50

Table 2 illustrates the summary of the pupils' indicators of their inhibitory control. It shows that the pupils' inhibitory control in head, toes, knees, and shoulders test and statue test are almost perfect (M=28.09, SD=9.306) which means that they had overcame temptations and distractions. It further reveals that pupils demonstrated the skills to use thoughts and impulses to resist temptations, and to think before doing the actions. This result implies that children are good in their inhibitory control. Children manage of their prepotent responses to achieve a goal (Miyake & Shah, 1999).

Table 3. Summary table of the components of mathematical skills

Components of Math Skills	Mean	SD	Perfect Score	Description
Classification	8.11	1.80	10	Good
Seriation	14.42	2.64	20	Good
Counting and Comparing	8.08	2.61	10	Good
One to One Correspondence	9.43	1.95	11	Good

Number and Number Words	6.66	1.47	10	Fair
Addition and Subtraction	2.94	0.99	5	Good
Mathematical Skills (Overall)	49.64	6.88	66	Good

Table 3 illustrates the summary of the pupils' components of their mathematical skills. Mathematical skills are the skills of numbers and counting. It shows in the table that pupils were good (M=49.64, SD=6.88) in almost all of the components of mathematical skills. It implies that they were able to classify sets of objects, arrange and sort numbers and objects, count the objects and compare it with more and less, count a set of counters while saying the number name, write the number name, and put the number of objects in a set together and take away some of the objects in the set. Furthermore, they had understanding in numbers and counting.

Early mathematics learning often takes place in daily experiences in which children are interacting with adults and peers. Children's behaviors can be expected to relate to the opportunities they have to develop in mathematical skills and to their success in benefiting from those opportunities.

Children begin to develop informal knowledge related to number, operations, and other mathematical concepts (Baroody, Lai, & Mix, 2006). This produces a situation where mathematical learning could be largely influenced by children's own behaviors and the extent to which they seek out and engage in activities that promote mathematical learning.

Table 4. Spearman's Rho (ρ) values showing correlations between indicators of working memory and components of mathematical skills

Components of Math Skills	Indicators of Working Memory								Working Memory (Overall)	
	Color Test		Shape Game		Stick Tapping		KRISP			
	ρ	Sig.	ρ	Sig.	ρ	Sig.	ρ	Sig.	ρ	Sig.
Classification	.111	.272	-.240*	.016	-.316**	.001	.270	.006	.080	.431
Seriation	-.133	.188	.310**	.002	-.245	.014	.168	.096	-.015	.885
Counting and Comparing	.131	.194	.164	.104	-.282**	.004	.080	.428	-.076	.420
One to one Correspondence	.025	.807	.333**	.001	-.598**	.000	-.104	.303	-.357**	.000
Numbers and Number Words	-.043	.672	.111	.273	-.024	.810	.059	.561	.046	.647
Addition and Subtraction	-.002	.986	.119	.240	-.370**	.000	-.003	.976	-.164	.103
Mathematica Skills (Overall)	-.016	.877	.229	.022	-.505**	.000	.148	.141	-.118	.241

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 4 from previous page presents the Spearman's rho (ρ) values showing correlations between indicators of working memory and components of mathematical skill. The table shows that in general, the working memory indicators and the pupils' mathematical skills do not correlate significantly. However, significant positive correlations are found between shape game and seriation (ρ=.310, p=.002) and between shape game and one to one correspondence (ρ=.333, p=.001). This data may point to the reality that the pupils find it easier to respond to one task at a time but may be confused when they are given a number of options. In the shape game, they are given a shape and were instructed to put the shape to the corresponding box that displays a label or a drawing of that shape. The skill to do that simple task is related to seriation because they were just asked to arrange the figures from smallest to largest, and to one-to-one correspondence as they were just asked to connect the object. The results however varied when they we given more options, such as more colors in the classification exercise. Significant negative correlations are found between shape game and classification (ρ=-.240, p=.016).

Results in stick tapping were also negatively correlated with classification (ρ=1.316, p=.001); counting and comparing (ρ=-.282, p=.004); one to one correspondence (ρ=-.598, p=.000); and addition and subtraction (ρ=-.370, p= .000). Furthermore, working memory and one to one correspondence were found to have a significant negative correlation (ρ=-.357, p=.000).

This result may be due to the nature of the children's working and latent memories. Working memory is characterized by its "transient properties where information can quickly enter, can easily be retrieved and altered, and can rapidly be lost if the child does not actively engage with it (Magrabi, 2010)."

It is possible that the mathematical skills of the children needed the use of latent memory which receives information and engages in a thorough processing. Developmentally is possible that the children who are good at stick tapping have yet to develop more their mathematical skills that needed more cognitive processes such as counting, addition, and subtraction. They needed to develop their visual-spatial working memory to remember patterns and images, and this has to be developed over a certain period of time.

Furthermore, there is still a need for "rehearsal" or repeated action (for example, repeated dialing of phone number to retain the information) so as to ensure retention. This need for rehearsal finds similarity with the study of Mall JT, Morey CC (2013), where participants who were doing well in their memory experienced less forgetting information.

Table 5. Spearman's Rho (ρ) values showing correlations between indicators of inhibitory control and components of mathematical skills

Components of Math Skills	Indicators of Inhibitory Skills				Inhibitory Skills (Overall)	
	Heead, Toes, Knees Shoulders (HTKS)		Statue Test (ST)			
	ρ	Sig.	ρ	Sig.	ρ	Sig.
Classification	.277*	.005	-.115	.255	-.293**	.003
Seriation	-.152	.131	.224*	.025	-.102	.314
Counting and Comparing	-.393**	.000	.178	.077	-.331**	.001
One to One Correspondence	-.490**	.000	-.024	.813	-.486**	.000
Numbers and Number Words	-.237*	.018	.323*	.001	-.158	.110
Addition and Subtraction	-.452**	.000	.023	.818	-.435**	.000
Mathematical Skills (Overall)	-.467**	.000	.130	.197	-.435**	.000

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 5 from the previous page provides the Spearman's rho (ρ) values showing correlations between indicators of inhibitory control and components of mathematical skills. The overall data of inhibitory control were found to have significant negative correlation with their mathematical skills (ρ=-.435, sig.=.000). However, there are certain components in mathematical skills that have significant positive correlations to head, toes, knees, shoulders (HTKS) such as classification (ρ=.227, sig.=.005); and statue test such as seriation (ρ=.224, sig.=.025) and number and number words (ρ=.323, sig.=.001).The results may imply that the pupils who are good at classification skills tend to control their impulses as they classify things into their appropriate groupings.
Significant negative correlation are found between HTKS and counting and comparing (ρ=-.393, sig.=.000); one to one correspondence (ρ=-.-.490, sig.=.000); number and number words (ρ=-.237, sig.=.018); and addition and subtraction (ρ=-.452, sig.=.000). This finding may be attributed to the nature of the children where they vary in their developmental progress and some have not yet enhanced their inhibitory skills but have developed skills in numeracy due to genetic or environmental factors (Piaget, 1980). The finding of study is related to the study of Van der Sluis et al. (2007)as cited by Toll (2013), that children with mathematical problems experience no difficulties with their inhibitory control skills.

Conclusion

The pupils vary in their demonstration of their executive functions. The study found that the use of executive function does not necessarily ensure the manifestation of good mathematical skills, as affirmed by other studies. The pupils may have responded to the exercises using the current information in their working memory which might be forgotten immediately because the tasks were fast and quick, whereas their mathematical skills, which may need the use of their latent or long-term memory, needed more time to develop. The tasks that need their mathematical skills require time for the children to process deeply the information. Furthermore, the negative correlation between their inhibitory control and mathematical skills may be attributed to the nature of the children where they vary in their developmental progress. It is possible that other factors may influence this finding.

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