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Preparing children for success: integrating science, math, and technology in early childhood classroom

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The purpose of the present study was to study if purposeful math, science, and technology curriculum projects and activities would support Pre-K children's performance in these subject matter areas. In this study, 58 Pre-K children from 4 Pre-K classrooms in a public Pre-K programme in North Carolina participated. Through a quasi-experimental, pre–post intervention design, two experimental classrooms were involved in science curriculum projects that integrated meaningful math and technology content. The curriculum projects revolved around the principles of scientific inquiry process (e.g. engage, investigate, discover, and review). The experimental group classrooms were supported through periodic professional development sessions for teachers and materials to implement more hands-on activities. Results showed that the experimental group children made a significant improvement in their math skills compared to those in the control group. The children's awareness and interest in science-related subjects as well as technology use such as 'Googling' to search or educational software games increased as the study progressed.

Keywords: science; math; technology; pre-kindergarten

Introduction

It is an established fact that when children are provided with developmentally appropriate, high-quality early care, and education, they are more likely to have opportunities to utilise their natural curiosity and excel in every area of their development (Barnett, 2008; Ramey & Ramey, 1998; Reynolds & Temple, 2008). Such an educational environment provides a successful integration of intentional teaching and child-centred curriculum that promotes learning across various content areas such as math, science, and technology (Orange County STEM Initiative, 2010). Recent neuroscientific research demonstrates that experiences in the first few years of life are very critical in shaping young children's brain architecture (National Scientific Council on the Developing Child, 2007; Sripada, 2012). In this biological context, children's early facility with openness to math concepts and their innate scientific curiosity provide a perfect opportunity to nurture their growth in science, math, and technology areas (e.g. National Research Council, 2009; US Department of Education, 2011). The purpose of this article is to illustrate a study designed to facilitate and support learning of science, math, and technology of pre-kindergarten children from socio-economically disadvantaged backgrounds.

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Science, math, and technology in early education

Research suggests that children's attitudes towards science concepts and learning science are essentially shaped during the early years of their education, and become hard to change by the time they reach adolescence (Archer et al., 2010; Newcombe et al. 2009). Studies (Fleer & Robbins, 2003; French, 2004; Howes, 2008; Mantzicopoulos, Samarapungavan, & Ptrick, 2009) reveal that early science instruction that is integrated across different disciplines (e.g. Science, literacy, and technology) supports young children in the formation of awareness and interest towards science, and eventually affects their overall school performance further down in their education. The notion that learning becomes more meaningful and prolonged when children make connections between the knowledge they already possessed and the new concepts they are introduced is already emphasised in developmentally appropriate practice for teachers working with very young children. National Science Teachers Association (NSTA 2004) stresses that when children are involved in 'inquiry process' to investigate various topics, children display more motivation and better recall information in long run. In fact, 'inquiry-based classroom instruction supports learners as they construct their own knowledge while teachers facilitate and guide investigations'.

As well as scientific concepts, early math knowledge (Duncan et al., 2007, Newcombe et al., 2009), is a strong predictor of later emerging abilities in elementary school such as problem-solving, understanding, and comprehension. The new national reports emphasise that in order for all children to enter elementary school with the necessary foundation for success, early childhood curricula should provide integrated instruction of math and math-related skills for all children, aged 3–6 (Cross, Woods, & Schweingruber, 2009; National Scientific Council on the Developing Child, 2007). Evidence suggests that early math knowledge is a powerful predictor of later learning (Duncan et al., 2007). Most young people's science aspirations and views of science are formed by primary school age, and solidify by age 14 (Archer et al., 2010). Research also shows that children from low-income families, on average, demonstrate lower levels of competence in math prior to entering school, and these gaps persist or widen as schooling continues (e.g. National Assessment of Educational Progress [NAEP], 2005). Purposeful integration of math concepts in classroom curricula and daily activities along with guided open-ended questions and conversations can help increase children's engagement and interest in math-related subjects (Baroody, 2000) because they may develop the ability to comprehend abstract math concepts even in the pre-operational stage (National Institute for Early Education Research [NIEER], 2009). For example, because of their ability to identify one-to-one correspondences, children can figure out problems involving simple operations such as '2+1' or '2–1'.

With continually evolving rapidity, technology, too, is taking its place in early childhood education classrooms. Parette, Quesenberry, and Blum (2010) argue that the discussion of technology integration should move beyond whether technology use is appropriate, and rather focus on how to integrate this medium in early childhood education classroom in a developmentally appropriate manner. Evidence from a number of research studies shows that technological media and specifically computer technology and software can aid young children's inquiry-based learning by providing age-appropriate everyday problem situations, allowing access to variety of resources through online search engines, and finally leveraging children's cognitive understanding, collaborative skills, and focused attention (Linder, 2012; McManis & Gunnewig, 2012; Shifflet, Toledo, & Mattoon, 2012; Wang, Kinzie, McGuire, & Pan, 2010). With regard to children's reading and writing performance, Gee (2006) postulates that age-appropriate computer games can help children better understand and retain the meanings of the words when they relate the words with their corresponding actions in the game environment. The Tomas Rivera Policy Institute's report (Taningco & Pachon, 2008) examines national data to investigate whether computer use and computer support for teachers have any significant effect on the academic performance of racially and ethnically diverse children's reading, writing, and math scores by fifth grade. The results reveal that factors such as computer utilisation for math and science in class and computer support provided to teachers do indeed have significant positive effect on the reading, writing, math and science scores for this student group. Similarly, Sunha and Mido (2010) discovered, through their study of the effects of computer use in children's math performance, that computer use for math significantly improved the math performance of children who speak limited English.

Need for science, math, and technology integration in the early childhood classrooms

The US Department of Education (2011) and the President's 2011 agenda emphasise the fact that children from low-income and minority families perform at lower levels in language, science, technology, engineering, and math (STEM) subjects. This growing achievement gap (e.g. Brenneman, Stevenson-Boyd, & Frede, 2009; Cross et al., 2009; NAEP, 2005) between children from minority and low-income families and their counterparts from middle- and high-income families is an urgent matter that begs attention as early as possible in young children's education. For many minority and low-income families, opportunities for quality early education to close this gap are quite limited. Locasale-Crouch et al. (2007) investigated the instructional and social emotional quality of state-funded Pre-Kindergarten (Pre-K) programmes throughout the country. The study revealed that of 632 classrooms, only 15% were defined as high-quality early education environments. Another sad statistic revealed by this study was that those under-performing programmes enrolled proportionately greater numbers of children from disadvantaged backgrounds. It has been reported that current math and science concepts emphasised in early childhood classrooms do not progress beyond teaching some discrete math and science topic such as rote counting and memorising facts (e.g. weather conditions, seasons, and farm animals) (NIEER, 2009). Mantzicopoulos et al. (2009) report that the instructional time dedicated to teaching science concepts in early grades is hardly close to 10% of total instructional time; therefore, a valuable window of opportunity to influence children's attitudes towards science is missed. Teachers' lack of professional knowledge and self-confidence in teaching math and science as well as integrating technology has also been found to be a contributing factor for the increasing achievement gap between children from different socio-economic groups (Maier, Greenfield, & Blutsky-Shearer, 2013; Wang et al., 2010). In the light of what has been discussed, the authors of this article believe that it is vital that math and science subject matter areas along with well-integrated developmentally appropriate technology should be consistently available to pre-schoolers in order to provide them with a solid foundation for their future learning.

Purpose of the study

The main purpose of this study was to examine whether content-specific /purposeful and intentional math, science, and technology projects and activities (informally and via explicit instruction) would enhance Pre-K children's learning of math and science skills and concepts including technology. The following research questions guided the research procedures and activities:

(1) Does children's learning of math and science differ according to the type and quality of math and science instruction and activities provided in class?
(2) What is the impact of integrating purposeful/intentional math and science content as well as supportive materials and resources on teachers' use of instructional strategies?
(3) What is the impact of using appropriate technology on children's learning of math and science in particular?

Method

Participants and setting

The participants were drawn from a public Pre-K programme in a mid-size town in North Carolina. The public Pre-K programme in North Carolina serves economically disadvantaged or developmentally at-risk children. The risk factors include: limited English proficiency, identified disability, chronic health condition, and/or low performance results on developmental screening tests. A total of 58 Pre-K children (24 girls and 34 boys) distributed across 4 classrooms participated in the study. The fours classrooms participating in the study were similar in their use of curriculum, assessment procedures, distribution of ethnic profile as well as academic performance. Upon selection and agreement of classroom teachers to participate in the study, parents or guardians of the children in all 4 classrooms (72 families in total) were contacted by means of a letter outlining the purpose of the study and requiring written parental permission for their child to take part. The letter was translated into Spanish for Latino families. Permission forms were returned for 86% of the children, resulting in an initial sample of 62 children. Four of these children had either missed the pre- or post-test, and thus removed from the data analysis, leaving a final sample of 58 children. Of the 58 children, 16 were White, 28 were African-American, 11 were Latino, and 4 were multiracial. The participants ranged in age from 4.10 to 5.70 years ($M = 5.1$, SD = .44) at the time of the study. Of this, 58% of children came from two-parent homes. All children except five were on the free/reduced lunch programme, nine children were considered English as a Second Language Learners and seven children were identified with a disability, with the majority of the latter receiving speech therapy. About 65% of the children had access to some form of computer at home.

Four classroom teachers were all female (three White and one African-American) with an average of 4.25 years of teaching experience (range = 3–6 years). The teachers ranged in age from 25 to 32 years. All teachers had a BA in early childhood education with a teaching licensure in Birth-Kindergarten instruction. All teachers were lead teachers in their pre-school classrooms.

Design

The study used a quasi-experimental, pre–post intervention design investigating the effects of content-specific math and science activities/projects supported with technology on Pre-K children's learning of math and science skills/concepts. It further addressed the question of whether or not teachers' instruction would differ as a result of making supportive materials and resources available to them. Accordingly, of the four classroom teachers who volunteered to participate in the study, two were randomly assigned to the treatment group receiving the math, science, and technology intervention and the other two to the control group. The study took place over eight weeks, starting in the first week of April and ending in the last week of May. The first and last week of the study were devoted to pre- and post-testing of children in math skills/concepts. Three trained project personnel, comprising two of the researchers, and a research assistant who was also an experienced teacher and research assistant, administered the Test of Early Mathematics ability, Third Edition, (TEMA-3) individually to all participating children. Each test took approximately 20–25 minutes per child to administer. Once the pre-test was completed, the children participated in the intervention for the next six weeks. Children's knowledge of scientific concepts was measured throughout the intervention period via observational notes as children engaged in science activities and experiences.

Study procedures

The research team received an internal fund to equip experimental group classrooms with appropriate math, science, and technology materials and software. Prior to the implementation of the intervention, the researchers and the teachers from the experimental group met four times in February and March to select activities for the projects for this study, identify the goals and objectives for each project, purchase the necessary materials, and plan and coordinate the math and science activities to be implemented for the experimental group. The project topics were recommended by the experimental group teachers in order to keep the study aligned with the school's curriculum programme, called 'Opening the World of Learning (OWL)'. This approach helped to support and supplement instruction in the areas identified for focus, monitoring, and assessment (e.g. letter recognition, phonological awareness, vocabulary, and math concepts). The North Carolina Foundations for Early Learning and Development was used as a guide to form the goals and objectives of the projects. The two teachers in the control group continued with the same curriculum topics and routines without the intervention the experimental classrooms received. Consequently, using topics from the OWL curriculum allowed for the uniformity of topics covered between the intervention and control groups

Three related OWL curriculum topics (living and non-living, seeds and plants, and ocean animals) were selected by the teachers for science, math, and technology intervention. The research team recommended the teachers to employ a scientific inquiry process recommended by NSEA (2004) to help children learn the selected science and math concepts. NSEA describes the inquiry process as a way in which 'students learn to conduct an investigation and collect evidence from a variety of sources, develop an explanation from the data, and communicate and defend their conclusions' (2004, p. 1). Steps of the scientific inquiry process for an early childhood classroom are specified as follows (Blake, 2009; Brewer, 2007; Gelman & Brenneman, 2004): (1)

Engage in topics and questions that are interesting and relevant to students' lives; (2) Investigate the concepts through different means of hands-on experiments and observations; (3) Discover patterns and relationships, and collect data to share findings; and (4) Review the findings and transition to a new topic. Accordingly, each project included a combination of 8–12 hands-on, engaging and developmentally appropriate learning activities for children to explore and investigate informally, and occasionally through deliberate instruction (intentional teaching). Additionally, 10 math and science software games as well as a few websites containing math-/science-related activities were included as part of the intervention materials. All the software and internet websites were approved by the chief technology officer at the school district. Each of the four classrooms was already equipped with five desktop computers, which were available to children during the centre time to use as an interest area. In addition to the classrooms' desktop computers, each experimental classroom was provided with two additional laptop computers to facilitate children's access to various computer software games.

Intentional teaching (deliberate instruction) was also incorporated when it was appropriate to introduce scientific and math concepts, methods, and language. According to National Association for the Education of Young Children (2010), 'in high quality mathematics education for 3–6-year-old children, teachers and professionals should … actively introduce mathematical concepts, methods, language through a range of appropriate experiences and teaching strategies'. Table 1 provides a description of each project including objectives and relevant learning activities for children to explore. A sample of appropriate software games is also included at the end of the table as technology resources for children. The appropriateness of the software games was determined by a group of 15 junior early childhood education major students using a software checklist developed by Haughland and Shade (1994). A total of 20 software games were evaluated and those receiving high marks on three distinct features, Child, teacher, and technical features, were chosen for use in this study. This narrowed our selection for use with children to 10 software games.

Throughout the intervention period, the teachers from the experimental group received three sessions of professional development (total of six hours) of research-based and appropriate professional development from the researchers concerning the three topics of study (e.g. living and non-living things, seeds and plants, and ocean animals). Each session was organised according to the topic of the study, and involved reflection, discussion and development of specific strategies, activity ideas, and applications of math and science concepts. With each topic, the research team also helped the teachers with ongoing support, feedback, and procuring of materials to enhance their classroom environment for math, science, and technology learning.

Measures

Mathematic skills

The TEMA-3 developed by Ginsburg and Baroody (2003) was used to provide a norm-referenced assessment of each child's math proficiency pre- and post-intervention. TEMA-3 is a reliable and valid test of early math ability that is appropriate for children aged from 3 years 0 months to 8 years 11 months. At the pre-school level, the test includes items measuring informal and formal concepts and skills in the following domains: numbering skills, number comparison facility, numeral writing, mastery of

Table 1. Description of learning activities and their purpose for intervention.

Expectations

These expectations are drawn from foundations: early learning standards for North Carolina preschoolers and strategies for guiding their success

Mathematical Thinking and Expression

- Use a variety of strategies to solve problems
- Make and check predictions through observations and experimentation

Scientific Thinking and Invention

- Identify, discriminate and make comparisons among objects by observing physical characteristics
- Use one or more of the senses to observe and learn about their environment
- Observe and care for living things (e.g. classroom pets and plants)
- Ask questions and seek answers about their environment through active engagement with materials
- Use simple tools for investigation of the classroom and the world

Engage in representational thought (e.g. thinking about things that are not present)

Topic/Project	*Purpose*	*Sample Learning Activities*
Living and Non-living things	• Identify what is living and non-living in the world around them	• Introduce the topic with a storybook
	• Observe and talk about living things, and non-living things	• To start the project, the teacher helped the children to make a web showing what they knew about living and non-living things
	• Generate a list of characteristics that distinguish living things from non-living things	• Generate a visual chart (e.g. KWHL) writing the characteristics of living things on one side and non-living things on the other side (post this on the white board) as described by children
	• Use senses and simple tools (e.g. magnifying viewer/glass, magnet) to examine living and non-living things	• Children will take pictures of living and non-living things in their environment to create an alphabet chart to put in the hallway and/or create a classroom book of living and non-living things
	• Know the similarities and differences between living things and non-living things	• Use Smartboard to show short videos of living and non-living things for discussion
	• Observe, describe, and compare living and non-living things	• Sort living and non-living objects collected by teachers or children themselves
	• Share, discuss and present findings of their simple investigation	• Children will bring items from home to share and discuss about their characteristics as a living and non-living item
	• Make simple recordings of observations through drawing or writing	• Children generate a magazine collage of living and non-living things
	• Develop descriptive vocabulary for identifying characteristics of living and non-living things	

(*Continued*)

Table 1. Continued.

Expectations		
Seeds and Plants	• Observe, describe, and compare plants as living things	• Make the transition from living and non-living things to seeds and plants with a book
	• Explore the needs of plants: light, temperature, water, space, food, and soil	• Discussions about what children know about plants
	• Explore seeds and plants both outside and in the classroom	• Create a web of all the things they know about plants, large class web with pictures
	• Identify the processes that permit plants to live	• Form questions about what children want to know about plants
	• Observe the growth of seeds into plants	• Observe, compare, and classify/ measure a variety of seeds and plants
	• Learn scientific terminology for their observations as appropriate	• Start a small flower/vegetable garden
	• Record changes over time through drawing or writing or photographs	• Document the growth of plants in the garden
	• Learn the difference between seeds and seedlings and how they are planted	• Use gardening tools to plant and maintain the garden
	• Learn about different types of gardening tools are how they are used	• Plant different seeds indoor and observe/record the process
	• Make predictions, form and test hypotheses	• Investigate earth worms
	• Discuss how plants and animals depend on each other	• Investigate different plants on internet
	• Identify edible and non-edible plants	• Conduct the celery experiment
	• Discuss careers of those who work with plants	• Discuss parts of a plant (flower) and label plants
	• Explore how the change in sunlight affects plants	• Match plants with the seeds that they make
		• Do an experiment with flowers (one is in water, another one is not)
		• Nature walk
		• Shadow box/collage
		• Taste different kinds of vegetables and fruits
		• Make fruit smoothies
		• Make finger paint with different colours similar to flowers
		• Invite experts to talk about plants
		• Visit one or two gardens in the neighborhood/community
		• Smartboard

(*Continued*)

Table 1. Continued.

Expectations		
Ocean Animals	• Identify characteristics and habitats of ocean life	• Make the transition from farm animals to ocean with a book
	• Discuss differences between the ocean animals/plants and those on land	• Ocean in a bottle (mix mineral oil into empty bottle and add water to fill)
	• Understand that ocean floor consist of varying living and non-living things	• Making sand (soft rocks and small shells)
	• Use online resources to find information about sea animals	• Children design and create a mural of ocean with ocean plants and animals
	• Identify different types of fish	• Freeing water experiment
	• Predict which items will sink and float in the water	• Saltwater painting
	• Create/draw pictures of ocean creatures using Kid PIX	• Create Jellyfish and other kinds of fish for comparison and display
	• Explore seaweed	• Boats (Exploring Density)
	• Learn about water safety and pollution	• Field trip to XXX Marine Biology or Beach or FortFisher Aquariums
		• Smartbaord
Sample Computer Software Games		
Number Concepts	• Caillou Counting (Publisher: Brighter Child; Ages: Pre-school; Cost: $9.99)	*Common Concepts/Skills Taught*
	• Mia's Science Adventure (Publisher: Kutoka; Ages: 6–10; Cost: $19.95)	• Counting; sequencing, numerical order & relationships
	• Jump Start Kindergarten (Publisher: Knowledge Adventure; Ages: 4–6; Cost, $19.99)	• Addition & Subtraction; multiplications & Division, geometric shapes; thinking skills
	• Millie's Math House (Publisher: The Learning Company; Ages 4–7; Cost: $17.99)	• Counting, addition & subtraction, comparing & contrasting , critical thinking
		• Counting; identify & compare shapes & sizes; patterning; addition & subtraction

number facts, calculations skills, and number concepts. Standard scores were used as the primary criterion measure due to existing evidence of validity and control on age effects (Allen & Yen, 1979).

Science skills

As is developmentally appropriate, there are no standardised tests of science available for young children; therefore, the research team used transcripts obtained from video recordings to determine children's learning and progress towards the attainment of science skills and concepts (e.g. observation, communication, classification, inference, and prediction). The two researchers each observed a total of 6 science activities (30 minutes each) centring on the following themes: Living and none-living, seeds and plants, and ocean animals. The following coding system was developed to code the children's conversations that were video recorded in order to assess children's gains in science-related concepts:

Teacher survey questionnaire

All four teachers completed a survey questionnaire providing information with regard to their education level, number of years working as a lead teacher, and the percentage of their daily class activities devoted to math and science instruction including the use of technology. They also responded to questions on how well they felt prepared to teach math, science, and technology, and whether or not their effort in teaching any of these subjects was supported by their school/district through professional development opportunities. Table 2 provides a sample of questions included in the teacher survey questionnaire.

Video recordings

During the course of intervention, the two experimental classrooms were video recorded twice a week for 30–45 minutes each. Video footage was taken either during circle time or centre time (indoor/outdoor) where the teacher and children (large/small group) were engaged in conversations, teaching and learning about science, math, or technology related concepts. These video footages were transcribed and qualitatively coded using the categories listed in Table 3 in order to understand the experimental group children's gains, specifically in science and technology. Furthermore, teachers' instructional strategies and interactions with children observed in the videos were rated at the beginning and end of the study using a Science, Math, and Technology Teacher Performance Rating Scale (see Table 4) developed by the research team. The scale consisted of three major areas and specific items for each area, respectively: Science (four items), math (four items), and technology (one item). Two graduate students who were blind to the circumstances but knowledgeable about early science teaching independently transcribed and rated the video recordings

Table 2. Sample items from the teacher survey questionnaire.

Sample Item:
• What is the highest level of formal education you have completed?
• What percentage of your daily large group activity is devoted to mathematics instruction?
• What percentage of your daily large group activity is devoted to science instruction?
• In your written weekly plan, what percentage of your lessons/activities is focused on teaching mathematical concepts/skills?
• Do you have a science area(s) or interest centre(s) in your classroom?
• Do children in your class have access to computer for play?
• How well are mathematics/science and technology integrated in your daily curriculum?
• How well is mathematics integrated in your daily curriculum?
• Rate the following mathematical concepts/skills taught in your class from being highly taught (1) to very seldom taught (7). __ One-to-one correspondence; __Number sense and counting; __Sets and classifying; __Comparing, __Shape;
• __Space, __Parts and whole
• How adequately do you feel you have been prepared for teaching mathematics with children 3–5 years old?

Table 3. Categories and brief description of science behaviours observed for children in the experimental group.

Science Observation of Children's Responses	Examples
Engaged by showing curiosity via asking and answering questions, making predictions, offering ideas and explanations, and emulating and making suggestions	WH questions, KWHL chart, thinking maps, concrete materials
Participating in developmentally appropriate activities to investigate a topic	Doing experiments inside and outside the classroom, exploring through hands-on small group discussions/activities, researching topics
Discovering patterns and relationships, collecting data, and sharing their findings	WH questions, making comparisons, large and small group discussions, drawing conclusions, graphing, charting, and creating representations of their ideas
Using content-related science language	Conversations, word wall, books, software, and websites

of both experimental classrooms. The reliability of the rating categories was established by having the two raters independently, and randomly, rate 35% of the video-taped transcripts. Reliability for the rating categories was calculated overall and for each category separately by dividing the number of agreements by the sums of disagreements plus agreement. The reliability estimates (Engaging children in science by questioning = 90%; Planning meaningful activities for investigation = 85%; Assisting and encouraging children to share ideas about science discovery = 92%; Reviewing the findings and transition to a new topic = 90%; Integrating number sense = 94%; Helping children to recognise spatial relationships = 87%; Using content-related language = 92%; and Modelling the use of technology = 86%) are adequate for each category. The overall reliability was 89%. Disagreement between the raters was discussed and resolved.

Document analysis

To document the amount of children's exposure to math and science content, the research team collected a sample of teachers' weekly plans from both control and experimental groups to analyse the type and frequency of math, science lessons offered during the intervention period. A total of eight weekly plans (two per class) were collected. These weekly plans were sampled activities that took place both at the beginning and towards the end of the project.

Results

In this study, both quantitative and qualitative means of data collection and analysis were utilised. Quantitatively, a one-way between-group analysis of variance (ANOVA) was used to evaluate whether the types and quality of math activities in the intervention had an effect on children's learning of pre-school math concepts and skills measured via TEMA-3. The results derived from ANOVA are presented in Table 5. A .05 significance level was used. Qualitative data collected through video recordings and teacher surveys were also transcribed and reviewed to examine: (1)

Table 4. Performance rating scale used to rate teachers' instructional strategies in math, science, and technology in experimental group.

	Categories	Not observed (0)	Occasion (1)	Sometimes (2)	Frequently (3)	Always (4)
Science	Engages children with questions to explore topics and predict what would happen. Expands on children's responses					
	Plans meaningful activities to investigate the topic with hands-on and open-ended learning opportunities combined with content-related language					
	Assists children to discover patterns and relationships, to compare and contrast, and share their findings					
	Review findings from activities/closure/transition to a new topic/raising new questions					
Math	Integrates numbers sense as a natural aspect of teaching					
	Helps children to recognise spatial relationships, recognise, and identify patterns					
	Represents data through different means (e.g. diagrams, graphs).					
	Uses content-related math language					
Technology	Utilises, models, and assist children with the use of technology to investigate problems and questions					

Table 5. Results of the ANOVA Test and Mean Scores for TEMA-3 Pre and Post.

	Mean (SD)							
Source	Ex	Co	Source	Squares	df	Square	*F*	Sig.
Pre TEMA-3	99.48 (10.98)	99.58 (12.00)	Between groups	0.155	1	0.155	0.001	.97
			Within groups	7414.276	56	132.398		
			Total	7414.431	57			
Post TEMA-3	107.28 (9.13)	101.86 (11.39)	Between groups	424.983	1	424.983	3.984*	.05
			Within groups	5973.241	56	106.665		
			Total	6398.224	57			

Note: Ex, experimental; Co, control.
*$P < .05$

the quality and quantity of the experimental group teachers' instructional strategies, and (2) the science gains the experimental group children made over the intervention period. Three research questions guided the analysis of the data collected.

Does children's learning of math and science differ according to the type and quality of math and science instruction and activities provided in class?. As shown in Table 5, there was a statistically significant difference between the two groups as determined by one-way ANOVA, F (1, 56) = 3.98, $p = .05$, indicating that the mean change score for TEMA-3 post-test was significantly higher for the children in the experimental group ($M = 107.28$, SD = 9.13) than for the children in the control group ($M = 101.86$, SD = 11.39). There was no significant difference in children's mean score for TEMA-3 pre-test, revealing that children from the experimental group ($M = 99.48$, SD = 10.98) scored similarly to children in the control group ($M = 99.58$, SD = 12.00) at the time of pre-test.

In order to understand whether children's science learning differed by the instruction and activities provided, children's responses from transcripts of video recordings were analysed based on the categories listed in Table 3. For the first category, 'engaged by showing curiosity via asking and answering questions, making predictions, offering ideas and explanations, emulating and making suggestions', the researchers comparing the earlier responses with those occurring towards the end of intervention noted an increase in children's awareness and interest in science-related concepts and in their skills in asking a variety of questions, making predictions, and producing explanations. The following excerpt shows children's progression from the first theme 'living and non-living things' to the last theme 'ocean animals'. For example, children's earlier responses are short and include fewer details in the first excerpt, whereas the responses in the second excerpt show the children's ability to come up with explanations based on the knowledge (e.g. living and non-living) they had learnt during intervention and their ability to make connections.

Living and non-living.

Mrs B: This circle map on this side is going to be for living things. I am going to draw a picture of a leaf in the middle
Zahara: It looks like a radio

Mrs B: And the leaf is going to be our symbol of living things
Mrs B: In this circle, we are going to write about non-living things. In this circle, I am going to draw a leaf, but I am going to take my red marker and draw a line through it. Because it is non-living
Mrs B: Some things in the world are living and some things in the world are non-living. Can you think of something that is living?
Mrs B: Cindy raised her hand. Thank you Cindy! Cindy can you name something that is living
Cindy: A Rabbit
Mrs B: That's a good one, Cindy! How do you know a rabbit is a living thing?
Cindy: Because they hop
Mrs B: They hop! Hopping is a kind of movement. So they move!
Mrs B: Can you guys think of something else that is living?
Zahara: People
Mrs B: People are living, you are right! Why people are living?
Zahara: Because they go in houses
Mrs B: So they need a shelter. Like if we slept outside, … ummm [prompting children to think]
Darya: We get scared!
Nicole: We get wet!
Mrs B: I am going to write shelter in here but I am going to put a question mark next to it. We may have to come back to this one. A shelter is a place where people live
Julies: A question mark!
Mrs B: Can you think of something that is not living …
Darya: Cats
Mrs B: Cats are non-living?
Mrs B: Are cats alive?
Children: Yeah
Mrs B: I think cats are living. How do we know they are living?
Darya: They run!
Nicole: They chase mouse!
Mrs B: They chase mice! Why do you think they chase mice?

Ocean animals.

Mrs B: I'm going to back up so we can see our … . our bubble map from last week. Do you remember what we were talking about last week?
Nicole: Living things!
Mrs B: Living things! And raise your hand if you can tell me some of the things [points at board] that living things … . a characteristic of a living thing. Raise your hand if you can remember what one of these say. Nicole?
Nicole: Mammals are a living thing.
Mrs B: Girl, how did you learn that? Mammals are living things, she said. How did you know that?
Nicole: Like a whale.
Mrs B: A whale. What is a whale? How do you know that a whale is a living thing?

Nicole: It's a mammal because .... it lives in the ocean and it has a spray hole. Well, it has a tail and it has eyes and it can move.

Mrs B: And it can move! Stay right there! That's a good one! What she just said, 'whales can move' goes in this bubble right here. They react to their environment.

Nicole: So they .... so they are mammals because they live in the water and they move.

Nicole: And they're alive!

Teachers in the experimental classrooms designed and implemented various hands-on learning activities for children to participate. The researchers considered this improvement under the second category, 'participating in developmentally appropriate activities to investigate a topic'. In the following excerpt, children are experimenting and first-hand observing the changes in the phenomena of animals. Even though the classroom was working on ocean animals at the time this observation was recorded, the teacher drew children's attention to the butterfly life cycle net that she previously purchased and located in a corner in the classroom:

Teacher is videotaping circle of students with caterpillar net in centre of circle

Mrs B: Alrighty, let's get started. Some of you noticed this morning, um, one of our containers of caterpillars has changed. Jayla, what happened to them?

Jayla: All of .... all of the caterpillars in that one have turned into chrysalides.

Mrs B: They've all turned into chrysalides. What's another word for a chrysalis?

Jayla: A cocoon!

Through the activities, the children were also able to 'discover patterns and relationships, collect data and share their findings'. This was the third category in our coding criteria.

Teacher is filming group of children examining celery stalks dipped in different coloured water

Mrs B: What happened?

Mario: Well .... when we put them in there, they slide up the stem. When we .... when we .... um ....

Mrs B: What slid up the stem?

Mario: The water that changed.

Mrs B: How do you know it went up the stem?

Mario: Because I can see the water go up that .... and that.

Mrs B: What did you see on the bottom, Aidan?

Students pausing to make observations about what has happened to the celery

Aidan: The red one .... the red .... the red one .... it dipped until here, and it make it get .... it make it get old.

Mrs B: So the water goes in at the bottom and goes all the way up to the leaves?

Aidan: Yup.

Such experiment provided the children with the opportunity to observe and note change in celery because of different factors, and drew conclusions as the result of their experience in this learning activity.

What is the impact of integrating purposeful/intentional math and science content as well as supportive materials and resources on teachers' use of instructional strategies?. The impacts of purposeful math and science integration were observed and examined both quantitatively and qualitatively from the transcripts compiled from the video recording of the experimental group teachers. At the beginning and end of the intervention, the video recordings of each experimental group teacher were examined and rated to identify science, math, and technology content-related instruction based on the criteria set in Table 4. We tabulated the ratings to see whether or not there were any changes from the beginning towards the end of the intervention in both quantity and quality of the instructional strategies used by the teachers in the experimental group.

Quantitatively, a one-way ANOVA was used to evaluate teachers' instructional strategies and interaction with children on the basis of the nine categories encompassing math, science, and technology. As is shown in Table 6, by the end of the intervention, teachers in the experimental group showed significant improvement in four of the nine categories: engaging children in review of findings from science activities, and focusing on closure and transition to a new topic or project, $F\,(1, 24) = 8$, $P < .03$; use of technology-related tools to investigate problems and questions, $F(1,\ 13) = 9.21$, $P < .00$;

Table 6. Means (and standard deviations) of teachers' strategies in math, science, and technology at the beginning and towards the end of the interventions for experimental group.

	Categories	Beginning of intervention EXP group Mean (SD)	End of intervention EXP group Mean (SD)	F Values
Science	1. Engages children with questions …	2.19 (1.37)	2.70 (1.30)	0.208
	2. Plans meaningful activities …	2.16 (1.11)	2.58 (0.900)	0.325
	3. Assists children to discover patterns & relationships …	2.62 (1.40)	2.62 (0.517)	0.00
	4. Review findings from activities/closure/transition …	1.75 (0.500)	2.75 (0.500)	8.00*
Math	5. Integrates numbers sense as a natural aspect of teaching …	0.000 (0.000)	2.25 (1.70)	9.00*
	6. Helps children to recognise spatial relationships …	0.583 (0.792)	0.833 (0.937)	0.545
	7. Represents data through different means (e.g. diagrams, graphs)	1.25 (0.500)	1.75 (1.25)	2.77
	8. Uses content-related math language.	0.750 (0.500)	2.00 (1.41)	6.18*
Technology	9. Utilises, models, and assist children with the use of technology	0.750 (0.707)	2.00 (0.925)	9.29**

$^{*}P < .05$.
$^{**}P < .01$.

integration of number sense as a natural aspect of teaching $F\,(1, 8) = 9$, $P < .02$; and use of math language, $F\,(1,\ 12) = 6.18$, $P < .02$. In other categories, the teachers in the experimental group remained unchanged or made insignificant improvements (see Table 6).

Findings from the descriptive analysis revealed significant difference in the complexity and responsiveness of teachers' instructional strategies at the beginning and towards the end of the project when covering math or science activities. For example, they were better able to engage children with questions to explore a topic, to plan more meaningful lessons to investigate a topic with hands-on and open-ended learning opportunities, and to assist children in discovering patterns and relationships including compare and contrast. The following excerpts were chosen randomly to illustrate the improvement from beginning towards the end of the intervention. It can be seen readily that the teacher, Mrs O, in the seeds and plants theme used more varied and content-related instructional strategies to engage children in the discussion, reviewed concepts that the children had previously learnt, and effortlessly guided their contributions to the lesson.

Living and non-living theme:.

Mrs O: Julies, what did you bring from home? You brought a couple things.
Julies: It's a rat.
Mrs O: is your rat living? It kind of looks like a real rat. Where does Diego go? [pointing to the hoops containing living and non-living items]
Julies: Um … .
Mrs O: Because Diego's a toy, right?
Julies: Yes.
Mrs O: Are toys living?
Julies: [Nods head yes.]
Mrs O: Are toys alive?
Julies: No.
Mrs O: No, so put the toy in the non-living pile. [The child puts Diego in the hula hoop marked 'non-living things'.]

Seeds and Plants.

Mrs O: How could we figure out if plants grow?
Gage: **Experiment**!
Mrs O: How could we do an experiment to see if plants grow?
Gage: Plant some seeds.
Isabella: We can let it be outside for a couple hours and let it inside for couple of hours.
Mrs O: That's one idea and I like that idea! What if we had two pots with seeds, leave one outside and one inside … …
Mrs O: Do you want to try it? We can then **measure** it and see which one is growing and how fast.
Gage: The one outside will grow bigger!
Mrs O: Let's move to an oval [teacher asks children to sit in an oval shape and goes over the procedures on how to plant seeds]

Mrs O: Isabella is very sure about her **hypothesis**. She thinks that the one outside will grow faster than the one inside. How are we going to find out?

Isabella: We could **measure** them.

Mrs O: Yes, that's a good way to find out if there is going to be a difference between the two.

Riana: We can take pictures of them

Mrs O: Yes! We can take pictures of them and keep a **record** of the changes on our class **computer** … What do you think? Is that something we could do!

During the intervention, the researchers provided professional development to the experimental group teachers through formal periodic meetings at the beginning of each curriculum theme. Towards the end of the intervention period, there was a dramatic change in the frequency and quality of math and science activities provided in the experimental classrooms. An examination of the teacher surveys conducted prior to intervention revealed that all four Pre-K teachers who agreed to partake in this study felt more confident to teach math (70%) than science (30%), and reported adequate knowledge of basic math concepts (100%). Paradoxically, despite their reported confidence in math, only 25% of teachers' instructional lessons (sampled via their weekly plans) were devoted to math activities prior to the intervention. Review of the weekly plans towards the end of the project, however, revealed that both groups had more math lessons integrated throughout their curricula with greater increase for experimental group (40%) than for the control group (28%) by the end of the intervention. With regard to science, all four teachers felt less prepared to teach science and indicated that they incorporated science activities into their curricula very seldom (12%). Review of the weekly plans at the beginning of the project showed an average of one–two lessons devoted to science per week. An examination of the weekly plans towards the end of the intervention, however, showed moderate-to-very little change for both groups (15% for control and 18% for experimental group. The science activities when implemented by the teachers in the experimental group; however, incorporated many skills such as making observation*s*, making predictions, comparing and contrasting, investigating, and interpreting data).

What is the impact of using appropriate technology on children's learning math and science in particular?. The teachers in the experimental group classrooms were encouraged and supported in incorporating technology in the daily happenings of their respective classrooms. The research team supplied the classrooms with laptops and a number of inexpensive but age- and developmentally appropriate computer software games, which were aligned with the science and math activities implemented in the classrooms. Furthermore, the teachers were provided with cameras to document children's engagement during the science and math learning. Children were also given the opportunities to handle those cameras to take pictures of their peers. Another means of technology utilised by the teachers was the internet search engine, 'Google'. Throughout the study, children started using technology-related phrases such as 'let's look at internet' or 'Googling' with increasing frequency to investigate different concepts related to their topic of study. The following excerpt highlights the quality of conversation between an experimental group teacher and her students after the introduction of the ocean animals project:

Jaiden: Mrs B, how do fish breathe underwater?
Mrs B: That's a great question, Jaiden! What do you think?
Jaiden: [Jaiden shrugs his shoulder], Don't know!
Mrs B: How do you think we can find out?
Tristan: We can research it!
Mrs B: How will you research it?
Jaiden: We can Google it.
Mrs B: How would you Google it?
Jaiden: You can type the word fish … .
Mrs B: Yes, we can check it on internet or check our information books about fish facts … .

The experimental group teachers' reports, observational notes and video recordings revealed that the software games installed in the classroom computers and laptops helped children to practise number concepts. Often, children were encouraged to engage in pairs at the computer centre, which led to more positive social interaction among peers. Children tended to stay focused longer on the task and be more encouraged to tackle a problem in a game when they were playing with friends. Teachers felt more confident in using the internet as a source of knowledge to support inquiry-based learning.

Discussion

The findings of this study suggest that implementing a robust early childhood education curriculum focusing on math, science, and technology could bring a positive change in children's overall learning of math, science, and technology as well as in teachers' attitudes and ability to plan an integrated curriculum for young children. A robust curriculum requires the following elements: (1) bringing interesting and relevant topics that are engaging for pre-schoolers, (2) maintaining a continuum across the concepts introduced to children (e.g. transitioning from living things versus non-living to seeds and plants and to ocean animals), (3) planning activities revolving around inquiry-based learning method*s* (e.g. asking questions about the topic, exploring it through hands-on activities, representing and sharing findings, and asking new questions), (4) promoting child-centred learning, integrating science and math across other subject matter areas, (5) using informal moments to explore a variety of concepts that are not planned previously, (6) supporting curriculum and classroom environment with a variety of open-ended and exploratory materials, and (7) supporting teachers in their professional development to encourage them to implement more science- and math-related activities.

The research literature (Bodovski, & Youn, 2011; DiPerna, Lei, & Reid, 2007; Dobbs-Oates, & Robinson, 2012) indicates a positive correlation between pre-school children's approach to learning (e.g. attention, persistence, and problem-solving) and academic success in elementary school. Certainly, the above-mentioned elements of an early childhood education create a learning environment in which children's attention and engagement in tasks are sustained longer. Furthermore, when the activities are child-centred and involve utilising multiple senses, children are better able to comprehend, remember, and recall information with an increasing level of detail.

Experimental group teachers participating in the current study reported their increased confidence in integrating a greater number of math and science concepts and activities into their curricula. This outcome echoes the findings from the study of

Geist and Geist (2009) in which the Head Start teachers reported increased awareness of the importance of daily math integration and improvement in children's interest in math-related subjects and learning activities. Considering the likelihood that intentional math and science activities have traditionally had little place in early childhood education classrooms because of teachers' low confidence about these subjects and lack of professional knowledge (DiPerna et al., 2007; Dobbs-Oates, & Robinson, 2012; Maier et al., 2013), we conclude that this finding could be indirectly related to children's increasing performance in science and math areas in the experimental group of this study. When kids start to enjoy the work and do well, the teachers get more confident.

The findings of this study showed that all children in experimental group classrooms showed improvement in their math concepts and skills based on the TEMA-3. This outcome is especially promising considering the many studies reporting that children who are ethnically, culturally, and linguistically diverse tend to lag behind in academic subjects, especially math and science (Bodovski, & Youn, 2011; Powers & Price-Johnson, 2007; US Department of Education, 2011). In the present study, developmentally appropriate, learner-centred activities helped the experimental group children to express themselves in variety of ways, and utilise their existing knowledge and their potential in math and science. On examination, the TEMA-3 pre-test scores for experimental group children were similar to the scores of control group children. However, the experimental group children surpassed their peers in the control group by the end of the intervention period.

Perhaps the most important point in the findings was the fact that integration of intentional math and science learning supported with technology in early childhood education programmes serving children from disadvantaged socio-economic backgrounds made a real and significant improvement in their math and science performance. It is evident from previous studies that quality early childhood curriculum and environment create the strongest effect on children who are negatively affected by the circumstances of poverty they face in their lives (Cross et al., 2009; Locasale-Crouch et al. 2007; NAEP, 2005). Numerous studies show that children living in poverty enter school with lower cognitive, language, and social emotional skills. As much as the family variables (e.g. lower education, instability in the house, lack of available resources, low levels of support for learning, etc.), the quality of the early care children receive prior to entering kindergarten plays an important role in children's school readiness. This study contributes to the body of evidence helping educators to understand the effects of developmentally appropriate early childhood curricula on young children's academic performance.

Although the study's findings show that the professional development provided throughout the intervention period helped to increase the experimental group teachers' confidence in planning and implementing more math-, science-, and technology-related activities and instruction, the results from the science, math, technology teacher performance scale were not significant in every category to justify a substantial improvement in experimental group teachers' overall instructional styles. Perhaps this is an area requiring consistent and continuous attention in order to create significant improvement in teachers' science, math, and technology teaching practices that were often overlooked.

Limitations of the study

Because of its limited grant budget, the study was able to support only two experimental classrooms. Therefore, the research investigators adopted a quasi-experimental model.

Another limitation of the study was the time-consuming bureaucracy of the public school setting. The investigators had first to communicate the study to the school principal who approved dissemination of the information to her teachers. Thereafter, the investigators assigned those teachers who volunteered for the study to experimental and control groups. Allocation of control and experimental group teachers was limited by school-related factors affecting the selection which were outside the control of the research team. Finally, due to time and resource limitations, families could not be a part of the project. Perhaps the study might have produced more conclusive results if parents had been involved in the project as originally planned, in order to provide reinforcement of the concepts and skills practised at school and ensure continuity between the school and home learning environments.

Implications

Although the study was relatively small in scale for generalisation of its findings to a larger population, it has important implications for planning and implementing math and science activities supported with technology, and professional development of early childhood education teachers. Since it is well established that children start learning and experimenting with science- and math-related concepts in the early years of their lives (e.g. Charlesworth & Lind, 2009; O'Hara, Demarest, & Shaklee, 2005), it is never too early to plan and implement developmentally appropriate science and math activities. Topics selected to introduce science and math concepts to pre-schoolers need to be familiar to children, yet show the potential to branch off to unfamiliar concepts. For example, in the present study, the living versus non-living things topic led to exploring living things such as seeds and plants and ocean animals. Also, the topics selected should present a continuum across time and subject matter areas. Such planning helps children to retain and recall the information in more detail, and apply it to other areas of learning. For example, children repeatedly referred to the term 'Googling' after conducting a search on the Google search engine with their teachers. Such familiarisation with the inquiry process is not only specific to science learning, but it helps children to develop the skills to question, explore, and investigate concepts in different subject matter areas. Teachers can use pre-schoolers' natural math and science curiosity about their world to guide children to ask questions, produce solutions to problems faced, and think critically. Inclusion of variety of learning materials (e.g. visual, tactile, audio, and natural) helps children to explore different concepts through their senses. The experimental classrooms in this study were supported with various materials from content-related books to planting tools, software, hardware, and so on. Children were encouraged to explore the materials during the activities. For example, one experimental group teacher collected shoe boxes from the parents and children created collages out of materials representing living and non-living things. Another example of the investigative process was that children were given cameras to take pictures of their peers during the activities.

Teachers have to overcome the old myth that science and math are for smart and/or crazy scientists wearing white lab coats. They need to search and critique their beliefs and self-doubts about integrating math, science, and technology in their classrooms. Teacher attitudes towards these subjects directly affect children's math, science, and technology performance in the subsequent years. In this context, the teacher's role ' … goes beyond that of entertainer to helping students recognise connections between the activity at hand to past experiences, as well as to new ideas and upcoming experiences' (Howes, 2008, p. 538).

More professional development opportunities should be available for early childhood education teachers. Because of budget restraints, early childhood teachers, especially those serving in non-public settings, have very little opportunity to seek and participate in workshops geared towards integrating math, science, and technology. Such obstacle can be overcome through continuing support and in-service training opportunities for teachers to improve their content knowledge and instructional skills in math and science. In fact, Brendefur, Strother, Thiede, Lane, and Surges-Prokop (2013) found that the professional development sessions revolved around core math concepts and planning active math learning opportunities for pre-schoolers significantly improved Head Start children's early math acquisition. Finally, connection to the home environment should be built and fostered in order to create improvement that has lasting and significant impact on children's learning. Learning kits, simple recipes, books, and activity ideas could be sent home to help parents involve their children in meaningful and authentic learning activities.

In summary, the findings of this study demonstrate that young children from low socio-economic backgrounds can be successful in attaining higher levels of competence in math, science, and technology when supported by teachers' skilful instruction, purposeful content and quality materials and resources. Children enter Pre-K with a variety of experiences in and questions about math and science. Given that early math, science, and technology are important at school entry and highly predictive of future academic success, enhancing classroom environments serving children identified as at-risk for school failure is a critically important mission for teachers of young children.

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