Canadian Journal of Educational and Social Studies
Vol. 3(2), 2023, pp. 33-44

Inquiry-Based Approach and Achievement in Mathematics Process Skills among Pre-School Children in Kajiado North Sub-County, Kajiado County, Kenya

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DOI: 10.53103/cjess.v3i2.110

Abstract

This study was designed to determine the effect of an inquiry-based approach on pre-school learners' acquisition of mathematics process skills. The study adopted a quasi-experimental research design to determine the differences in performance between control and experimental groups. A post-test was administered to both experimental and control groups, and the scores were analyzed by descriptive statistics and t-test. Findings showed that activities involving inquiry-based approach were a precursor to higher achievement in mathematics. The study recommended of inquiry-based approach for application in teaching pre-school mathematics and other related activity areas based on its advantages in pre-school learners' achievement in mathematics.

Keywords: Inquiry-Based Approach, Pre-school, Mathematics Education, Mathematics Process Skills, Achievement in Mathematics

Introduction

Inquiry-based approach has become one of the most effective methods of learning science and mathematics. Experimental studies back the proposition that Inquiry-Based approaches expand possibilities in teaching and learning and merit further development (Berie, Damtie, & Bogale, 2022; Zudaire, Buil, Uriz, et al., 2022). Pre-school teachers should be encouraged to adopt this approach for instruction of learners in the early years. In the words of Farooqi (2020), inquiry-based instruction is critical in creating interactive, engaging, and learner-centred learning environments. This is consistent with the view that

inquiry-based approach has the potential of building a strong foundation in mathematics for learners in the early years' education. Litkowski, Duncan, Logan, and Purpura, (2021) argue that children's mathematics skills develop extensively during preschool hence should be supported by an interactive and engaging learning environment. Moreover, early mathematics skills that can be used to inform preschool classroom practices and facilitate the design of intervention studies.

Evidence based on cognitive and developmental theories suggests that early math skills are linked to future academic achievement (Cortes, Green, Barr, & Ryan, 2022; Karademir, &Akman, 2019; Dilek, Taşdemir, Konca, & Baltacı, 2020). Research further supports the position that early years are vital for developing math knowledge and skills (Ramanathan, Carter, & Wenner, 2022; Litkowski, Duncan, Logan, and Purpura, 2021; Trawick-Smith, Swaminathan, & Liu, 2016). It is worth noting that early years' math activities teach fundamental skills that can be recast into advanced math since they form the basis for additional life skills. However, all this should be done within a conducive environment for academic growth. Lee and Boyd, (2008) argue that academic settings that promote freedom and facilitate thinking contribute to developing math skills.

Notably, pre-school children can engage in scientific practices and inquiry and develop understanding at a conceptual level. (Ramanathan, Carter, & Wenner 2022). Despite the pivotal role of pre-school learner engagement, opportunities for inquiry-based mathematics activities in pre-school classrooms are limited (Zudaire, Buil, Uriz, et al., 2022; Litkowski, Duncan, Logan, and Purpura, 2021). Indeed, Zudaire, Buil, Uriz, et al. (2022) add that programs for learner engagement in pre-school are delimited. Various factors contribute to this situation, such as teachers' low self-confidence in teaching science and the belief that young children cannot develop specific reasoning skills (Zudaire, Buil, Uriz, et al., 2022). Education programs should therefore be designed to allow learners to develop mathematical knowledge, skills, and attitudes early.

Evidence confirms an enabling learning environment and adequate resources can help children develop math skills independently (Karademir, & Akman, 2021; Björklund, van den Heuvel-Panhuizen, & Kullberg, 2020; Zudaire, Buil, Uriz, et al., 2022; Lee, Joswick, & Pole 2022). In addition, children discover mathematical facts through games early in life (Lee, Joswick, & Pole, 2022). Educational programs should be content-rich and include systematic activities to attain a high-quality math education in early childhood (Starkey & Klein, 2008). Creating a conducive learning environment only benefits learners when appropriate instructional approaches are applied.

Several factors, however, determine instructional approaches to be used for a particular (mathematics) lesson. These include age, learners' developmental level, entry behavior, subject matter or content, lesson objectives, availability of resources, and classroom dynamics (Lee, Joswick, & Pole, 2022; Björklund, van den Heuvel-Panhuizen, & Kullberg 2020). The inquiry-based approach is one of the instructional approaches that

can bridge the gap in pre-school learner engagement in several ways.

Researchers attribute several benefits to using the inquiry-based approach in pre-school education. A study by Karademir and Akman (2019) concludes that the Inquiry-Based Mathematics Activities Module (IBMAM) positively affect pre-schoolers' number and operations skills. It also helps enhance math concepts, enables pre-schoolers learn new concepts as well as meaningful ways of using their math skills. In addition, learners are able to structure concepts and skills learned by inquiring, researching, and experiencing. This improves their curiosity.

Inquiry-based approach also enhances learner motivation. A study by Dilek, Taşdemir, Konca, and Baltacı (2020), reports that children recognized science as an activity area following inquiry-based STEM activities. The study also reported positive changes in the learners' motivation towards science. Additionally, inquiry-based approach can also be used with technology for learning.

Notably, pre-school teachers transition from being transmitters of knowledge to facilitators while engaging in inquiry with the learners. On the other hand, learners actively participate in learner-centred approach when supported by teachers. However, much as studies have explored how pre-school learners engage in inquiry-based science, there needs to be more research on what teachers need to do to ensure their learners engage in meaningful, inquiry-based science (Berie, Damtie, & Bogale, 2022; Ramanathan, Carter, & Wenner, 2022)

In order to encourage the development of math skills, math programs should let learners be active in structuring knowledge (Trawick-Smith, Swaminathan & Liu, 2016). A study investigating the effects of the Inquiry-Based Mathematics Activities Module (IBMAM) on preschoolers in Turkey established that the inquiry-based approach contributed to all areas of development of a child. It provides fun and educational setting that increases preschoolers' motivation. The observations showed that the applied Inquiry-Based Mathematics activities stimulated active participation and enabled young children use their scientific process skills regularly. Besides, parents witnessed positive changes in their children (Karademir & Akman, 2021).

In Kenya, the Kenya Institute of Curriculum Development (KICD), formally KIE (2008), pre-school mathematics syllabus, refers to the basic concepts and subject matter as touching three significant areas: classification, numbers, and measurement, which enhance exploration of the environment. The curriculum, emphasizes an inquiry-based approach to make learning more active and meaningful to children, thereby enhancing the achievement rate in mathematics process skills. The study being reported aimed to establish whether an inquiry-based approach affects pre-school children's acquisition of mathematics process skills. In addition, the study sought to answer the following question: What is the difference in the acquisition of mathematics process skills between children taught using an inquiry-based approach and those taught using a traditional approach?

Methodology

The study employed a quasi-experimental research design involving manipulation of independent variables, which determined their effect on the dependent variable (Kothari, 2004). It incorporated a teaching experiment and a post-test as well as experimental and control groups to determine the effect of treatment (inquiry-based approach) on children's achievement in mathematics. The experiment was done without affecting the existing classroom setting, thus controlling the reactive effect since participants were less aware of their participation in an experimental study. The teaching experiment was carried out in six (6) ECDE centers involving children of mixed abilities taught by their regular teachers in their everyday school settings. Seven (7) schools formed the control group. Teacher participants were trained and briefed on the purpose of the study. They were required to introduce children to the mathematics concepts, guide them and intervene through probing questions and providing feedback to children's queries and responses.

The study population constituted 63 public ECDE Centers, 91 private ECDE Centers, 3395 pre-school children, and 154 pre-school teachers in Kajiado North Sub-County, Kajiado County, Kenya. In order to obtain a sample size of schools, the study used Mugenda and Mugenda (2003) thumb rule of a 10% sample size from the target population. Later, a systematic random sampling procedure (rotary) was employed to sample pre-schools from both public and private pre-schools. Finally, the pre-school teachers (handling pre-unit classes) were randomly and purposively picked from sampled pre-schools since they were deemed resourceful in supplying information sought by the study. As a result, the sample comprised 15 ECDE Centers, 15 pre-school teachers and 310 pre-school children, totaling a sample size of 340.

In investigating the relationship between an inquiry-based approach and children's achievement in mathematics, questionnaires were administered and alongside interview schedules to seek information from pre-school teachers. In addition, observation was carried out to check on the application of the inquiry-based approach in terms of the availability of instructional resources and acquisition of mathematics process skills. A post-test purposed to gauge the internalization of mathematics process skills was administered. learners in both control and experimental groups. Research instruments were appraised and validated by experts in the faculty of education at the University of Nairobi. The instruments were also pilot-tested. A test-retest technique was used to assess reliability of the instruments by administering the same instrument twice to non-participating subjects.

Learners were taught concepts on numbers: number value, filling in missing numbers, and classifying objects for two weeks. Those in the experimental group were exposed to inquiry-based approach. They were required to conduct their investigations and experiments, ask questions and freely interact with their environment. Those in the control group were taught using the traditional approach of teaching. The two groups later were

given an assessment test on the taught concepts, which were marked out of 100, and the scores were recorded and analyzed descriptive statistics. A t-test was used to check the difference in means between the control and experimental groups.

Results

This section presents the study findings, which are organized in four parts; the acquisition of mathematics process skills, the learning environment, and the students' t-test model for the comparison of two means.

Acquisition of Mathematics Process Skills

Learners endowed with mathematics process skills stand a better chance of demonstrating good performance in mathematics at preschool and successive tiers of education. The study sought to determine the development and internalization of mathematics process skills among pre-school learners. In order to measure the acquisition of mathematics process skills, an observation schedule was used to obtain information on children's acquisition and competence in the skills. The observation was made on children in both control and experimental groups. Regular teachers of the learner participants observed them during mathematics activities in and out of class. Learner participants were required to complete a given task to determine competency in a particular skill. For instance, those who counted from one to nine were considered competent in counting. It was established through the study that learners were able acquire five process skills and displayed varied levels of competence Learners in the experimental group who used inquiry-based approach emerged with superior scores in all the five process skills compared to their counterparts in the control group. A summary of the outcome is presented in Table 1. Table 1 summarizes learners' competence in five mathematics process skills.

Table 1: Mathematics process skills

Process Skill	Traditional Approach (Control-Group)	Inquiry-Based Approach (Experimental-Group)
	Percentage score	Percentage Score
Observing	82	94
Classifying	80	100
Counting	92	100
Counting on	82	90
Number Values	88	96
	(M=84.8, n=164)	(M=96, n=105)

The findings revealed that learners exposed to the inquiry-based approach had a better achievement with a superior mean score (M=96, n=105). Learner participants exposed to the traditional approach in the control category displayed a lower level of achievement with a mean score of 84 (M=84.8, n=164). Exposure to practical experiences, adequate and appropriate manipulative materials and exploratory activities accounted for the superior achievement among the experimental group.

Learners' T-Test Model for the Comparison of Two Means

The significance of the findings (tests) was tested using the paired t-test regarding the experimental and the control group. The paired samples t-test was used to determine if the two means differed. The results are as presented in Tables 2,3 and 4.

Table 2: Paired samples statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Experimental	98.0000	6	1.69823	.69330
	Control	83.6667	6	4.44687	1.81543

Table 3: Paired samples correlations

		N	Correlation	Sig.
Pair 1	Experimental & Control	6	-.208	.693

Table 4: Paired samples test

		Paired Differences					T	Df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Experimental – Control	14.33333	5.07924	2.07359	9.00300	19.66367	6.912	5	.001

The results indicated that the parametric Pearson correlation or 'r-value is insignificant at -0.208, and the p-value (Sig) for the correlation coefficient is larger than p

< .05 and significant. (Tables 2 and 3 are a link to Table 4). From the study's findings, the t was calculated at 5 degrees of freedom both at a 95% confidence interval of the difference = 6.912. Since p= .001 (less than 0.05 at 95% confidence level). Table 3 shows that the experimental group had a mean of 98.0000 (n=6) and a standard deviation of 1.69823, while the control group had a mean of 83.6667 (n=6) and a standard deviation of 4.44687. The superiority in achievement of the experimental group is further evidenced by a bigger value (98%) of mean and a smaller standard deviation (1.69823) compared to a mean of about 84% and a bigger standard deviation (4.44687).

Additional Findings

The study further sought information on instructional methods commonly used by preschool teachers and status of the learning environment (Facilities and resources).

Common Instructional Methods for Pre-School Mathematics

It emerged that majority of the teachers reported using demonstration as a method of teaching preschool mathematics. Figure 1 displays information on the percentage of participating teachers reporting use of demonstration, group project, memorization and lecture.

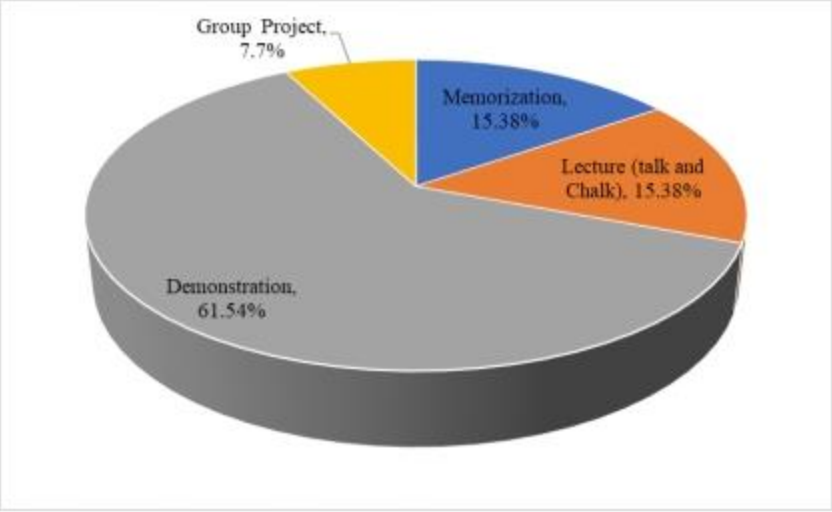

Figure 1: Teachers' rating on the use of instructional method

Most teachers reported using demonstration method (61.54%) (n=13), which utilizes the senses of sight and hearing only, cited inadequate instructional resources, and inadequate time and space as the reason for using the method in teaching pre-school mathematics. Demonstration is teacher-centered and less likely to involve learner-based activities.

Learners need more opportunities to manipulate and interact with concrete materials as witnessed with activity-based approach. Fifteen percent (15.38%, n=13) of the participating teachers drill learners to memorize mathematical facts and concepts. A similar proportion of teachers (15.38%, n=13) reported us of the lecture method ("talk and chalk"). Only 7.70% (n= 13) reported use of group projects. There was no mention of field trips as a way of utilizing the inquiry approach. The teachers cited the lack of enough time and finance in the case of field trips as the reason for not using the method. However, through field trips, learners can discover, explore and carry out their investigations, which is one way of using the inquiry approach. It is through field trips that learners develop observation skills, one of the process skills in mathematics. Be it as it may, the study confirms a paltry 7% use methods that encourage and involve learner activities. Majority of the teachers (about 93%) deny preschool learners' opportunity for practical experiences and active participation.

Learning Environment

Impact of the learning environment on making sense of mathematical skills and concepts cannot be ignored. The study strived to obtain information on the effect of the learning environment on learners' ability to classify objects as one of the process skills. To realize this, an observation schedule was prepared to find out the availability of facilities and resources necessary for mathematics learning. These included observation of facilities and resources such as classrooms, mathematics corners, sand corners, water points, learning resources, playgrounds, and play materials. This observation was informed by the fact that the learning environment of a pre-school education program is a vital factor in facilitating mathematics learning and in enhancing the acquisition of mathematics process skills. Table 5 summarizes information on facilities and resources found preschool learning environments.

Table 5: Availability of facilities and resources

Facilities/Resources	Available %	Not available %	Adequate %	Inadequate %
Classrooms	100	-	60	40
Mathematics corner	38.5	62.5	23	77
Sand corner	15	85	-	-
Water point	54	46	23	77
Learning resources	92	8	15	85
Play ground	85	15	62.5	37.5
Play materials	92	8	23	77

It is worth noting that 77% of the participating teachers reported inadequate resources in the mathematics corner. This is a limiting factor on the use of activity-based

approach since the much-needed facilities and resources are inadequate. Forty percent (40%, n=13) reported inadequate space within the classrooms, thus limiting the natural flow of activities. Within the classrooms, activity corners such as mathematics corners are equipped with mathematical toys, building blocks, and bottles to enhance active manipulation. Findings reveal that only 38.5% (n=13) of the pre-schools had mathematics corners, and only 23% (n=13) had adequate materials. In addition, most pre-schools (85%) did not have sand corners as 46% (n=13) lacked water points, with only 23% having enough for use by learners. So profound were the learning materials out of the 92% (n=13) schools with materials; only 15% had enough. Furthermore, some schools (15%) did not have playgrounds, as 8% needed more play materials.

It is evident that inadequate materials is a factor militating against use of activity based approach. Efforts by preschool teachers to use inquiry-based approach may be frustrated absence of adequate resources hence inability to use the approach. From the findings, it is clear that most schools require improvement in terms of a prepared learning environment, as most lacked models and resources like building blocks. Such resources are necessary to maximize achievement in mathematics in terms of skills like classification, counting, and counting on. Notably, playing with blocks is one of the main activities in pre-schools as it gives learners the opportunity to classify (based on shape, color, and size), measure, and count objects.

Discussion

The result from the study points out that the acquisition of mathematics skills among pre-school learners varied between the control and experimental groups and was significantly associated with the aspects of the inquiry-based approach. The performance of learners in the experimental group outdid those in the control group. The findings of this study suggest that exposure to inquiry–based approach gives learners more opportunities to carry out their investigations, thus making them more competent in acquiring mathematics process skills. This finding is consistent with the study conducted by Karademir and Akman (2021), which indicated that an Inquiry-Based Mathematics Activities Module (IBMAM) contributed to all areas of development by providing a fun and conducive learning environment that augmented pre-schoolers' motivation. It also provided pre-school learners different perspectives, encouraged active participation, and enabled continued learning.

The findings are also supported by Farooqi (2020) who reported that inquiry-based instruction in pre-school mathematics can positively impact learner engagement and achievement. From the findings, it is evident that all pre-schools have classrooms; however, they have inadequate space and teaching resources within the classrooms, thus limiting the natural flow of activities. This may have contributed to the choice of teaching methods used. These findings are consistent with Hunter, Syversen, Brodal, Graves et al.

(2020) who suggest that much as teachers uphold a strong preference for child-centered learning, the changing outdoor space requires augmented intentionality to achieve set objectives. Thus, teachers should be provided with an enabling learning environment, training, and resources for fully exploiting inquiry-based approaches.

Conclusion

Based on the findings, it is concluded that learners taught using inquiry-based approach acquire mathematics process skills such as observing, classifying, counting, counting on, and mastering number values better than those taught using traditional approach. Learners become more competent and proficient in mathematics process skills when exposed to activity-based approach. Pre-school learners require a learning environment rich in manipulative materials to provide an opportunity for active interaction, which encourages practical activities. It is further concluded that a better understanding of the relationship between inquiry-based approach and mathematics process skills will guarantee improvement in mathematics teaching and enhance future learning and achievement.

Recommendations

Based on the findings, the following recommendations were made:

Through the Ministry of Education, the government should organize workshops and refresher courses for pre-school teachers, managers of early childhood development programs, and other stakeholders, such as training institutions, to build capacity on appropriate mathematics teaching at the preschool level

Inquiry-based approach is recommended for application in teaching pre-school mathematics and other related activity areas due to its ability to produce superior results

Pre-school teachers need not rely on the administration to provide instructional materials but should embrace the idea of improvisation. This will help mitigate the use of an expository approach to teaching as they provide no opportunity for active participation and utilization of learner's curiosity.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

The authors acknowledge the pre-school teachers that participated in the study and the University of Nairobi for hosting the program where the initial study was taken

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