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The Effects of Kindergarten Experiences on Children's Elementary Science Achievement

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ABSTRACT. Recent research on brain development suggests that early childhood education has longitudinal influences on children's cognitive, socioemotional, and behavioral outcomes. The purpose of the study was to determine the effects of kindergarten science activities and children's early science and reading performances on their elementary science achievement. A structural equation model was constructed utilizing data from the Early Childhood Longitudinal Study-Kindergarten Class of 1998-99 (ECLS-K), conducted by National Center for Educational Statistics. Results revealed positive effects of enriched science experiences and reading development in kindergarten on children's science achievement at third grade. Children who were more frequently involved in science activities in a richer science environment in kindergarten had higher levels of science achievement at third grade.
Key Words: Kindergarten, science achievement, activity-based curriculum

INTRODUCTION

Research supports the strong connection between early childhood education and children's intellectual development. The quality of interventions and instruction in early childhood programs affects children's later school success (Blachman, 2000; Francis, Shaywitz, Stuebing, Shaywitz, & Fletcher, 1996; Lyon, 1999; Snow, Burns, & Griffin, 1998). Furthermore, recent research on brain development (Garber, 1988; Walker, Greeenwood, Hart, & Carta, 1994) suggests that early childhood education has longitudinal influences on children's cognitive, socioemotional, and behavioral outcomes. Particularly, early success in reading and science is critical to cognitive growth in children.

Researchers suggest that science should be introduced to children as early as possible (Rillero, 2005; French, 2004; Gould, Weeks & Evans, 2003; Kokoski & Downing-Leffler, 1995). Some argue that children's thought is rich and complex in early stages. Therefore, children are ready to learn science and math in kindergarten (Gelman, & Brenneman, 2004; Fleer, & Robbins, 2003b). Tytler and Peterson's longitudinal study showed that children's capacity to learn science is well above the curriculum expectations (2003). Unlike what traditional science education research in the past suggests young children's experiences of and interest in science is strong (Fleer, & Robbins, 2003a).

New educational policies target the improvement of science teaching at schools (Patton, & Kokoski, 1996). However, in most early childhood classrooms, science is not emphasized as much as other subjects. In these classrooms, "science area" is not more than a table with some shells and leaves on it (Sprung, 1996). In practice, learning science is not separate from learning other subjects and there is an interaction between science and other domains of instruction in kindergarten. Early science experiences improve children's language and math skills as well. One of the most influential interactions is observed between children's school success in science and their reading development in kindergarten.

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Reading is the fundamental skill in a child's life upon which the success in other learning domains depends. Mastery of cognitive and socio-emotional skills and knowledge in later grades is, to a great extent, related to a child's ability to comprehend reading basics in early years. Therefore, studying early reading and language development has an invaluable importance to shape policy decisions. Research has demonstrated the importance of early years in reading as children who read poorly in first and second grade tend to remain poor readers in later grades (Blachman, 2000; Snow, Burns, & Griffin, 1998). Children also tend to communicate with the new words they learnt during the science experiences. Gelman and Brenneman (2004) recommend preschool teachers to provide repeated opportunities and meaningful context in order to help young children to use scientific vocabulary appropriately. Science learning activities need to be promoted through relevant conversations and carefully framed questions.

Although there has been some interest on the long-term effects of kindergarten education on individuals' later success in life, there is limited research investigating the effects of specific learning activities in early years on children's future school success (Wolfgang, Stannard, & Jones, 2001). In one of the few studies available, Wolfgang, Stannard, and Jones (2001) examined the correlation between 37 preschoolers' block performance and their achievement in later grades. There was a positive correlation between preschool block performance and math achievement in middle and high school. However, kindergarten science and reading development is one of the subjects of which long-term effects are not addressed adequately by researchers. On the whole, little is known about the effects of science experiences and reading ability in kindergarten on children's science achievement in elementary grades. Furthermore, the sample sizes of the existing research have been limited, raising questions about the generalizability of the result to other contexts and populations. Utilizing the data from the Early Childhood Longitudinal Study-Kindergarten Class of 1998-99 (ECLS-K), it is intended to expand the body of knowledge regarding kindergarten experiences and science achievement in later grades. To sum up, this study aims to help closing the gap in the area by investigating the long-term effects of preschool science experiences and reading level on children's future school success. It was hypothesized that children who had better science experiences and a better initial reading level in kindergarten would exhibit higher levels of science achievement at the end of the third grade.

Research Objectives

The purpose of the study is to determine the effects of kindergarten science activities and children's early science and reading performances on their future science achievement. The following are some of the research questions that led the analyses presented in this study.

1. What are the effects of using science-learning tools, science areas, and involvement in science activities in kindergarten on children's science achievement at third grade?
2. What is the effect of early reading achievement on children future science performance?

METHODOLOGY

Data Source, Sample, and Measures

This research utilized data from the Early Childhood Longitudinal Study-Kindergarten Class of 1998-99 (ECLS-K), conducted by National Center for Educational Statistics (NCES). ECLS-K is a "multisource, multimethod study that focuses on children's early school experiences beginning with kindergarten" (NCES, 2001, p, 1-1). The ECLS-K gathers data from a nationally representative sample of children from kindergarten through fifth grade. A total of 21,260 children throughout the US are first sampled at kindergarten level and followed up through fifth grade. The ECLS-K is a longitudinal study that followed the same children from kindergarten through the 8th grade. Information was collected in the fall and the spring of kindergarten (1998-99), the fall and spring of 1st grade (1999-2000), the spring of 3rd grade (2002). The data set utilized in this study was released for researchers' use in 2004.

The ECLS-K study includes data collected from students, teachers, schools, and parents. The child data were utilized in the current study. After conducting a preliminary analysis including missing data patterns

and case analysis, some of the cases were excluded from the study. The working sample was generated from child data if a child had complete records on study variables in both rounds as kindergarten and 3rd grade level. The last working sample included 4,490 kindergarten children. Since ECLS-K is not a simple random sample, which means not all schools, teachers, and children had an equal probability of selection; an appropriate student weight was initially normalized and then adjusted for the analysis. Using SPSS (Statistical Program for the Social Sciences), the standard errors were corrected with average root design effect (DEFT) to calculate standard errors, assuming the data were collected with a simple random sample (SRS). In the SPSS, the standard errors were corrected using DEFT. The standard error of an estimate under the actual sample design was approximated with the following formula;

$$SE_{DESIGN} = \sqrt{DEFF \times Var_{SRS}} = DEFT \times SE_{SRS}$$

After using the appropriate study weight for children data, the sample was nationally representative of 1,205,271 children.

Hypothesized Model and Variables

To evaluate influences of kindergarten science activities and children's early science and reading performances on their future science achievement, a structural equation model [SEM] was constructed with the ECLS-K Longitudinal data utilizing *MPlus* software with version 3.1 (Muthén & Muthén, 2000). A total of seven variables were included in the model as listed below:

1. *Third Grade Science Achievement* [ELEMSCI]: Children's 3rd grade science performance Item Response Theory [IRT] scores.
2. *General Knowledge* [KINGEN]: Children's general knowledge IRT (Item Response Theory) scores in kindergarten, including science and social studies. Science items measure two broad classes of science competencies: a) conceptual understanding of scientific facts, and b) skills and abilities to form questions about the natural world.
3. *Kindergarten Reading Achievement* [KINREAD]: Children's literacy IRT scores at kindergarten level.
4. *Frequency of Using Science Equipment* [FRSCIEQP]: Refers to how frequently children used science equipments (e.g., magnifying glass, scales, thermometers, etc.) at Kindergarten level. It was scored on a 6-point scale from never to daily.
5. *Science or Nature Area* [SCINATU]: Whether kindergarten class had a science or nature area. Dichotomously scored (available=1, not available=0).
6. *How Often Science* [OFTENSC]: Refers to how often children in kindergarten classes usually worked on lessons or projects in science area. (A 5-point scale from never to daily).
7. *Computers for Science Concepts* [COMSCI]: Scored on a 6-point scale from never to daily to show how frequently children used computers for learning science concepts at kindergarten.

In particular, the test specifications for science were developed largely from recommendations of an advisory group of experts and included two broad classes of science competencies: Conceptual Understanding and Scientific Investigation (Rock & Pollack, 2002, p, 2-13):

> "Conceptual Understanding refers to both the child's factual knowledge base and the conceptual accounts that children have developed for why things occur as they do. Consistent with current curriculum trends, the emphasis in the ECLS–K will be more on the adequacy of accounts than the grasp of discrete facts, particularly as the children move up in grade level. Scientific Investigation refers to children's abilities to formulate questions about the natural world, to go about trying to answer them on the basis of the tools available and the evidence collected, and to communicate their answers and how they obtained them."

In addition, in an effort to develop a new reading assessment test, NCES sought permission to barrow or adapt items from published tests including the Peabody Individual Achievement Test-Revised (PIAT-R), Peabody Picture Vocabulary Test-Revised (PPVT-R), the Primary Test of Cognitive Skills (PTCS), the Test of Early Reading Ability (TERA-2), the Test of Early Mathematics Ability (TEMA-2), and the Woodcock- Johnson Tests of Achievement-Revised (WJ-R) (Rathbun, West, & Germino-Hausken, 2004; Rock & Pollack, 2002).The ECLS-K reading assessment for the kindergarten included five proficiency levels as follows: (1) identifying upper- and lower-case letters of the alphabet by name; (2) associating letters with sounds at the beginning of words; (3) associating letters with sounds at the end of words; (4) recognizing common "sight" words; and (5) reading words in context.

For the purposes of this longitudinal study, a composite variable on an Item Response Theory (IRT) based scale in science, reading, and general knowledge that combines all those skills mentioned above, was utilized in a continuous form. IRT has several advantages over raw number-right scoring. Scores based on the full set of test items were calculated using IRT procedures. IRT uses the pattern of right, wrong, and omitted responses to the items actually administered in a test and the difficulty, discriminating ability, and "guess-ability" of each item to place each child on a continuous ability scale. It is then possible to estimate the score the child would have achieved if all of the items in all of the test forms had been administered. By using the overall pattern of right and wrong responses to estimate ability, IRT can compensate for the possibility of a low ability student guessing several hard items correctly.

Reliability statistics for instruments in each subject area for each round of data collection were provided and NCES (2003, p.3-23) states that "for the IRT-based scores, the reliability of the overall ability estimate, theta, is based on the variance of repeated estimates of theta". Reliability estimates, for instance, for the reading IRT scores were 0.93, 0.95, 0.96, and 0.94, for the fall kindergarten, spring kindergarten, spring first-grade, and spring third-grade, respectively.

RESULTS

Table 1 presents the minimum and maximum values, means, and standard deviations for the study variables in the data. The average children's science achievement in 3rd grade was found to be 36.26 (SD=8.90) based on IRT scale that takes ability estimate parameters into account.

Table 1. Descriptive statistics of study variables (N=4,490)

Variables	Min	Max	M	SD
ELEMSCI	11.33	58.76	36.26	8.90
KINGEN	8.41	47.46	28.82	7.11
KINREAD	16.15	124.40	40.26	12.82
FRSCIEQP	1	6	3.85	1.36
SCINATU	0	1	(38%=Yes; 62%=No)	
OFTENSC	2	5	3.77	0.79
COMSCI	1	6	2.13	1.51

M=Arithmetic mean; SD=standard deviation

The mean of children's general knowledge scale score including both social and science performance at the kindergarten level is relatively lower (MKINGEN =28.82; SD=7.11) than their reading scale scores at kindergarten level (MKINREAD =40.26; SD=12.82) and science scale scores (ELEMSCI) at the third grade as well. Regarding the use of science equipments during kindergarten years children mostly utilized various tools such as magnifying glass, scales, microscopes, etc. (MFRSCIEQP =3.85; SD=1.36). The data indicate that only 38% of the kindergarten class has a science or nature area (SCINATU). Children in kindergarten classes frequently worked on lessons or projects in science area (MOFTENSC =3.77;

SD=0.79). Finally, it is reported that children not frequently used computers for learning science concepts at kindergarten level (MCOMSCI =2.13; SD=1.51).

Analysis of the initial hypothesized model, presented in Figure 1, revealed that this model adequately fitted the data based on the root mean square error of approximation (RMSEA) descriptive model fit statistics. The RMSEA for this model (0.037) is well below the value of 0.06 recommended by Hu and Bentler (1999) as an upper boundary. The comparative fit index (CFI) is another measure of how much better the model fits compared to an independence model. Values of roughly 0.9 or larger are often assumed to represent acceptable fir. In this model, the CFI was estimated as 0.993, greater than the expected CFI index.

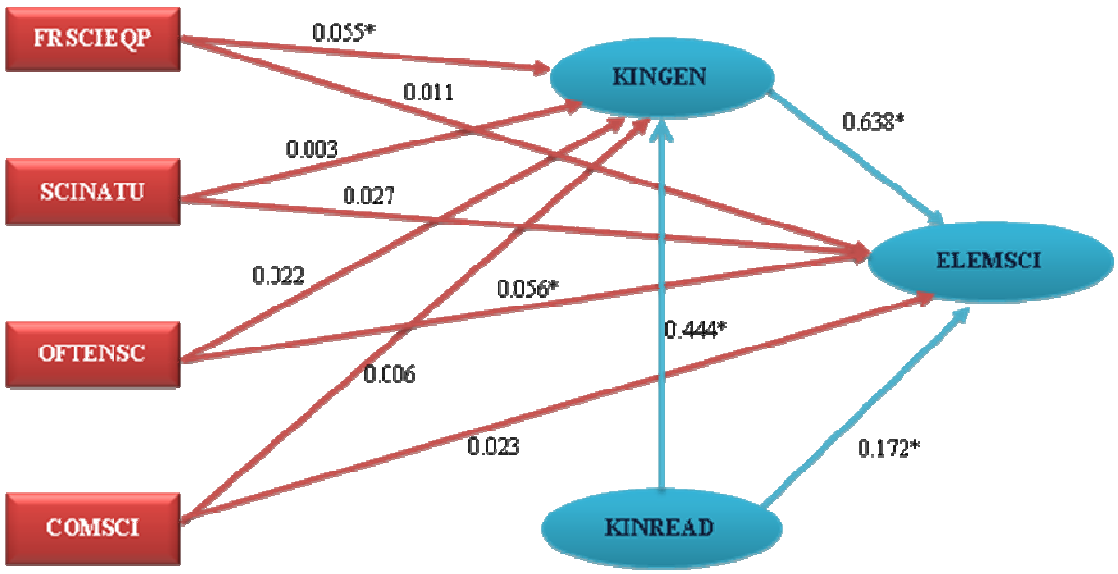

Figure 1. Estimated standardized direct effects for the hypothesized (initial) structural equation model

The standardized direct causal effects and the observed reliabilities (R^2) presented by the hypothesized model are summarized in Table 2. The associated standard errors were very small except for SCINATU and OFTENSC. Low standard errors indicate relatively high degree of precision of knowledge of population effects. Beginning with ELEMSCI, indicating children's 3rd grade science achievement, the outcome of the ultimate interest of this study, the determinant with the largest direct causal effect (0.638) was kindergarten general knowledge score (KINGEN) incorporating science and social skills. Namely, children early science experiences and performance is the leading indicator of later success in science. The next most important determinant of ELEMSCI was children's reading scores at kindergarten level (KINREAD) with estimation of a total direct causal effect of 0.172. In other words, the result revealed that there is a positive and statistically significant relationship between kindergarten reading achievement and elementary science performance. The remaining determinants of 3rd grade science achievement, OFTENSCI, SCINATU, COMSCI, and FRSCIEQP, which had causal effects 0.056, 0.027, 0.023, and 0.011., were positively but not statistically associated with science success. Overall, approximately, 54.3% of the variance of ELEMSCI was explained by these six determinants.

Table 2. Standardized Causal Effects for the Revised Model

Outcome	Determinant	Causal Direct Effects
ELEMSCI (R^2= .543)	KINGEN	0.638* (0.018)
	KINREAD	0.172* (0.010)
	FRSCIEQP	0.011 (0.088)
	SCINATU	0.027 (0.250)[a]
	OFTENSC	0.056*(0.153)[a]
	COMSCI	0.023 (0.084)
KINGEN (R^2= .200)	KINREAD	0.444* (0.010)
	FRSCIEQP	0.055* (0.092)
	SCINATU	0.003 (0.268)[a]
	OFTENSC	0.022 (0.157)[a]
	COMSCI	0.006 (0.094)

a The large sample standard error is shown in parentheses.
* Effect statistically significant (z-statistics > 2).

The primary determinant of kindergarten general knowledge score (KINGEN) was reading performance at kindergarten years (KINREAD) with an effect of 0.444. The frequency of using science equipments (FRSCIEQP) by children also significantly affected their science scores at the kindergarten level (0.055). The effects of remaining determinants of KINGEN were relatively low which were OFTENSCI, COMSCI, and SCINATU had causal effects of 0.022, 0.006, and 0.003. These five determinants was accounted for approximately 20% of the variance of KINGEN, including children's kindergarten science knowledge and skills.

DISCUSSION and CONCLUSIONS

Although previous research stressed the importance of early science experiences on children's later school success, there is limited number of research on this area. Few studies have assessed both the science and reading skills of children when they enter kindergarten and have documented the development of these skills through 3rd grade (Denton, West, & Walston, 2003). Existing research has also been limited with some methodological issues such as small sample sizes. Utilizing the ECLS-K, this study presents results from a large sample. The results of this study would assist policy makers to design more effective kindergarten programs that foster children's school success in later grades.

Results ensure the positive effects of enriched science experiences and reading development in kindergarten on children's science achievement at third grade. Children who were more frequently involved in science activities in a richer science environment in kindergarten had higher levels of science achievement at third grade. Kindergartners carry a natural eagerness and curiosity to discover their environments. Regardless of their previous experiences, science enables them to answer questions about themselves and the surrounding environment. Daily routines offered them at kindergarten provide them with a foundation that helps them make sense of their world. Furthermore, developmentally appropriate activities that stimulate kindergartners' interest in science investigations encourage them to develop a lifelong pursuit for scientific information and exploration. This relationship between the kindergarten and third grade science achievement found in the current study is particularly of importance because of another study that related third grade science achievement to success in late years. The causal-comparative study conducted by Burriss (2002) revealed that the differences in achievement existing at the end of the 3rd grade among 367 students who attended public kindergarten, non-public kindergarten, or no kindergarten continued to exist throughout their school years. The results also indicated that students with kindergarten

experience, either public or non-public, scored significantly higher than students without kindergarten experience on standardized math, science, and language scores as well as having better cumulative grade point averages. It is believed, therefore, that the policy makers and school administrators should put efforts in implementing a challenging, activity-based, developmentally appropriate, and inquiry-based science curriculum to foster young children's early science development.

In addition, it was quite significant to observe the strong and positive relationship between kindergarten reading achievement and the science achievement in third grade. Children who were better readers in kindergarten attained higher science achievement in later grades. This finding is of importance since reading is the fundamental skill in a child's life upon which the success in other learning areas depends.

Lyon (1999) stated that a large number of students fail to acquire basic reading skills in early elementary grades. Of those children who struggle to achieve basic levels of reading by third grade, 75% are expected to be poor readers at the end of high school (Francis, Shaywitz, Stuebing, Shaywitz, & Fletcher, 1996; Lyon, 1998). Consequently, students who learn to read and acquire basic language skills in kindergarten attain higher levels of reading at the end of high school (Hanson & Ferrel, 1995). Research extensively illustrated that children who are poor readers at the end of first grade generally do not obtain average-level reading skills by the end of elementary school (Francis et al., 1996; Juel, 1988; Torgesen and Burgess, 1998). Children's abilities to comprehend and learn new concepts are influenced by their difficulties with word recognition and fluency (Juel, 1988; Torgesen, Wagner, & Rashotte, 1994). Furthermore, children who have difficulties in reading tend to have negative attitudes toward reading, fewer opportunities for vocabulary growth, and less practice in reading (Stanovich, 1986) than their peers who attain desired levels of reading. The current study offers a new vein to the issue by relating the kindergarten reading performance to the science achievement in third grade.

Although the results are encouraging, it should be noted that the current study was limited with a sample of kindergarteners and third graders. Results from a meta-analysis study by Bredderman (1983) should be reminded at this point that students that had had activity-based programs in elementary school and had later experienced traditional science programs during middle school years could not be consistently distinguished from control groups. Results from the two studies compliment each other to provide invaluable insight for teacher and school administrators that developmentally appropriate and activity-based science curriculum should be followed up kept in place in later grades as well.

Future research efforts may continue to explore the relationship between reading and science achievements in later grades. Furthermore, a longitudinal study with more data collection points in first and second grades would contribute to the issue by providing more evidence.

Okul Öncesi Deneyimlerin Çocukların İlköğretimFen Başarısına Etkisi

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ÖZ. Beyin gelişimi araştırmaları okul öncesi eğitimin çocukların bilişsel, sosyal-duyusal ve davranışsal gelişimi üzerinde uzun dönemli etkilerini ortaya koymaktadır. Bu çalışmanın amacı, anaokulunda sunulan fen etkinliklerinin ve çocukların anaokulundaki fen ve okuma becerilerinin ilköğretim üçüncü sınıftaki fen başarısına etkisini incelemektir. Çalışmada Ulusal Eğitim İstatistikleri Merkezi tarafından hazırlanan Okul Öncesi Uzun Dönem Araştırması-Anaokulu Sınıfı 1998-99 verileri kullanılarak bir yapısal eşitlik modeli geliştirilmiştir. Sonuçlar anaokulundaki zenginleştirilmiş fen deneyimlerinin ve okuma becerisinin ilköğretim üçüncü sınıftaki fen başarısı üzerine olumlu etkileri olduğunu ortaya koymuştur. Anaokulunda daha fazla fen etkinliklerine katılan öğrencilerin üçüncü sınıfta daha yüksek fen başarısı sergilediğini belirtmektedir.
Anaktar Sözcükler: Anaokulu, fen başarısı, etkinlik temelli öğretim programı

ÖZET

Amaç ve Önem: Okulöncesi eğitimin gelecek yıllardaki öğrenci başarısı üzerine etkilerinin pekçok araştırmacı tarafından vurgulanmasına rağmen bu alandaki uzun dönemli etki araştırmaları oldukça sınırlıdır. Bu çalışmada anaokulunda çocuklara sunulan fen etkinliklerinin ve çocukların anaokulundaki fen ve okuma başarılarının ilköğretim üçüncü sınıftaki fen başarısına etkisi incelenmiştir.
Yöntem: Ulusal Eğitim İstatistikleri Merkezi tarafından hazırlanan Okul Öncesi Uzun Dönem Araştırması-Anaokulu Sınıfı 1998-99 çalışmasının araştırmacılara sunduğu olanaklardan yararlanılarak 4,490 öğrenciye ait uzun dönemli veriler kullanılmıştır. Aynı öğrenciler anaokulundan ilköğretim üçüncü sınıfa kadar izlenmiş ve gelişimlerine yönelik veriler toplanmıştır. Örneklemin seçiminde tam rassal yöntem kullanılamadığı için, örneklemin evren temsil edebilmesini sağlayacak ağırlıklar kullanılarak bu işlem sonucu elde edilen veriler analiz edilmiştir. Verilerin analizinde Yapısal Eşitlik Modellemesi yöntemi kullanılmıştır.
Bulgular: Altı değişkenle önerilen yapısal eşitlik modelinin verilerle desteklendiği gözlenmiştir. İlköğretim üçüncü sınıftaki fen başarısının en önemli iki belirleyicisi anaokulundaki fen başarısı ve anaokulundaki okuma başarısı olarak belirlenmiştir. Beklenen bu etkilerin ardından, anaokulundaki fen etkinliklerinin sıklığı en etkili değişken olarak saptanmıştır. Modelde bulunan diğer değişkenler de anaokulundaki fen araç gereçlerinin kullanım sıklığı, anaokulunda bir fen/doğa alanının varlığı, ve fen kavramlarının öğretiminde bilgisayar kullanım sıklığı olarak belirlenmiştir. Belirlenen değişkenlerle kurulan yapısal eşitlik modeli, üçüncü sınıftaki fen başarısına ilişkin varyansın %54'ünü açıklamıştır.
Tartışma, Sonuç ve Öneriler: Bu çalışma alanda eksikliği hissedilen uzun dönemli araştırma gereksinimi doğrultusunda okul öncesi eğitimin gelecekteki okul başarısı üzerine etkilerini incelemek amacıyla gerçekleştirilmiştir. Veriler, anaokulundaki fen başarısının ve zenginleştirilmiş fen etkinliklerine katılma sıklığının ilköğretimdeki fen başarısı üzerine olumlu etkileri olduğunu ortaya koymuştur. Öğrencilerin ilköğretimde fen alanında daha başarılı olabilmeleri için fen etkinlikleriyle çok daha önce okul öncesi dönemde tanıştırılmaları gerektiği görülmektedir. Erken çocukluk döneminde fen etkinliklerine daha sık katılan ve sınıflarında daha fazla fen araç gereçleri bulunan öğrenciler ilköğretim üçüncü sınıfta daha yüksek fen başarı düzeyi sergilemiştir. Araştırmada ortaya konan bir başka olumlu ve önemli sonuç da

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anaokulundaki okuma becerileriyle ilköğretim fen başarısı arasındaki ilişkidir. Okuma becerisi diğer tüm alanlardaki başarıya etkileri olduğuna inanılan bir temel değişkendir. Araştırmalar genellikle erken çocukluk yıllarındaki okuma becerisinin gelecekteki okuma ve genel okul başarısına etkilerini incelemiştir. Bu çalışma, birbirinden ilgisiz gibi gözüken iki değişken arasındaki olumlu etkiyi doğrulamaktadır. Anaokulunda daha iyi okuma becerilerine sahip olan çocuklar ilköğretim üçüncü sınıfta daha yüksek fen başarısı sergilemiştir. Bu sonuçlar ışığında, yasa yapıcılar, okul yöneticileri ve öğretmenler anaokulu sınıflarında çocukların mümkün olduğunca erken fen etkinlikleriyle ve araç gereçleriyle tanışmalarını sağlayacak ortamlar düzenlenmesini sağlamalıdır. Düşünülenin aksine, anaokulu yılları fen kavramlarının öğretimine başlamak için erken değildir. Çocuklar bu yaşlardaki anlamlı fen etkinliklerinin olumlu sonuçlarını gelecekteki okul başarısına yansıtabilmektedirler.

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