

The Influence of Early Science Experience in Kindergarten on Children's Immediate and Later Science Achievement: Evidence From the Early Childhood Longitudinal Study

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Abstract: This study explores the impacts of selected early science experiences in kindergarten (frequency and duration of teachers' teaching of science, availability of sand/water table and science areas, and children's participation in cooking and science equipment activities) on children's science achievement in kindergarten and third grade using data for 8,642 children from the Early Childhood Longitudinal Study-Kindergarten cohort (ECLS-K). A theoretical model that depicts the relationships between the study variables was developed and tested using structural equation modeling. Results demonstrated that availability of science materials in kindergarten classrooms facilitated teachers' teaching of science and children's participation in science activities. Likewise, the frequency and the duration of kindergarten science teaching was a significant predictor of children's science activities but not of the children's end of kindergarten science achievement scores. Children's engagement with science activities that involved using science equipment also was not a significant predictor of their end of kindergarten science achievement. However, children's participation in cooking activities was. Children's prior knowledge, motivation, socio-economic status, and gender were all statistically significant predictors of their science achievement at the end of kindergarten and end of third grade. Results of this study indicate that early science experiences provided in kindergarten are not strong predictors of children's immediate and later science achievement. Findings of the study suggest that the limited time and nature of science instruction might be related to the limited effect of the science experiences. Implications for teacher education programs and educational policy development are discussed. © 2010 Wiley Periodicals, Inc. *J Res Sci Teach* 48: 217–235, 2011

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Young children develop fundamental understandings of observed phenomena and essential science process skills during their earliest years (Eshach & Fried, 2005; Gallenstein, 2003; Lind, 1999). These basic science understandings and skills begin to develop as early as infancy, with the sophistication of children's competency developing with age (Kuhn, Amsel, & O'Loughlin, 1988; Kuhn & Pearsall, 2000; Lind, 1999; Meyer, Wardrop, & Hastings, 1992; Piaget & Inhelder, 2000). Research studies in developmental and cognitive psychology indicate that environmental effects are important during the early years of development, and the lack of stimuli may result in a child's development not reaching its full potential (Hadzigeorgiou, 2002). Science instruction in the early years can provide the necessary opportunities for young children to develop basic understandings of the natural phenomena and fundamental process skills such as observing, inferring, and exploring. Thus, experiential science education in early childhood is of great importance to many aspects of child development, and researchers suggest that science education should begin during the early years of preschool (Eshach, 2003; Eshach & Fried, 2005; Ginsburg & Golbeck, 2004; Kallery, 2004; Watters, Diezmann, Grieshaber, & Davis, 2000).

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There are several reasons to teach science in the early years. Children have a natural tendency to enjoy observing and thinking about nature (Eshach & Fried, 2005; Patrick, Mantzicopoulos, Samarapungavan, & French, 2008; Ramey-Gassert, 1997). Science content and skills are a natural fit with the way young children explore and try to explain their environments. Young children are motivated to explore the world around them, and science experiences in the early childhood classrooms, if implemented well, can capitalize on this inclination and be highly motivating and consistently interesting to young children (French, 2004; Patrick, Mantzicopoulos, & Samarapungavan, 2009). Engaging children with science experiences at early ages helps children to develop positive attitudes toward science (Eshach & Fried, 2005; Patrick et al., 2008), which is linked to science achievement (Bruce, Bruce, Conrad, & Huang, 1997; Neathery, 1997; Osborne, Simons, & Collins, 2003). Thus, developmentally appropriate engagement with quality science learning experiences can enhance children's development of science skills and knowledge and lay a solid foundation for the subsequent development of scientific concepts children will encounter throughout their academic lives (Eshach & Fried, 2005; Gilbert, Osborne, & Fenshama, 1982).

The provision of quality science learning experiences to young children in the early years has been impeded by a lack of systematic instructional frameworks and curricula in Pre-K science that are linked to standards (NAEYC, 2002), teachers' lack of science and pedagogical content knowledge (Appleton, 1995, 2003; Kallery & Psillos, 2001; Watters et al., 2000), and inadequate teacher resources (Appleton & Kindt, 1999). Children seem to have fewer opportunities to learn science concepts than any other concepts in the early years (Early et al., 2010). Teachers' limited content knowledge in science and science teaching pedagogy (Garbett, 2003; Kallery & Psillos, 2001; Nayfeld, 2008; Tu, 2006), their low science teaching efficacy (Pell & Jarvis, 2003; Schoon & Boone, 1998), and the pressure to teach language and literacy (Greenfield et al., 2009) are the major reasons early childhood teachers devote less time to teaching science. Limited exposure to science concepts in the early years might be detrimental to children's science learning experience. A lack of longitudinal studies that investigate the impact of early science learning experiences on children's science achievement in later grades limits our ability to assess the effectiveness of the science instruction provided in the early years and to derive implications for the training of the pre- and inservice early childhood teachers in teaching science concepts. Therefore, the present study aimed to examine the impact of young children's early science experiences in kindergarten on their science achievement at the end of kindergarten and in third grade. This timeframe allowed for the assessment of children's science achievement at the beginning (Kindergarten), the end of kindergarten, and the end (third grade) of their early childhood schooling experiences.

Theoretical Framework

Opportunity–Propensity Framework

The present study utilized the opportunity–propensity framework (Byrnes, 2003; Byrnes & Miller, 2007; Byrnes & Wasik, 2009; Jones & Byrnes, 2006) to study the impact of kindergarten science experience on children's science achievement in third grade. While the opportunity component of this framework refers to factors such as classroom materials and instructional practices that offer a context to learn academic content, the propensity component refers to factors such as previous knowledge and motivation that increase the likelihood of children benefiting from opportunities to learn (Byrnes & Miller, 2007; Byrnes & Wasik, 2009). The opportunity–propensity framework suggests that children are more likely to realize their potential of learning a particular content if they are provided opportunities to learn that content and have desire and capability to benefit from the opportunities provided to them (Byrnes & Wasik, 2009). In this framework, factors such as socio-economic status and gender are considered as antecedent factors. Antecedent factors explain why some children are more likely than others to benefit from opportunities provided to them (Byrnes & Wasik, 2009). The antecedent factors can also be used to account for the variation in the outcome variable so that the unique contributions of propensity and opportunity factors to children's learning can be identified.

Theoretical Model Tested in the Study

Recent studies in developmental psychology and cognitive science indicate that early learning experiences are crucial for children's cognitive development (Brecht & Schmitz, 2008; Lawson, 2003; Lindsey, 1997; Rushton & Larkin, 2001). Findings of the Neo-Piagetian studies suggest that young children

are capable of performing various cognitive tasks including making predictions based on their observations and deriving conclusions, which are the basis of scientific thinking and learning (Carey, 2004; Carey & Spelke, 1994; Kuhn & Pearsall, 2000; Metz, 1997; Opfer & Siegler, 2004; Ruffman, Perner, Olson, & Doherty, 1993; Spelke, Breinlinger, Macomber, & Jacobson, 1992; Wellman & Estes, 1986; Zimmerman, 2000). Providing early science experiences in kindergarten has the potential to capitalize on children's early potential as reported in the literature, and early experiences seem to be essential for children's development of core scientific knowledge and essential inquiry skills (Eshach & Fried, 2005; Patrick et al., 2009; Samarapungavan, Mantzicopoulos, & Patrick, 2008).

One measure of children's science experiences in early childhood classrooms is the amount of the instructional time allocated for science teaching. Frequent and longer periods of science instruction in the early years as well as children's involvement in science activities provide greater opportunities for children to develop fundamental science inquiry skills and understanding of basic science concepts, which subsequently may lay the foundation for the understanding of more complex science concepts in later grades. Indeed, the science concept maps (K-12) illustrated in the *Atlas of Scientific Literacy* (American Association for the Advancement of Science [AAAS], 2001) suggest that the understanding of many complex science concepts, such as evaporation, condensation, and the cause of the lunar phases, are tied to the children's understandings of the more basic science concepts in kindergarten. Studies on learning progressions in science also suggest that conceptual understanding of science topics and accompanied scientific reasoning skills develop successively (Duschl, Schweingruber, & Shouse, 2007; Hmelo-Silver & Duncan, 2009; Liu & Lesniak, 2006; Smith, Wiser, Anderson, & Krajcik, 2006). Understandings of foundational science concepts facilitate students learning of more sophisticated concepts and scientific thinking skills (Plummer & Krajcik, in press; Smith et al., 2006). Previous longitudinal studies that examined the effect of early learning experiences on children's later academic achievement provided evidence that early learning experiences in kindergarten predicts children's general academic achievement in elementary and upper grades (Bodovski & Farkas, 2007; Campbell, Pungello, Miller-Johnson, Burchinal, & Ramey, 2001; Gersten, Darch, & Gleason, 1988; Kozminsky & Kozminsky, 1995). For example, children who received quality early learning experiences in kindergarten performed significantly better on mathematics and reading achievement tests at the age of 8, 15, and 21 (Campbell et al., 2001). Therefore, the amount of science instruction in kindergarten and children's participation in science activities could be important predictors of children's immediate and later science achievement because it increases the likelihood of children's learning of various basic science concepts as well as the development of fundamental science process skills.

Furthermore, previous studies suggest that the availability of instructional materials influences teachers' choices of instructional practices and students' success (Appleton & Kindt, 1999; Goffin & Wilson, 2001; La Paro & Pianta, 2000; Miller, Dyer, Stevenson, & White, 1975; Yi, 2006). An abundance of science materials in kindergarten classrooms could increase teachers' motivation and opportunity to address basic science concepts and inquiry skills as well as children's engagement in various self-initiated or teacher-directed science activities (Inan, Trundle, & Kantor, in press; Olmsted, Parks, & Rickel, 1970; Tu, 2006).

Socio-economic status and gender are two important predictors of children's academic learning. A large body of literature provides evidence that children with higher socio-economic statuses and boys are more likely to perform better on science achievement tests than their peers with lower socio-economic statuses and girls (Arnold & Doctoroff, 2003; Becker, 1998; Bradley & Corwyn, 2002; White, 1982). Prior knowledge appeared to be one of the most powerful predictor of children's learning and achievement in several studies. Students with high prior knowledge tend to learn course content better than the children with low prior knowledge (Steinkamp & Maehr, 1983; Tobias, 1994). Motivation is another predictor of children's achievement. Children's motivational beliefs facilitate their engagement with learning activities, thereby increasing the likelihood of successful learning (Patrick et al., 2009; Samarapungavan et al., 2008; Steinkamp & Maehr, 1983).

Based on the relevant literature, we hypothesized that socio-economic status and gender would influence children's opportunities to learn science (frequency and duration of science teaching, availability of water and sand table, and science or nature area with manipulatives, engagement with science equipment and cooking or food related items), their willingness and capacity to benefit from science learning opportunities (approaches to learning and prior knowledge), as well as their immediate and later science achievement

scores (end of kindergarten and third grade assessments). Prior knowledge and motivation (approaches to learning) were hypothesized as predictors of children’s immediate and later science achievement. The availability of science materials (water and sand table, and science or nature area with manipulatives) was hypothesized to influence the frequency and duration of science teaching and children’s participation in science activities (engagement with science equipment and cooking or food related items). The frequency and duration of science teaching were hypothesized to influence children’s participation in science activities (engagement with science equipment and cooking or food related items). We also hypothesized that the frequency and duration of science teaching and children’s participation in science activities would predict children’s immediate science achievement. We allowed the following variables to covary in the model: the availability of a water and sand table with the science and nature area, the frequency of science teaching with the duration of science teaching, activities that involve the use of science equipment with the cooking activities, and prior knowledge and approaches to learning. Figure 1 illustrates the hypothesized theoretical model which was generated based on the relevant literature and the opportunity–propensity framework.

Purpose of the Study

The purpose of this study was to investigate the effects of early science experiences on children’s science achievement in kindergarten and third grade. More specifically, answers to the following research questions were sought in the study.

1. Do antecedent variables of socio-economic status and gender predict children’s opportunities to learn science (frequency and duration of science teaching, availability of water and sand table, and science or nature area with manipulatives, engagement with science equipment and cooking or food related items), their willingness and capacity to benefit from science learning opportunities (approaches to learning and prior knowledge), and children’s immediate and later science achievement (end of kindergarten and third grade assessments)?
2. Do prior knowledge and motivation (approaches to learning) predict children’s immediate and later science achievement (end of kindergarten and third grade assessments)?
3. Does the availability of science materials (water and sand table, and science or nature area with manipulatives) predict teachers’ teaching of science (frequency and duration of science teaching) and children’s participation in science activities (engagement with science equipment and cooking or food related items)?
4. Does the frequency and duration of science teaching predict children’s participation in science activities (engagement with science equipment and cooking or food related items)?
5. Do the frequency and duration of science teaching and children’s participation in science activities (engagement with science equipment and cooking or food related items) predict children’s immediate science achievement (end of kindergarten assessment)?

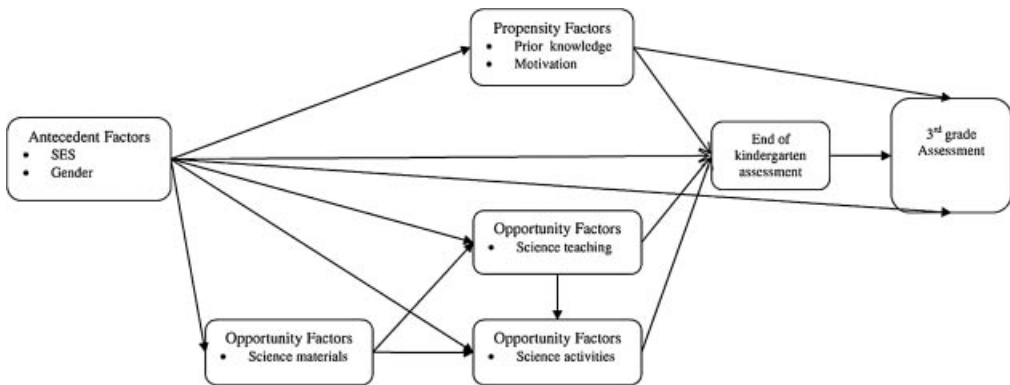


Figure 1. Hypothesized model of children’s science experiences and achievement.

Table 1
Distribution of the sample by gender and race

Variable	n	Unweighted %	Weighted %
Child gender			
Boys	4,281	49.5	49.7
Girls	4,361	50.5	50.3
Child composite race			
White, non-Hispanic	5,268	61.0	63.5
Black or African American, non-Hispanic	967	11.2	12.4
Hispanic, race specified	720	8.3	8.6
Hispanic, race not specified	710	8.2	8.6
Asian	473	5.5	2.4
Native Hawaiian, other Pacific Islander	116	1.3	0.6
American Indian or Alaska native	148	1.7	1.7
More than one race, non-Hispanic	234	2.7	2.1
Not ascertained	6	0.1	0.1
Total	8,642	100	100

Methodology

Sample

The Early Childhood Longitudinal Study-Kindergarten cohort (ECLS-K) data were obtained using a complex sampling design that included stratification, clustering, and oversampling of certain subpopulations (e.g., Asian-American, private schools) (National Center for Educational Statistics [NCES], 2002a). The base year sample (1998–1999) consisted of 22,666 children from 953 public and 460 private schools. Of these, 17,401 children were followed longitudinally until the third grade. The sample of the current study included only first-time kindergarten students and students who remained in the same school across the study. These criteria were used to avoid potential confounding effects of repeating kindergarten and changing schools. The sample resulting from these selection criteria consisted of 8,642 children from the ECLS-K data set. Table 1 presents the distribution of the sample by gender and race.

Over 30% of the children's parents reported that they had up to high school diploma or equivalent. While 32.4% of the parents reported that they completed a vocational program or had some college experience, about 20% of the parents reported that they completed a bachelor's degree. Over 12% of the parents reported that they had a graduate level education. Table 2 presents parents' highest education level. Twenty-six percent of the parents reported having a yearly income of less than \$25,000. While about 32% of the parents reported having a yearly income of \$25,000 to \$50,000, over 33% of the parents reported having a yearly income of higher than \$50,000 but equal to or less than \$100,000. Over 9% of the parents reported that their income was higher than \$100,000. Parents' education and income variables were used to create a composite socio-economic status (SES) variable.

Table 2
Parents' level of education

Parent Highest Education Level	Frequency	Percent
8th grade or below	235	2.7
9th–12th grade	439	5.1
High school diploma/equivalent	2,087	24.1
Voc/tech program	486	5.6
Some college	2,312	26.8
Bachelor's degree	1,736	20.1
Graduate/professional school—no degree	231	2.7
Master's degree (MA, MS)	708	8.2
Doctorate or professional degree	408	4.7
Total	8,642	100

Instruments

Kindergarten Teacher Questionnaire (Spring 1999). The *Kindergarten Teacher Questionnaire* was used to collect information about teachers' backgrounds, training, and classroom practices (NCES, 2006a). The content of the *Kindergarten Teacher Questionnaire* was designed by the experts of the ECLS-K advisory board (NCES, 2006a). The present study reports data obtained through the questionnaire administered spring 1999. Teachers' responses to the six items were extracted from the data base: availability of a water and sand table, and the availability of science equipment in the classroom, frequency of science teaching, duration of science teaching, children's involvement in science activities, and children's involvement in cooking activities. While the frequency and duration of science teaching and children's involvement in science activities were used as indicators of opportunities to learn science, the availability of classroom materials were used as predictors of science learning opportunities.

Science Materials (Water and Sand Table, and Science or Nature Area With Manipulatives). These two variables were extracted from teachers' responses to the following question: "Does your classroom have the following interest areas or centers for activities?" (No = 0, Yes = 1). Of the 11 possible interest areas or centers, two were directly related to the teaching and learning of science concepts in kindergarten because they were likely to contain science related instructional materials. Therefore, teachers' responses to two science education related categories were utilized in this study: *Water and sand table*, and *science or nature area with manipulatives*. The selected indicators for the availability of science materials clearly are not representative of the whole range of possible science materials. However, the types of materials available in a typical kindergarten classroom are limited. The indicators that were included in the model are based on the literature that describes the type of materials that are very typical in early childhood classrooms (Inan et al., in press).

Frequency and Duration of Science Teaching. These variables were obtained from teachers' responses to following question: "How often and how much time do children in your class(es) usually work on lessons or projects in the following general topic areas, whether as a whole class, in small groups, or in individualized arrangements?" The response categories for the frequency of science instruction were never (1), less than once a week (2), 1–2 times a week (3), 3–4 times a week (4), and daily (5). The response categories for the duration of the science instruction were 1–30 minutes a day (1), 31–60 minutes (2), 61–90 minutes (3), and more than 90 minutes (4).

Children's Science Activities (Science Equipment and Cooking or Food Related Items). These variables were extracted from teachers' responses to the following question: "How often do your children use the following materials or resources in your class?" The response categories for this item were not available, never (1), once a month or less (2), 2 or 3 times a month (3), once or twice a week (4), 3 or 4 times a week (5), and daily (6). Of the nine possible activities provided in the instrument, two were directly related to learning of science concepts in kindergartens: *Science equipment (e.g., magnifying glass, scales, thermometers)* and *Cooking or food related items*. Using a magnifying glass to examine insects or rock samples, measuring quantities and temperature, and using food related items to develop measuring skills and to study basic properties of matter are typical science activities in kindergarten classrooms, and these activities involve science process skills. Therefore, these two variables were used as the indicators of children's science activities in the study.

General Knowledge Test (Used as a Prior Knowledge Assessment and End of Kindergarten Assessment). The general knowledge test assesses children's understandings of how the natural and social world works. The same test (general knowledge test) was used at the beginning and at the end of kindergarten to assess children's science achievement. Science related items in the general knowledge test focused on two competencies of young children: (1) conceptual understanding of earth and space science, life science, and physical science concepts; and (2) scientific process skills such as asking questions, deriving conclusions, and making predictions (NCES, 2002a).

The general knowledge test was field-tested, and psychometric properties of the items were evaluated using Item Response Theory. The general knowledge test consisted of two forms: a routing form and a

second-stage form. The routing form included 12 items. Based on students' achievement on the routing form, students were given one of the two corresponding second forms, low-level or high-level form, including 25 and 29 items respectively. This procedure was used to eliminate possible ceiling and floor effects on the test scores. One-on-one child assessments were conducted to administer the instrument during the fall of 1998 and spring of 1999. In the present study IRT-based scores, ranged from 0 to 51, were used due to their superior psychometric properties. The reliability coefficient of the observed scores for the fall and spring kindergarten assessments were $\alpha = 0.88$ and $\alpha = 0.89$ respectively (NCES, 2002a). Children's scores from the fall assessment were used as measures of their prior knowledge before they started kindergarten and their scores from the spring assessment were used as measures of children's end of kindergarten science achievement. A more detailed description of the development and validation of the general knowledge test can be found in ECLS-K psychometrics reports (NCES, 2002a).

Approaches to Learning. A subscale, approaches to learning, of a social skills rating system (Gresham & Elliott, 1990) was used to assess children's motivation and self-regulatory characteristics. Teachers rated children based on their attentiveness, persistence, eagerness to learn, learning independence, flexibility, and organization using a four-point scale ranging from 1 (never) to 4 (very often). The split-half reliability of the approaches to learning scores was 0.89 for the fall kindergarten assessment (NCES, 2002b). Approaches to learning scores were used as measures of children's motivation to benefit from instructional activities.

The Third Grade Science Achievement Test. The third grade science achievement test included items that encompassed two broad classes of science competencies: conceptual understandings and scientific investigations. Items in the conceptual understanding category aimed to assess children's factual knowledge of their explanations for the scientific phenomena. Items in the scientific investigation category aimed to assess children's process skills, such as formulating questions, testing questions, using tools, and communicating results. The test items were drawn from the physical, life, and earth and space science content areas. The science achievement test placed equal emphasis on each content area (NCES, 2005).

The third grade science achievement test was field-tested and psychometric properties of the items (e.g., calibration of item difficulty and discrimination, differential item functioning, and identification of flawed items that require revisions) were evaluated using Item Response Theory. The third grade science achievement test consisted of two forms: a routing form and a second-stage form. The routing form included 15 items, and was based on students' achievement on the routing form, students were given one of the three corresponding second forms each included 20 items. This procedure was followed to eliminate possible ceiling and floor effects on the achievement scores. The instrument was individually administered during spring 2002. In the present study IRT-based science achievement scores, ranged from 0 to 100, were used due to their superior psychometric properties. The reliability of the third grade IRT-based science achievement test scores was 0.88 (NCES, 2005). A more detailed description of the development and validation of the third grade science achievement test can be found in ECLS-K psychometrics reports (NCES, 2005).

Basic Demographic Information. Data concerning children's gender were obtained from the *Teacher Questionnaire*. Information about children's socio-economic status was obtained from the *Parent Questionnaire* (NCES, 2005). Parents' responses to two items on their yearly income (categories ranging from 1 to 4; 1 = less than \$25,000, 2 = \$25,000–\$50,000, 3 = higher than \$50,000 but equal to or less than \$100,000, 4 = higher than \$100,000 and the highest educational level (categories ranging from 1 to 9, see Table 2)) were used to create a composite socio-economic status variable (SES). The composite SES variable was calculated as the unweighted sum of the z scores (ranging from -3.02 to 18.98) for the income and educational level variables and included in the analysis.

Procedures

Path analysis technique was used to test the hypothesized model in the study. Path analysis technique is a subset of the structural equation modeling (SEM) approach and it allows researchers to estimate hypothesized causal relationships among the observed variables (Kline, 2005). This technique only includes a structural component of the structural equation modeling approach and does not include the measurement model component (Schumacker & Lomax, 1996). Therefore, path analysis is suitable when a multiple-indicator

approach is not feasible (Kline, 2005). Hierarchical linear modeling approach (HLM) and Multilevel SEM are two commonly used analytical tools that are used to analyze multilevel data. Simulation studies indicated that HLM and Multilevel SEM produce nearly identical results and conclusions about the data (Chou, Bentler, & Pentz, 1998; Li, Duncan, Harmer, Acock, & Stoolmiller, 1998). However, Multilevel SEM allows researchers more flexibility in model specification and hypothesis testing (Wendorf, 2002). Therefore, path analytic approach was employed in the present study.

The maximum-likelihood (ML) method of estimation is typically used in path analysis. However, the ML method assumes simple random sampling and therefore is not appropriate to analyze the ECLS-K data (Jöreskog & Sörbom, 1993). Instead, the complex survey design procedure, which employs full information maximum likelihood method of estimation, was used to analyze the data in the present study (Jöreskog & Sörbom, 2006). The missing data for the study variables were estimated by EM imputation algorithm within the Lisrel software.

ECLS-K used multistage probability sample design to collect data. This design requires using appropriate weight, stratification, and cluster variables in analyzing the ECLS-K data. Data in the present study were weighted to correct for the study design effect to ensure that results are nationally representative. The complex survey design estimation procedure, which utilizes full information maximum likelihood estimation method (FIML), was employed using LISREL version 8.80. The FIML method of estimation is robust to violations of the normality assumption (Raykov & Marcoulides, 2008).

Typically, several goodness-of-fit indices (e.g., Goodness-of-fit-index, Comparative Fit Index, and Root Mean Square Error of Approximation) are used to evaluate structural equation models (Hu & Bentler, 1999). However, in the complex survey design analysis only the following values are provided by the LISREL software version 8.80 to evaluate the fit of the model tested: the full information maximum likelihood Chi-square and its corresponding *p*-value, and the root mean square error of approximation (RMSEA). Therefore, these values were used to evaluate the model fit in the study.

Results

Descriptive Statistics

While the mean approaches to learning scores were higher for girls than boys, the boys tended to score higher on prior knowledge, end of kindergarten assessment, and the third grade science achievement tests than girls. Children with a high SES tended to be rated as more motivated to learn by their teachers than their peers with low and middle SES. An examination of prior knowledge, end of kindergarten assessment, and third grade science achievement test scores revealed a trend that suggested a positive relationship between children's SES and their test scores. Children with a higher SES tended to have higher mean scores on the prior knowledge, end of kindergarten assessment, and third grade science achievement tests than their peers with a lower SES. Table 3 presents the means and standard deviations of approaches to learning, prior knowledge, end of kindergarten assessment, and third grade science achievement test scores.

Analysis of the teachers' responses showed that almost half of the teachers had water and sand table and more than half of the teachers had a science or nature area in their classrooms. Table 4 presents the percentages of teachers who had science related instructional materials in their classrooms.

Table 3

Means and standard deviations of propensity and outcome variables by gender and SES

	Approaches to Learning		Prior Knowledge		End of Kindergarten		Third Grade Science	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Female	3.18	0.63	23.01	7.27	27.61	7.50	43.96	13.42
Male	2.93	0.66	23.59	7.69	28.25	7.80	47.11	14.10
Low SES	2.91	0.68	19.36	6.46	24.12	7.00	38.08	12.65
Middle SES	3.08	0.64	23.06	6.95	28.12	7.03	46.16	12.52
High SES	3.18	0.61	26.90	7.05	31.95	6.89	52.31	12.53

Table 4
Availability of science materials

Availability	Water and Sand Table (%)	Science or Nature Area (%)
Yes	47.8	63.8
No	52.2	36.2
Total	100.0	100.0

About half of the teachers stated that they teach science one or two times a week. While few teachers stated that they did not teach science in the kindergarten classroom, only about 15% of the teachers stated that they taught science daily. The majority of the teachers stated that when they taught science, their lessons lasted 1 to 30 minutes. Few teachers stated that their science teaching lasted more than 90 minutes in their kindergarten classrooms (see Table 5).

Most teachers reported that their students used science equipment about two or three times a month in their classrooms. While over 16% of the teachers reported that their students used science equipment daily, about 6% of the teachers reported that their children did not use science equipment in their learning activities. Most teachers reported that their students engaged in cooking activities about once a month or less while learning science. While about 8% of the teachers reported that their students engaged in cooking activities daily, more than 13% of the teachers reported that their students did not engage cooking activities in their kindergarten classrooms (see Table 6).

Evaluation of the Path Model

The significance levels of all hypothesized paths (direct effect) were assessed using two-tailed tests. Path coefficients with z -statistics equal or larger than ± 1.96 ($\alpha = 0.05$) were declared as statistically significant. The model tested in this study provided an excellent fit to the data (Full Information ML $\chi^2 = 16.36$, $df = 20$, $p = 0.69$; RMSEA = 0.00). The Chi-square statistics were not significant at the 0.05 level indicating the model tested in the study did not significantly differ from the true population model that generated the data. Traditionally RMSEA values lower than 0.10 are considered indicators of an acceptable fit (Browne & Cudeck,

Table 5
Frequency and duration of science instruction

Frequency	How Often Science (%)	Time for Science (%)	Duration
Never	3.2	75.8	1–30 minutes
Less than once a week	8.2	21.4	31–60 minutes
1–2 times a week	47.5	2.0	61–90 minutes
3–4 times a week	26.5	0.4	More than 90 minutes
Daily	14.6	0.4	Not ascertained
Total	100.0	100.0	

Table 6
Children's science activities

Frequency	Science Equipment (%)	Cooking Activities (%)
Never	6.3	13.6
Once a month or less	17.4	38.2
Two or three times a month	26.4	22.3
Once or twice a week	23.1	14.4
Three or four times a week	10.0	3.8
Daily	16.8	7.7
Total	100.0	100.0

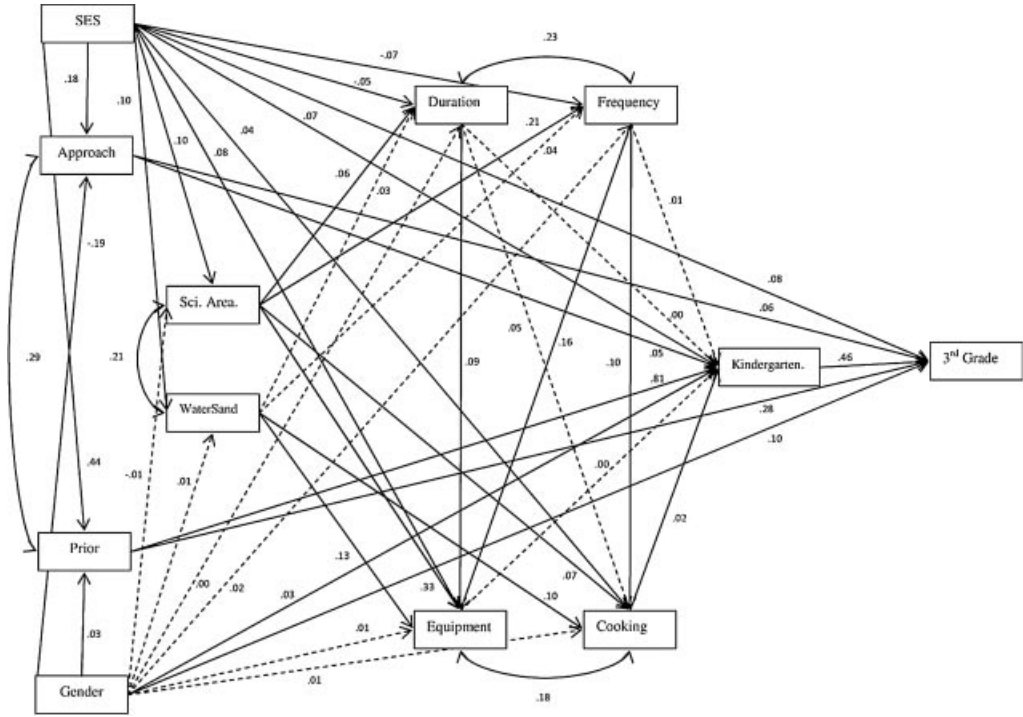


Figure 2. The structural model of early science experiences and science achievement. Note: Dashed lines not significant at $\alpha = 0.05$. Error terms are not illustrated.

1993; Schumacker & Lomax, 1996) and RMSEA values lower than 0.06 are considered indicators of a well-fitting model (Hu & Bentler, 1999). In the present study the RMSEA value was 0.00 (90% CI: 0.00–0.01) indicating the model fits the data very well. Figure 2 illustrates the structural model tested in the study (Covariance matrix is available upon request).

Antecedent Factors

Results demonstrated that Socio-economic status was a statistically significant predictor of the availability of science and nature area ($p < 0.01$) and water and sand table ($p < 0.01$) in kindergarten classrooms. SES also was significant predictor of the children’s engagement of cooking ($p < 0.01$) and science equipment activities ($p < 0.01$). The relationship between SES and the frequency ($p < 0.01$) and duration of science teaching ($p < 0.01$) was statistically significant, but this relationship was in a negative direction.

Gender was not a statistically significant predictor of the availability of science materials ($p > 0.05$), the frequency and duration of science teaching ($p > 0.05$), or children’s engagement of science activities ($p > 0.05$). Thus, results suggest that gender was not a statistically significant predictor of science learning opportunities, but socio-economic status was a statistically significant predictor of these variables. Children with high SES were more likely to be in classrooms where science materials were available, and their teachers were less likely to teach science in kindergarten classrooms.

Children’s socio-economic status was a statistically significant predictor of their prior knowledge scores ($p < 0.001$) and their approach to learning scores ($p < 0.001$). Children’s gender also was a statistically significant predictor of prior knowledge scores ($p < 0.01$) and approach to learning scores ($p < 0.001$). These results suggest that there was a difference among children in propensity factors, including children’s ability and motivation to benefit from learning opportunities. More specifically, children with higher socio-economic status were more likely to have higher prior knowledge and motivation to learn than

children with lower socio-economic status. While girls were more likely to have higher motivation to learn than boys, the boys were more likely to have higher prior knowledge.

Both socio-economic status and gender were statistically significant predictors of children's end of kindergarten assessment ($p < 0.001$) and their science achievement in third grade ($p < 0.001$). Boys and children with high SES were more likely to obtain higher scores on the end of kindergarten assessment and third grade science achievement test than girls and children with a lower SES. The achievement gap between girls and boys seemed to be widened from the end of kindergarten to the third grade assessment in favor of boys. Table 7 presents the path coefficients for the antecedent variables.

Propensity Factors

The children's prior knowledge was a statistically significant predictor of their end of kindergarten assessment score ($p < 0.001$) and third grade science achievement score ($p < 0.001$). Likewise, the approaches to learning score was a statistically significant predictor of the end of kindergarten assessment score ($p < 0.001$) and third grade science achievement score ($p < 0.001$). These results suggest that children who had a high prior knowledge and who were rated as highly motivated to learn by their teachers were more likely to be successful on the end of kindergarten assessment and the science achievement test in third grade than their peers with a low prior knowledge and who were less motivated to learn. Children's end of kindergarten assessment scores was as significant predictor of their third grade science achievement scores. Table 8 presents the path coefficients for the propensity variables.

Opportunity Factors

The availability of *water and sand table* was not a significant predictor of the frequency ($p > 0.05$) and duration ($p > 0.05$) of science teaching. However, it was a significant predictor of children's use of science equipment ($p < 0.01$) and participation in cooking activities ($p < 0.01$). On the other hand, teachers who

Table 7
Path coefficients and z-scores for the antecedent variables

Antecedent Variables	Path Coefficient	z-Scores
Antecedents predicting propensity		
SES → prior knowledge	0.44	20.85*
SES → approaches to learning	0.18	14.00*
Gender → prior knowledge	0.03	2.31*
Gender → approaches to learning	-0.19	-15.27*
Antecedents predicting opportunities		
SES → science area	0.10	4.87*
SES → water and sand table	0.10	3.71*
SES → time for science teaching	-0.05	-2.37*
SES → frequency of science teaching	-0.07	-2.75*
SES → use of science equipment	0.08	4.02*
SES → cooking activities	0.04	2.27*
Gender → science area	-0.01	-0.56
Gender → water and sand table	0.01	0.76
Gender → time for science teaching	0.00	0.19
Gender → frequency of science teaching	0.02	1.87
Gender → use of science equipment	0.01	1.43
Gender → cooking activities	0.01	1.19
Antecedents predicting achievement		
SES → end of kindergarten assessment	0.07	8.81*
SES → third grade assessment	0.08	6.75*
Gender → end of kindergarten assessment	0.03	3.89*
Gender → third grade assessment	0.10	13.26*

*z-Scores larger than 1.96 are significant at $p < 0.05$ level.

Table 8
Path coefficients and z-scores for the propensity variables

Propensity Variables	Path Coefficient	z-Scores
Prior knowledge → end of kindergarten assessment	0.81	96.90*
Prior knowledge → third grade assessment	0.28	16.82*
Approaches to learning → end of kindergarten assessment	0.05	7.90*
Approaches to learning → third grade assessment	0.06	7.46*
Approaches to learning ↔ prior knowledge	0.29	29.28*
End of kindergarten → third grade assessment	0.46	29.05*

*z-scores larger than 1.96 are significant at $p < 0.05$ level.

reported that they had a *science and nature area* in their classrooms were more likely to teach science often ($p < 0.001$) and for a longer period of time ($p < 0.05$) with their kindergarten children. The availability of a *science and nature area* was also positively related to children’s use of science equipment ($p < 0.001$) and participation in cooking activities ($p < 0.05$). When materials were available in the kindergarten classroom, children were more likely to be engaged in science activities.

Results also indicated that the frequency and duration of science teaching had a statistically significant effect on children’s science activities ($p < 0.01$) except for the effect of the duration of science teaching on cooking activities ($p > 0.05$). The frequency and duration of science teaching were not significant predictors of children’s end of kindergarten assessment scores ($p > 0.05$). In other words, how often and how long teachers taught science in kindergarten did not impact children’s science achievement. Likewise, children’s use of science equipment did not have a statistically significant direct effect on children’s end of kindergarten assessment scores ($p > 0.05$). However, cooking activities, although weak, was a significant predictor of the end of kindergarten assessment scores ($p < 0.05$). Table 9 presents the path coefficients for the opportunity and resource variables.

Table 9
Path coefficients and z-scores for the opportunity and resource variables

Opportunity and Resource Variables	Path Coefficient	z-Scores
Opportunities predicting achievement		
Time for science teaching → end of kindergarten assessment	0.00	0.52
Frequency of science teaching → end of kindergarten assessment	0.01	0.84
Use of science equipment → end of kindergarten assessment	0.00	0.08
Cooking activities → end of kindergarten assessment	0.02	2.14*
Resources predicting opportunities		
Science area → time for science teaching	0.06	2.48*
Science area → frequency of science teaching	0.21	6.99*
Science area → use of science equipment	0.33	11.96*
Science area → cooking activities	0.07	6.44*
Water and sand table → time for science teaching	0.03	1.04
Water and sand table → frequency of science teaching	0.04	1.38
Water and sand table → use of science equipment	0.13	5.14*
Water and sand table → cooking activities	0.10	3.76*
Opportunities (teaching) predicting opportunities (activities)		
Time for science teaching → use of science equipment	0.09	3.48*
Time for science teaching → cooking activities	0.05	1.70
Frequency of science teaching → use of science equipment	0.16	5.13*
Frequency of science teaching → cooking activities	0.10	3.63*
Correlations between resources and opportunities		
Science area ↔ water and sand table	0.29	7.59*
Time for science teaching ↔ frequency of science teaching	0.23	6.44*
Use of science equipment ↔ cooking activities	0.18	6.98*

*z-Scores larger than 1.96 are significant at $p < 0.05$ level.

Amount of Variance Explained by the Model

SES, gender, prior knowledge, motivation, frequency, and duration of science teaching, and children's engagement with science activities explained 75% of the variance in the end of kindergarten assessment scores. The end of kindergarten assessment scores, prior knowledge, motivation, SES, and gender explained 61% of the variance in children's third grade science achievement test scores.

Gender and SES explained 20% of the variance in children's prior knowledge scores and they accounted for 7% of the variance in children's approaches to learning scores. Gender, SES, and classroom resources accounted for over 5% of the variance in the frequency and 1% of the variance in the duration of science teaching. Gender, SES, frequency, and duration of science teaching, and classroom resources explained 4% of the variance in children's involvement of cooking activities and 23% of the variance in their use of science equipment.

Discussion

Socio-economic status appeared to be a strong predictor of children's pre-kindergarten science achievement scores (prior knowledge). Although, SES also was a significant predictor of the end of kindergarten and third grade science achievement test scores, the magnitudes of path coefficients were much weaker for the end of kindergarten and third grade science achievement tests. These results suggest that experiences in kindergarten and early elementary grades reduce the influence of SES difference between children with high and low SES as they move into elementary school.

We examined whether boys and girls have differential access to science learning opportunities in kindergarten. Results indicated that teachers provide equal science learning opportunities to boys and girls in kindergarten and there was no significant difference between boys and girls in their participation in science activities. However, boys were more likely to obtain higher scores on pre and end of kindergarten science achievement tests than were girls, and the difference in science achievement scores between girls and boys became more pronounced at the third grade assessment. These results suggest that kindergarten experiences might not be the cause of a science achievement gap observed in the literature. The observed gap seems to start widening in early elementary grades. Future studies should examine children's science learning experiences in early elementary grades, which seem to be the breaking point, to identify the possible causes of gender difference in science achievement in later grades. Although, there were no significant differences between boys and girls in the frequency and duration of science instruction they received and their participation in science activities in the present study, previous studies suggest that there might be a difference between girls and boys in the nature of science experiences they have in kindergarten. More specifically, research studies provided evidence that teachers unintentionally tend to pursue the reasoning for boys in more detail and give them more opportunity to respond in discussion of scientific concepts than girls, which might positively influence the development of boys' identities as science learners as well as their motivation to learn science (Shakeshaft, 1995; Whyte, 1986). Therefore, future studies also should examine the nature of teacher-child interaction in science learning in early years.

The availability of a water and sand table was not a significant predictor of the frequency and duration of science teaching, but it was a significant predictor of children's engagement in science activities. These results suggest that a water and sand table is not a preferred place for teacher initiated science teaching activities. However, a water and sand table was a preferable place for child initiated science activities in kindergarten. This finding of the underutilization of available science materials by teachers and children's tendency to spend more free choice time in science areas in kindergarten is consistent with results reported in other studies (Early et al., 2010; Nayfeld, 2008).

The availability of a science and nature area facilitated early childhood teachers' teaching of science and children's engagement in science activities. However, the frequency and duration of science teaching and children's engagement in science activities in kindergarten were not statistically significant predictors of children's end of kindergarten assessment scores. None of the opportunity variables, except the cooking activities, contributed to children's end of kindergarten science achievement. Although, statistically significant, this effect was practically insignificant.

Propensity variables were statistically significant predictors of children's science achievement test scores at the end of kindergarten and in the third grade. Specifically, children with high prior knowledge and children who were motivated to learn were more likely to obtain higher scores on the end of kindergarten assessment scores and third grade science achievement test scores than children with lower prior knowledge and motivation. The overall results suggest that science learning opportunities provided in kindergarten made a negligible contribution to children's immediate and later science achievement.

Previous studies that used the ECLS-K dataset to examine the impact of early literacy and mathematics experiences on academic achievement in kindergarten and later grades reported statistically significant relationships between children's achievement and early literacy and mathematics experiences (e.g., Bodovski & Farkas, 2007; Byrnes & Wasik, 2009; NCES, 2006b). Results of these studies suggest that early childhood teachers are well equipped with effective instructional strategies in introducing basic mathematics concepts and developing literacy skills in the early years. Results of the current study differ from previous investigations in that they indicate that early science experiences in kindergarten are not significant predictors of children's immediate and subsequent science achievement.

One explanation for these results is a possible mismatch between the science concepts taught in kindergarten and the science concepts assessed with the instrument used to measure science achievement. However, previous studies on early childhood teachers' practice and perceptions of teaching science in the early years offer several other possible reasons for the observed ineffectiveness of science experiences in kindergarten. First of all, children seem to have fewer opportunities to learn science than literacy, social studies, and art (Early et al., 2010). Children do not learn science in early years because few science learning opportunities are provided for them (Greenfield et al., 2009; Tilgner, 1990). Indeed, in the present study, the majority of teachers reported that they teach science once or twice a week with a total of up to 60 minutes.

Early childhood teachers spend less time on science instruction for several reasons including lack of time, self-confidence, materials, space, and science and pedagogical content knowledge (Appleton & Kindt, 1999, 2002; Cho, Kim, & Choi, 2003). The lack of content knowledge in science has been reported to be one of the most important reasons that teachers of young children do not teach science (Appleton, 1992; Cho et al., 2003; Harlen, 1997; Tobin, Briscoe, & Holman, 1990). For example, Kallery and Psillos (2001) reported that only about 22% of the early childhood teachers in their study felt that they had sufficient scientific content knowledge. Garbett (2003) found that many early childhood teachers had a limited understanding of the science concepts they are expected to teach, which makes them uncomfortable teaching science (Appleton, 1995; Pell & Jarvis, 2003; Schoon & Boone, 1998; Tilgner, 1990). Indeed, a recent study that investigated the reasons teachers do not teach science in the early years found that teachers do not feel confident in teaching science and using science equipment. Also, teachers reported that they feel pressured to teach language and literacy and they are not able to find time in the school day to teach science (Greenfield et al., 2009).

A lack of pedagogical content knowledge for teaching science with young children presents another major obstacle for early childhood teachers. Kallery and Psillos (2001) reported that many early childhood teachers have difficulty addressing children's science related questions and devising inquiry-based science activities in early childhood classrooms. Teachers use a variety of coping strategies to compensate for their lack of science and pedagogical content knowledge including teaching as little of the subject as possible, teaching more biology versus physical science, relying on commercially developed lessons, using non-fiction children trade books, and avoiding all but simple hands-on activities (Akerson, 2004; Appleton & Kindt, 1999; Harlen, 1997).

The results of the current study could be interpreted as empirical support for the body of literature that suggests that early childhood teachers might not be well equipped with the effective instructional strategies needed to teach young children science. Contemporary science education literature suggests teaching science as inquiry. Teaching science as inquiry in the early years essentially involves investigations where children use developmentally appropriate materials to make observations and answer questions. Considering this definition of science teaching, activities most teachers engaged in and reported as science instruction might be unrelated to the teaching of science content in the present study. Indeed, Tu (2006) reported that almost 87% of the activities teachers labeled or described as science activities in their preschool classroom were unrelated to science. Although more than half of the classrooms observed in Tu's study had adequate science

materials and teachers had high levels of education and teaching experience, teachers tended to not utilize these resources appropriately to teach science. In a similar study, Nayfeld (2008) observed the science areas in four preschools and found that science areas were rarely used by teachers and children. During the period where science areas were observed, only 15% of the time science areas were occupied by children. In the present study, a total of 88.6% of teachers claimed to teach science at least once per week. Yet only about half that many (44.9%) reported using science equipment that often. These results suggest that many early childhood teachers in this study were teaching science concepts without available science equipment. These findings, however, do not imply that teachers in the present study intentionally misrepresented their science teaching practices. Rather, these results suggest that what early childhood teachers consider and practice as science teaching might not fit with the conceptualization of effective science instruction suggested in the contemporary science education literature (e.g., Minner, Levy, & Century, 2010).

The findings of the present study suggest that current early childhood science instruction is not effective and supports the need for improving early childhood teachers' knowledge of science and science pedagogy. An increasing body of literature suggests that methods courses and inservice teacher training programs that incorporate science and pedagogical content knowledge can enhance preservice and inservice teachers' knowledge and skills of effective instructional strategies of teaching science to young children and improve teachers' efficacy belief for teaching science (e.g., Huinker & Madison, 1997; Morrell & Carroll, 2003; Oliveira, 2010; Palmer, 2006). Therefore, early childhood preservice and inservice teacher education programs should focus on providing well-designed science methods instruction to improve science teaching practices of the teachers of young children.

Addressing teachers' limited knowledge of science and science pedagogy, supplying kindergartens with science materials, and building teachers' confidence in teaching science seems to be a part of the solution. Educational policy documents that suggest literacy and language performance of children as a sole criterion for success should be revised. Bringing a balance to the educational policy documents might reduce the pressure teachers reportedly felt. Consequently, teachers might devote more time to teaching science in the early years.

Teacher variables (opportunity factors) analyzed in this study are based on self-reports. Additional research is needed to see what early childhood teachers consider to be science teaching and how their perception and practices of teaching science relates to what the contemporary science education literature offers as effective science teaching for young children. Moreover, indicators of science learning experiences analyzed in this study were limited to variables available in the dataset, which makes it difficult to assess the quality of science instruction provided to children. Future investigations should seek to provide rich descriptions of what is going on during science lessons in kindergarten classrooms. These investigations should employ mixed methods and gather a variety of data, including observations of science teaching practices, artifacts produced by children during their science activities, and perceptions of their needs, intentions, and practices in regard to teaching science. Findings of such studies can map the current state of teaching science in early years and inform teacher educators in addressing the needs of early childhood teachers.

To the degree that the results of this large-scale longitudinal study are generalizable across the general population of kindergarten teachers, they point to a major concern in early childhood science instruction. Antecedent and propensity factors with which children came to kindergarten classrooms were the only significant predictors of their science achievement. If policy makers and educators aim to make a difference in children's learning by closing the gender and SES gaps in science achievement, it is essential for early childhood teachers to be equipped with more useful science content knowledge and effective instructional strategies for teaching science to young children, and renounce literacy and language as the sole criterion for success in early education.

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