Early Childhood Education Journal (2020) 48:305–312
https://doi.org/10.1007/s10643-019-00985-x

The Effect of Balanced Learning® Curriculum on Young Children's Learning of Science

Mesut Saçkes[1] · Kathy Cabe Trundle[2] · Maria Shaheen[3]

Published online: 1 October 2019

Abstract
The purpose of this study was to examine the effect of the Primrose® Balanced Learning® Curriculum on young children's science performances. The sample of this study included 158 children attending two private preschools. The study utilized a single group pre-post-test design. The children were tested before and immediately after the implementation of the Primrose® Balanced Learning® Curriculum to assess their science performances. Children's interest in learning science was assessed before the implementation of the curriculum. The results demonstrated that the observed change in children's science scores from pre to post assessment was substantial, corresponding to about a medium effect size. Although both sexes made progress in their science performance, the girls made greater gains. Boys and girls did not differ in their interest in learning science, but prekindergartners regardless of their sex were more likely to demonstrate higher interest in learning science than their younger peers. The preliminary findings of this curriculum development effort suggest that the systematic instructional framework based on a balanced learning view has potential to promote young children's learning of science.

Keywords Preschoolers · Science education · Motivation

Early science learning opportunities have been largely neglected in preschool curricula, which has led to fewer science learning opportunities for young children compared to other content areas (Early et al. 2010; Greenfield et al. 2009; Nayfeld et al. 2011; Saçkes et al. 2011). More specifically, teachers of preschoolers and kindergartners teach science concepts and skills once or twice per week with about 1% to 11% of classroom time devoted to science activities, and these science learning events typically do not effectively utilize available science resources while targeting mostly life science concepts at the exclusion of other science domains (Early et al. 2010; Saçkes 2014; Saçkes et al. 2011; Tu 2006). Efforts to provide young children quality early science learning opportunities have been hindered for various reasons including a lack of curricula in Pre-K science that are linked to standards and based on developmentally appropriate practices (NAEYC 2003; NGSS Lead States 2013; Saçkes et al. 2011).

A limited number of studies have examined instructional interventions designed for young children's learning of science (e.g., Hadzigeorgiou 2002; Hobson et al. 2010; Kallery 2011; Valanides et al. 2000; Opfer and Siegler 2004). The overall findings of these studies suggest that early science instruction can enhance young children's learning of science concepts. Nevertheless, these studies, in general, have focused on the teaching of specific science concepts and skills over a short duration of time. The availability of complete curricular programs that target science concepts and develop young children's science skills are even more scarce (French 2004). To date, few curricula have been developed which focus on preschool and kindergarten science: *Preschool Pathways to Science* (Gelman and Brenneman 2004), *ScienceStart!* (French 2004), *Scientific Literacy Project* (Patrick et al. 2009), and *MyTeachingPartner–Math/Science* (Kinzie et al. 2014). These curricula are limited in that they introduce science concepts in isolation from and not integrated with other content, except mathematics or literacy, and these limited curricula predate recent science reform efforts such as the *Next Generation Science Standards*

✉ Mesut Saçkes
msackes@gmail.com

[1] Necatibey School of Education, Balıkesir University, Balıkesir, Turkey

[2] School of Teacher Education & Leadership, Utah State University, Logan, UT, USA

[3] Primrose Schools, Atlanta, GA, USA

(NGSS Lead States 2013). Almost all available curricula also exclude fundamental standard based science concepts, such as those in the earth and space sciences, and they mainly focus on life science concepts and devote limited attention to physical science concepts. Most importantly, the evaluation of the effectiveness of the curricula designed for preschoolers was either absent (Gelman and Brenneman 2004), limited to children's acquisition of vocabulary and language development (French 2004), or reported no effect on children's science learning (Kinzie et al. 2014). In contrast, the *Scientific Literacy Project* (SLP), which was designed to promote science learning in kindergarten classrooms, reported promising findings regarding the influence of early science instruction on kindergartner's science learning and motivational beliefs about learning science (Patrick et al. 2009; Mantzicopoulos et al. 2013). These positive results were tempered by limitations in the curriculum. For example, SLP focused mainly on specific life science concepts (habitat, life cycle, needs of living things, etc.) with little attention to physical science concepts, and the curriculum was designed only for kindergarten children and did not include younger children in preschool settings. No previous studies examined the influence of a systematic instructional framework, which was designed to include a full spectrum of science concepts on younger children's (preschoolers and pre-kindergartners) science learning. Therefore, the present study aimed to examine the impact of a novel science curriculum on preschoolers and pre-kindergartners' science performance.

Balanced Learning Curriculum

Early childhood researchers and professionals have not reached consensus on the types of learning opportunities young children should experience during the early years. While a group of educators and researchers suggest that learning opportunities in early childhood classrooms should be primarily based on child-initiated play activities and perceive no to little room for teacher-directed learning activities (Bredekamp 1987; Elkind 1987; Hatch 2002), others advocate that the basic mathematical, scientific, and literacy skills and concepts can be targeted in early childhood classrooms (Gelman and Brenneman 2004; Ginsburg and Golbeck 2004; Greenes et al. 2004; French 2004; Saçkes 2014). A more balanced view, which integrates play with intentional teaching of basic academic skills and concepts, has emerged in recent years (Bodrova 2008; Bredekamp 2006; Hyson 2003; Spodek and Saracho 2003; Miller et al. 2013; Trundle and Saçkes 2012). The curriculum designed within the scope of the current study, The Primrose® Balanced Learning® Curriculum, reflects this balanced view of early learning opportunities.

The Primrose® Balanced Learning® Curriculum is based on the premise that early learning opportunities should be based on the balance of "purposeful play" and "nurturing guidance". In the curriculum, the concepts and skills are introduced, developed, and reinforced with children using the early learning cycle (Miller et al. 2013; Trundle and Smith 2017). The early learning cycle has four key phases: Play, Explore, Discuss, and Assess. Teachers and children constantly move through the different phases over and over throughout the day, and learning experiences engage children in *hearts-on*, *hands-on*, and *minds-on* activities.

The Play part of the cycle aligns with purposeful play, or the child-initiated experiences a child has throughout the day. During this phase, the teacher purposefully selects and places materials with which the children engage. Then she purposefully observes the children and how they interact with the materials. The children engage with the materials—noticing, wondering, and questioning. By design, this purposeful play stimulates curiosity, connects with children's prior experiences, and engages children in *hearts-on*, affective learning.

The Explore phase begins when a teacher first engages with children as they play. During this phase, the teacher helps guide and extend the children's' thinking through meaningful questioning and planned investigations. This helps take learning to the next level as learning shifts from incidental during play to intentional learning during exploration. Now, we've moved into the nurturing guidance, or teacher-guided, part of our approach. During this phase children may plan, predict, observe, record, and represent data while the teacher asks clarifying questions to nurture and guide the discovery. This type of learning experience represents *hands-on* learning where children are engaging with materials during planned, intentional investigations.

Next, in the Discuss phase, the teacher and children talk about what they observed as they reflect on the experiences of exploration. The teacher may introduce new scientific vocabulary that the children are not likely to learn on their own. Vocabulary introduction is accomplished through scaffolding the new terms with the children's own words used during play and exploration. The teacher also guides the children to identify patterns and relationships as they construct reasonable explanations for the natural phenomena observed during exploration. This process is referred to as "teacher-directed" learning, and it also falls under the "nurturing guidance" part of our approach. This critical phase of *minds-on* learning provides an opportunity for children to cognitively make sense of the results from their *hands-on* explorations and understand the targeted concept as the teacher explicitly labels the learning.

Finally, in the Assess phase, teachers evaluate whether the children have grasped the new concept or developed a new skill while noting any insights or learning preferences that can help inform future instruction. Based on their evaluation, teachers may move the materials to a new center and add different materials to the familiar ones to provide opportunities for new science learning experiences.

Science content areas targeted in the curriculum include earth materials, objects in the sky, weather, properties and movements of objects, living things, conservation, and patterns of change. Science investigations were implemented during small group, teacher-guided lessons 3 days per week. These teacher-guided lessons were designed to support children's development of science process skills and content knowledge as well as specific academic vocabulary. Science was also incorporated throughout the week through learning center experiences, books, and whole group circle time lessons.

An Example Activity on Magnets

The activity starts by having children play with toys that includes magnets, such as magnet wands or toy trains. The children would naturally play by putting pieces together, pulling them apart and trying to connect them at different angles. The teacher would observe their interactions, letting them initiate how they wanted to play with the magnets.

To start the Explore phase of the Early Learning Cycle, teachers engage children by asking them for examples of how they have used or played with magnets before. By linking the magnets back to the children's prior experiences, teachers engage them in the *hearts-on* aspect of our learning cycle.

Next, during the Explore part of the learning cycle, the teacher introduce a purposefully planned magnet investigation to the children that focuses on the question *What happens when you put two magnets near each other?* During this guided, *hands-on* investigation, the children are still exploring and investigating on their own, but the teacher is leading them to think more critically and guiding them to focus their observations. She encourages the children to use their own words to describe what they observe happening.

In the Discuss phase, the teacher would take a more direct approach with the children, not only asking questions, but also introducing new scientific terminology or information. For example, the teacher scaffolds the language by connecting scientific terms to words the children use to describe what they observed. If the children discuss how two magnets "stick together" or "kiss" she introduces the term "attract" as the scientific word for "sticking together." Children often say "*the magnets ran away from each other" or "the magnets chased each other."* The teacher then scaffolds these descriptions to the term "repel." This phase includes *minds-on* learning where the children make sense of their *hands-on* experiences as the teacher explicitly labels the learning.

During the Assess phase of the cycle, the teacher listens to see how often the children interject the new scientific word as they play. She notices which children retain the new language and which children need more support to connect with the new terminology. Also, she looks for and monitors the development of skills like observing and sharing observations. Following the investigation and discussion, the magnets and materials remain in the activity center for further exploration as the children return to play. At times teachers move the magnets to a new center and add different materials to the familiar ones to provide opportunities for new experiences (Fig. 1).

Purpose

The present study reports the results of a pilot study, which aimed to investigate the effect of the Primrose® Balanced Learning® Curriculum on young children's science learning utilizing a single group pre-post-test design. More specifically, the following research questions provided the focus for the present study. Is the Primrose® Balanced Learning® Curriculum effective in increasing children's science scores from pre to post assessment? Does the effect of the instructional intervention depend on child's age, sex, and/or motivation to learn science?

Fig. 1 Balanced early learning cycle

Methods

Sample

The sample of this study included 158 children attending two private preschools. The first sample (pre-tested children) consisted of 158 children including 86 boys (54.4%; 26 preschoolers and 60 prekindergartners) and 72 girls (45.6%; 22 preschoolers and 60 prekindergartners) with an average age of 51 months (SD = 6.4; range 36–65 months). The second sample (post-tested children) consisted of 98 children including 57 boys (58.2%; 18 preschoolers and 39 prekindergartners) and 41 girls (41.8%; 13 preschoolers and 28 prekindergartners) with an average age of 50 months (SD = 6.7; range 37–65 months). Children were assessed as part of an external evaluation of a new, school-wide curriculum and as a matter of regular classroom practice. Parents were informed by the school that children's learning and interest in science would be assessed during their class time, and they were told that the results would help the school validate the new curriculum and inform future improvement efforts. They also were informed by the school that no personally identifiable information would be reported back to the school organization because all individual responses would be combined with many other responses and summarized in a report by an external evaluator to protect anonymity. The external evaluator deidentified all data before the researcher for this study received them. Since the data were from an evaluation project of a regular school program and all data were previously deidentified and could not be linked back to individual children, the Institutional Review Board (IRB) deemed that the current project did not qualify as human subject research as defined in 45 CFR 46.102(e) and/or (l) and was not subject to oversight by the IRB.

Instruments

Lens on Science (LENS)

The Lens on Science assessment (Greenfield 2015) is a computer-adaptive, IRT-based child assessment of science knowledge and process skills. LENS items were generated based on concepts and skills included in the preschool and kindergarten standards at state and national levels. The test items were designed based on a range of science processes skills and concepts from "life science," "earth and space sciences," "technology and engineering" and "physical and energy sciences". Children sat in front of a touch-screen monitor and were given headphones to listen to verbal instructions that prompted them to respond under a supervision of a trained researcher. An IRT based ability score was calculated in about 15 min with the administration of approximately 35–40 items using an adaptive format (Bustamante and Greenfield 2019). The assessment included an item bank of approximately 500 items. Rasch model was employed to examine the psychometric properties of the items. The test items are scaled to have a mean item difficulty of zero (range from − 2.7 to 4.4). The majority of the items (80%) have difficulty values between − 1.40 and 1.42. For the large majority of the items (87%), correlation between the item and the ability estimate was larger than 0.20 indicating items effectively discriminate children with low and high science performances. For a sample of 1753, 3 to 5 years old students attending the Miami-Dade Country Head Start program, the average standard error of the Rasch ability estimate was 0.31 corresponding to a reliability of .87. In the current study, the Lens on Science assessment was used to measure children's science performances before and after the implementation of the Balanced Learning Curriculum.

Teachers Ratings of Children's Science Motivation (TRMS)

The "Teacher Rating Scale of Children's Motivation for Science" was developed by Patrick and Mantzicopoulos (2015). The scale includes two sub-scales (Mantzicopoulos et al. 2013). "The Interest in Learning Science" (ILS) subscale and "The Need for Support vs. Independence for Learning Science" subscale. In the present study, "The Interest in Learning Science" subscale was used to assess children's science interest before the implementation of the program. The ILS subscale includes seven items targeting teacher perceptions of how much children are interested in science (e.g., "How excited or enthusiastic is he/she during science?" "How hard does he/she try in science?"). The internal consistency of the ILS subscale was 0.90 (Patrick and Mantzicopoulos 2015).

In the present study, the psychometric properties of "the Interest in Learning Science" subscale of TRMS was examined, as there was no published evidence regarding the factorial structure of this scale. A total of nine teachers from two study schools completed ILS to assess 122 children's science interest in their classrooms (64 children were boys and 48 were girls; 78 were Pre-kindergartners and 34 were preschoolers). The factorial structure of the Interest in Learning Science subscale of TRMS was examined using principal component analysis. R software version 2.10.1 (R Development Core Team 2012) was used to perform PCA on Polychorich correlation matrices. Two components with eigenvalues larger than 1 emerged (component 1: eigenvalue = 4.31, variance = 61.6%; component 2: eigenvalue = 1.10, variance = 15.8%). The results of the parallel analysis indicated that the second factor was not viable.

Given the one-factor structure of the original scale and the results of the parallel analysis, single factor solution was accepted for the data. The internal-consistency of the Interest in Learning Science subscale scores was calculated using the Cronbach's alpha. The Cronbach's alpha for the seven-item Interest in Learning Science subscale was $\alpha = 0.86$. The factor loadings ranged from 0.42 to 0.91.

Data Analysis

The relationship between children's LENS scores and their sex, age, and ILS scores were examined using independent sample *t* tests and Pearson correlation coefficients. The comparison of ILS scores were based on sex, and age/class was performed using a two-way ANOVA test. The change in children's LENS scores from pre to post-test was examined using a dependent sample *t* test and Generalized Linear Mixed Modeling. Analyses were performed with SPSS version 24.

Results

Comparison of LENS and ILS Scores

Table 1 presents the means and standard deviations for the pre and post LENS scores and "the Interest in Learning Science" (ILS) scores by sex and class. Girls and Pre-kindergartners tended to have higher LENS scores than boys and their younger peers at both assessment points. Children's pre and post-LENS scores were compared using a two-way ANOVA test. The results for the pre assessment indicated no significant difference between boys and girls ($p = 0.31$), but the differences between preschoolers and pre-kindergartners was significant favoring pre-kindergartners ($F_{(1,154)} = 15.38$, $p = 0.001$, $\eta^2 = 0.14$). A similar trend was observed for the post assessment results. While there was no significant difference between boys and girls ($p = 0.07$), the differences between preschoolers and pre-kindergartners was significant favoring pre-kindergartners ($F_{(1,194)} = 34.42$, $p = 0.001$, $\eta^2 = 0.26$).

Likewise, girls and Pre-kindergartners appeared to obtain higher ILS scores. The scores children obtained from "Interest in Learning Science" subscale were compared using a two-way ANOVA test. The results indicated no significant difference between boys and girls ($p = 0.28$). However, the differences between preschoolers and pre-kindergartners was significant favoring pre-kindergartners ($F_{(1,83)} = 8.41$, $p = 0.005$, $\eta^2 = 0.13$).

There was a positive moderate and statistically significant association between children's age and their pre LENS ($r = 0.40$), post LENS ($r = 0.52$), and ILS ($r = 0.30$) scores. The relationships between children's "Interest in Learning Science" (ILS) scores and their pre LENS ($r = 0.25$) and post LENS ($r = 0.25$) scores were also positive and statistically significant. The relationship between pre LENS and post LENS scores was moderate and statistically significant ($r = 0.49$). Older children and children who were assessed as interested in learning science by their teacher were more likely to obtain higher score on the pre and post LENS assessments.

Table 1 Descriptive statistics for LENS and ILS scores

Sex	Class	Pre LENS	Post LENS	ILS
Boys	Preschool			
	Mean	0.21	0.32	25.86
	Std. dev.	1.09	1.39	3.37
	Pre-kindergarten			
	Mean	0.99	1.69	27.55
	Std. dev.	1.20	1.34	4.60
	Total			
	Mean	0.72	1.09	27.02
	Std. dev.	1.22	1.51	4.29
Girls	Preschool			
	Mean	0.43	0.68	23.62
	Std. dev.	0.95	0.86	2.90
	Pre-kindergarten			
	Mean	1.17	2.27	27.66
	Std. dev.	1.26	1.11	4.72
	Total			
	Mean	0.90	1.53	26.41
	Std. dev.	1.20	1.28	4.61
Total	Preschool			
	Mean	0.31	0.48	24.78
	Std. dev.	1.03	1.19	3.30
	Pre-kindergarten			
	Mean	1.07	1.93	27.60
	Std. dev.	1.23	1.28	4.62
	Total			
	Mean	0.80	1.28	26.72
	Std. dev.	1.21	1.43	4.43

The Effects of Program Intervention

To initially examine whether the observed change in children's LENS scores from pre to post assessment was significant, a paired-sample *t* test was performed using the effective sample of 98 children who were tested on both the pre and post assessments. The results demonstrated that from the pre (mean = 0.77) to post (mean = 1.26) test there was a mean increase of 0.49 in children's LENS scores. This increase was statistically significant ($t = 3.70$, $p = 0.0001$) with an effect size of $d = 0.36$.

A detailed analysis of the LENS measures was conducted using Generalized Linear Mixed Modelling approach. In the analysis, identity was selected as the link function and first-order autoregressive covariance matrix was used as it yielded the lowest BIC value. A Satterthwaite approximation was preferred in computation of the degrees of freedom due to unbalanced data, and the restricted maximum likelihood (REML) method was used to estimate model parameters. The results demonstrated that Time ($F_{(1,100)}=14.811$, $p=0.0001$), Age ($F_{(1,90)}=17.48$, $p=0.0001$), ILS ($F_{(1,135)}=6.133$, $p=0.015$) main-effects, and Sex × Time ($F_{(1,87)}=6.905$, $p=0.01$) interaction effect were statistically significant. On the other hand, the main effect of Sex ($F_{(1,94)}=2.51$, $p=0.116$) and interaction effects of Sex × Age ($F_{(1,105)}=0.31$, $p=0.581$) and Age × Time ($F_{(1,97)}=3.887$, $p=0.052$) were not statistically significant.

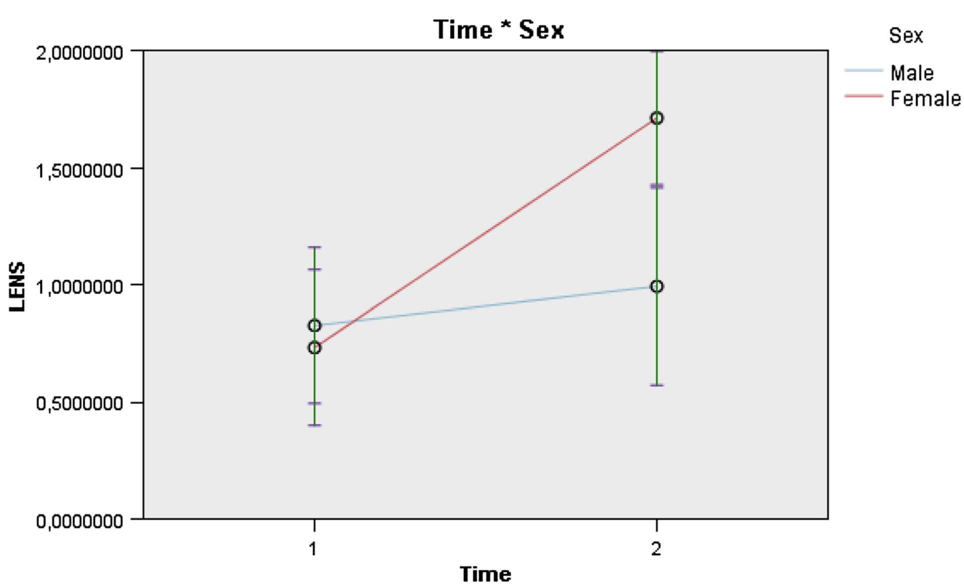
The Time 1 (pre-test) coefficient was negative and statistically significant ($\beta=-1.28$, $t=-4.625$, $p=0.0001$) suggesting there was a statistically significant increase in children's LENS scores from pre- to post-test. The coefficient for Age 1 (preschoolers) was also negative and statistically significant ($\beta=-1.30$, $t=-4.482$, $p=0.0001$) suggesting preschoolers tended to obtain lower LENS scores than prekindergartners. The coefficient for ILS (Children's Interest in Learning Science) scores was positive and statistically significant ($\beta=0.053$, $t=2.476$, $p=0.015$) suggesting children who were assessed as interested in learning science by their teacher were more likely to obtain higher score on the LENS assessments. The coefficient for the interaction between child's Sex (boys and girls) and Time (pre- and post-test) was positive and statistically significant ($\beta=0.814$, $t=2.628$, $p=0.01$). This interesting finding suggests that girls were more likely to benefit from the program implementation than were the boys. See Fig. 2.

Discussion

The results of this pilot study indicated that the Primrose® Balanced Learning® Curriculum was effective in developing children's science performance. The observed change in children's science scores from pre to post assessment was substantial, corresponding to about a medium effect size. Although preschoolers tended to demonstrate lower science performances than their older peers before and after the implementation of the curriculum, the curriculum was effective for both age groups. These findings are very encouraging because as to date, only a single study focused on the effectiveness of a science curriculum designed for preschoolers and prekindergartners (Kinzie et al. 2014), and this study reported no effect of the science curriculum. These preliminary findings of this curriculum development effort suggest that the systematic instructional framework based on a balanced learning view has potential to promote young children's learning of science.

In the present study, girls tended to obtain higher science scores than boys, but the difference in mean science scores between boys and girls was not statistically significant. On the other hand, the Sex (boys and girls) by Time (pre- and post-test) interaction was found to be statistically significant suggesting that girls were likely to benefit more from the curriculum implementation than were the boys. Although both sexes made progress in their science performance, the girls made greater gains. Previous studies with older children suggested that the gap in the achievement and the motivation between girls and boys in science appeared widen from the end of kindergarten in favor of boys, which might be due to the differential nature of science experiences girls and boys have in early

Fig. 2 Sex × time interaction



childhood classrooms (Patrick et al. 2009; Saçkes et al. 2011). Although early childhood teachers provided equal science learning opportunities to boys and girls in terms of quantity and time, the nature of the teacher–child interactions during the science learning activities appeared to be moderated by the child's sex (Saçkes et al. 2011). More specifically, previous studies reported that boys were offered more opportunities to participate in discussions of scientific concepts, and teachers tended to encourage boys to engage more often with scientific reasoning. Thus, early learning experiences provided in typical early childhood classrooms in previous studies were more likely to promote boys' motivation for learning science and their science performances (Patrick et al. 2008, 2009; Saçkes et al. 2011). The Primrose® Balanced Learning® Curriculum reported in the current study appears to have potential to close the gender gap in science achievement.

The results of the current study also indicated that children who were interested in learning science were more likely to obtain higher science scores. These findings highlight the importance of motivational beliefs on young children's learning of science and are congruent with recent studies with older kindergarten children (Mantzicopoulos et al. 2013; Patrick et al. 2009; Patrick and Mantzicopoulos 2015; Samarapungavan et al. 2011). In the present study, boys and girls did not differ in their interest in learning science, but prekindergartners regardless of their sex were more likely to demonstrate higher interest in learning science than their younger peers. Children's interest in science scores were associated with their science performances before and after the curriculum implementation and were measured in equal strength. The findings that prekindergartners and children who were assessed as interested in learning science by their teacher were more likely to obtain higher scores on the pre and post science assessments deserve attention with further studies. The developmental pathways that lead to interest in learning science in young children should be examined in longitudinal studies. The overall results of the present study indicated that the Primrose® Balanced Learning® Curriculum was effective in promoting young children's learning of science. Although all children regardless of their age, sex and motivation benefited from the Balanced Learning Curriculum, older children (prekindergartners), the girls and the children with higher interest in learning science made greater gains. These findings have potential to inform the practice of early childhood educators and professionals as they design and implement early science learning opportunities for their children.

Several limitations of the present study need to be addressed in subsequent studies. In the current study, a single group pre-post-test design was employed, and no control group was used to compare children's science performances. Thus, our conclusion regarding the effectiveness of the curriculum is mainly based on the observed growth in children's science performances from pre to post assessments. This growth might be due to maturation or any other factors beyond the curriculum. However, observing such growth in performances as a factor of maturation was calculated to be very unlikely. Future studies should include a control group and utilize a quasi-experimental, preferably true-experimental design, to examine the effect of the curriculum on children's science performances. Children's interest in learning science was only assessed before the implementation of the curriculum. Thus, we were unable to examine the impact of the curriculum on children's interest. Future studies should assess motivational beliefs more than once to examine the change in children's motivation due to the curriculum implementation. The current study findings indicated that girls were more likely to benefit from the Balanced Learning Curriculum. More research studies are needed to identify the elements that make a systematic instructional framework supportive of science learning and motivation to learn science in both sexes in early years and beyond.

References

Bodrova, E. (2008). Make-believe play versus academic skills: a Vygostkian approach to today's dilemma of early childhood education. *European Early Childhood Education Research Journal, 16*(2), 357–369.

Bredekamp, S. (1987). *Developmentally appropriate practice in early childhood programs serving children from birth through age 8*. Washington, DC: NAEYC.

Bredekamp, S. (2006). Staying true to our principles. *Journal Educating Young Children, 12*(2), 21–24.

Bustamante, A. S., & Greenfield, D. B. (2019). Measuring motivation orientation and school readiness in children served by Head Start. *Measurement and Evaluation in Counseling and Development, 52*(2), 128–144. https://doi.org/10.1080/07481756.2018.1547617.

Early, D. M., Iruka, I. U., Ritchie, S., Barbarin, O. A., Winn, D. C., Crawford, G. M., et al. (2010). How do pre-kindergarteners spend their time? Gender, ethnicity and income as predictors of experiences in pre-kindergarten classrooms. *Early Childhood Education Quarterly, 25,* 177–193.

Elkind, D. (1987). *Miseducation: preschoolers at risk*. Random House: New York.

French, L. (2004). Science as the center of a coherent, integrated early childhood curriculum. *Early Childhood Research Quarterly, 19*(1), 138.

Gelman, R., & Brenneman, K. (2004). Science learning pathways for young children. *Early Childhood Research Quarterly, 19*(1), 150–158.

Ginsburg, H. P., & Golbeck, S. L. (2004). Thoughts on the future of research on mathematics and science learning and education. *Early Childhood Research Quarterly*, *19*(1), 190–200.

Greenes, C. Ginsburg, H. P., & Balfanz, R. (2004). Big math for little kids. *Early Childhood Research Quarterly, 19*(1), 159–166.

Greenfield, D. B. (2015). Assessment in early childhood science education. In K. C. Trundle & M. Saçkes (Eds.), *Research in early childhood science education* (pp. 353–380). Netherlands: Springer.

Greenfield, D. B., Jirout, J., Dominguez, X., Greenberg, A., Maier, M., & Fuccilo, J. (2009). Science in the preschool classroom: A programmatic research agenda to improve science readiness. *Early Education and Development, 20*(2), 238–264.

Hadzigeorgiou, Y. (2002). A study of the development of the concept of mechanical stability in preschool children. *Research in Science Education, 32*(3), 373–391.

Hatch, J. A. (2002). Accountability shovedown: resisting the standards movement in early childhood education. *Phi Delta Kappan, 83*(6), 457–462.

Hobson, S. M., Trundle, K. C., & Saçkes, M. (2010). Using a planetarium software program to promote conceptual change with young children. *Journal of Science Education and Technology, 19*(2), 165–176.

Hyson, M. (2003). Putting early academics in their place. *Educational Leadership, 60*(7), 20–23.

Kallery, M. (2011). Astronomical concepts and events awareness for young children. *International Journal of Science Education, 33*(2), 341–369.

Kinzie, M. B., Whittaker, J. V., Williford, A. P., DeCoster, J., McGuire, P., Lee, Y., et al. (2014). MyTeachingPartner-Math/Science pre-kindergarten curricula and teacher supports: Associations with children's mathematics and science learning. *Early Childhood Research Quarterly, 29*(4), 586–599.

Mantzicopoulos, P., Patrick, H., & Samarapungavan, A. (2013). Science literacy in school and home contexts: Kindergarteners' science achievement and motivation. *Cognition and Instruction, 31,* 62–119.

Miller, H. L., Trundle, K. C., Smith, M. M., Saçkes, M., & Mollohan, K. N. (2013). Preschoolers' ideas about day and night and objects in the sky before and after play-based science instruction. Paper presented at the annual meeting of the Association for Science Teacher Education International Conference, Charleston, 9–12 Jan 2013.

National Association for the Education of Young Children (2003). *Early childhood curriculum, assessment and program evaluation*. Washington, DC: NAEYC.

Nayfeld, I., Brenneman, K., & Gelman, R. (2011). Science in the classroom: Finding a balance between autonomous exploration and teacher-led instruction in preschool settings. *Early Education and Development, 22*(6), 970–988.

NGSS Lead States. (2013). *Next generation science standards: For states, by States*. Washington, DC: The National Academies Press.

Opfer, J. E., & Siegler, R. S. (2004). Revisiting preschoolers' living things concept: A microgenetic analysis of conceptual change in basic biology. *Cognitive Psychology, 49,* 301–332.

Patrick, H., & Mantzicopoulos, P. (2015). Young children's motivation for learning science. In K. C. Trundle & M. Saçkes (Eds.), *Research in early childhood science education* (pp. 7–34). Netherlands: Springer.

Patrick, H., Mantzicopoulos, P., & Samarapungavan, A. (2009). Motivation for learning science in kindergarten: Is there a gender gap and does integrated inquiry and literacy instruction make a difference. *Journal of Research in Science Teaching, 46*(2), 166–191.

Patrick, H., Mantzicopoulos, P., Samarapungavan, A., & French, B. F. (2008). Patterns of young children's motivation for science and teacher-child relationship. *The Journal of Experimental Education, 76*(2), 121–144.

R Development Core Team (2012). *R: a language and environment for statistical computing*. Vienna, Austria: Author

Saçkes, M. (2014). Parents who want their PreK children to have science learning experiences are outliers. *Early Childhood Research Quarterly, 29*(2), 132–143.

Saçkes, M., Trundle, K. C., Bell, R. L., & O'Connell, A. A. (2011). The influence of early science experience in kindergarten on children's immediate and later science achievement: Evidence from the Early Childhood Longitudinal Study. *Journal of Research in Science Teaching, 48*(2), 217–235.

Samarapungavan, A., Patrick, H., & Mantzicopoulos, P. (2011). What kindergarten students learn in inquiry-based science classrooms. *Cognition and Instruction, 29*, 416–470.

Spodek, B., & Saracho, O. N. (2003). "On the shoulders of giants": exploring the traditions of early childhood education. *Early Childhood Education Journal, 31*(1), 3–10.

Trundle, K. C., & Saçkes, M. (2012). Science and early education. In R. C. Pianta (Ed.), *Early childhood education* (pp. 240–258). New York: Guilford Press.

Trundle, K. C., & Smith, M. M. (2017). A hearts-on, hands-on, minds-on model for preschool science learning. *Young Children, 72*(1), 80–86.

Tu, T. (2006). Preschool science environment: What is available in a preschool classroom? *Early Childhood Education Journal, 33*(4), 245–251.

Valanides, N., Gritsi, F., Kampeza, M., & Ravanis, K. (2000). Changing pre-school children's conceptions of the day/night cycle. *International Journal of Early Years Education, 8*(1), 27–39.