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Exploring Science through Stories: Investigating Effects on Teachers' Self-Efficacy and Preschoolers' Scientific Skills and Curiosity

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Abstract
This study investigates how Story-Based 5E Teacher e-Workshops affect preschool teachers' science education self-efficacy beliefs and their students' scientific skills and curiosity. The research was conducted in kindergartens in İstanbul using a quasi-experimental design with three randomly assigned groups: experimental group 1 (41 teachers/144 children), experimental group 2 (39 teachers/137 children), and the control group (38 teachers/135 children) experimental group 1 received Story-Based 5E Teacher e-Workshops, experimental group 2 only read science stories, and the control group followed the regular curriculum. Three validated scales measured teachers' self-efficacy beliefs and children's scientific process skills and curiosity before and after the 10-week intervention. Data analysis revealed significantly higher post-test scores in teachers' self-efficacy beliefs and children's scientific development in experimental group 1, compared to both experimental group 2 and the control group. experimental group 2 showed only minor improvements, whereas the control group exhibited no significant changes. These findings suggest that story-based 5E model training effectively enhances both teachers' professional competence and students' scientific development in preschool education.

Keywords 5E model · Story-based learning · Science education · Preschool teachers · Preschool children

Introduction

In an era of rapid scientific and technological advancement, early childhood science education plays a critical role in developing children's cognitive skills and fostering their future interest in science. Recent research emphasizes that early science learning lays the groundwork for children's later scientific understanding and inquiry abilities (O'Connor et al., 2021). However, many preschool classrooms still allocate limited time for science, focusing instead on literacy and social development (Tu, 2006). This underemphasis fails to fully nurture children's natural scientific potential. Early childhood science activities build fundamental knowledge and tap into children's innate curiosity, fostering analytical thinking and problem-solving skills (Zimmerman & Klahr, 2018). Several preschool teachers feel unprepared or anxious about teaching science, often citing a lack of content knowledge and confidence in developmentally appropriate strategies for science instruction (Brenneman et al., 2011; Spektor-Levy et al., 2011; Tu, 2006). In response to these challenges, early childhood educators and researchers have increasingly turned to inquiry-based instructional models, particularly the 5E learning cycle, to enrich science teaching (Bybee, 2009; Eisenkraft, 2003). The 5E model enables children to connect new information with prior experiences and progressively construct understanding.

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Complementary to the 5E structure, narrative-based strategies have also gained traction in early science education (Ruiz-Martín & Bybee, 2022; Uyanık et al., 2024). Storytelling and picture books are widely used in early childhood classrooms and can be powerful tools for presenting scientific concepts in familiar, meaningful contexts (Gönen et al., 2009). Abstract ideas become more concrete and relatable for young children when scientific content is embedded within age-appropriate narratives. For example, reading a story about a curious rabbit exploring its environment can introduce concepts like plants, weather, or shadows in a way that aligns with a child's lived experiences. Research shows that narratives provide a coherent structure for explaining causal relationships, helping children understand science concepts and retain information more effectively (Avraamidou & Osborne, 2009; Bruner, 1990).

Given this background, the current study aims to investigate the effects of story-based 5E teacher e-workshops on preschool teachers' self-efficacy in science education, as well as on preschool children's scientific process skills and curiosity levels.

Theoretical Background and Conceptual Framework

The 5E Instructional Model

This study is grounded in the 5E instructional model, a constructivist and inquiry-based framework designed to enhance science learning. Developed for science education, the model consists of five phases: Engage, Explore, Explain, Elaborate, and Evaluate (Bybee, 2009). Each phase corresponds to a specific stage in the learning process. In the Engage phase, children's curiosity is sparked and prior knowledge is activated—often through a question, puzzling event, or engaging story. The Explore phase involves hands-on investigations, enabling learners to observe and gather information through experience. During the Explain phase, children articulate their ideas, while the teacher introduces formal terms and addresses misconceptions. In the Elaborate phase, learners apply new knowledge in varied contexts, deepening their understanding. Finally, in the Evaluate phase, both teacher and learner reflect on learning outcomes using tools like observation and discussion.

Each phase of the 5E model supports the constructivist principle that knowledge is actively constructed based on prior experience. Engage and Explore foster inquiry, while Explain and Elaborate support concept formation and transfer (Eisenkraft, 2003; Trundle & Smith, 2017). Research confirms that the 5E approach improves children's science understanding and process skills (Koyunlu Ünlü & Dökme, 2022; Polanin et al., 2024). In this study, the training program equips teachers with the skills to implement the 5E cycle, aligning with how young children learn best—through hands-on, curiosity-driven activities.

Story-Based Learning and Narrative Thinking

In addition to inquiry, narrative thinking plays a vital role in how young children understand the world. Story-based learning enables abstract scientific concepts to become accessible through familiar sequences, characters, and situations (Bruner, 1990). The dual coding theory (Paivio, 1990) supports this, suggesting that learning improves when verbal and visual information are processed simultaneously—something naturally achieved through picture books and storytelling.

Stories can evoke emotional engagement, spark curiosity, and foster empathy—making them a powerful tool in early science education. For instance, a story about a bear wondering where the sun goes at night can serve as a meaningful context to introduce the concept of day and night. Research shows that narratives improve children's memory and understanding of causal relationships (Avraamidou & Osborne, 2009; Hadzigeorgiou & Hadzigeorgiou, 2016; Klassen & Klassen, 2014). In the context of the 5E model, stories can be strategically placed during the Engage and Elaborate phases to enhance children's attention, emotional connection, and conceptual understanding. This integration supports not only scientific knowledge but also language, imagination, and critical thinking.

Although story-based approaches offer strong pedagogical advantages, they also present certain challenges. If not carefully designed, stories may oversimplify scientific ideas, and children's interpretation of narratives can vary across cultural and linguistic contexts. Effective use of story-based inquiry requires teachers to balance narrative engagement with scientific accuracy—a competency that may not be fully developed through short-term professional development. These considerations highlight that narrative-based science instruction, while promising, is not universally straightforward.

Children's Scientific Skills and Curiosity

Preschool children's scientific skills and curiosity emerge through their natural tendencies to explore, question, and make sense of their environment, and these foundational abilities are best nurtured through guided, play-based inquiry that values wonder, experimentation, and the intrinsic motivation to learn (Bjerknes et al., 2024; Jirout, 2020; Jirout & Klahr, 2012; Uyulan & Aslan, 2025; Worth, 2010). Early science interventions have been shown to nurture children's innate curiosity and

help channel it into developing a scientific mindset (Zimmerman & Klahr, 2018). Such interventions can enrich vocabulary and scientific disposition, contribute to holistic cognitive growth, and instill enthusiasm for continuous learning. Curiosity drives learning, particularly in science education. As an intrinsic motivator, curiosity compels exploration and question-asking. Young children naturally exhibit curiosity about everyday phenomena, making it central to science education.In early childhood, curiosity comes naturally—young children often exhibit wonder about everyday phenomena (e.g., "Why is the sky blue?" or "What happens if I mix these colors?"). Loewenstein's (1994) information-gap theory explains how curiosity emerges when people notice gaps between what they know and want to know, motivating them to seek answers. In preschool settings, children's curiosity is triggered by surprising phenomena, leading them to investigate further.

In early childhood education, fostering scientific curiosity requires a safe environment where children can express wonder and seek answers. Teachers play a crucial role by modeling curiosity and validating questions. The 5E model both nurtures and utilizes curiosity: Engage sparks interest, Explore enables discovery, Explain addresses questions, Elaborate extends learning, and Evaluate promotes reflection (Spektor-Levy et al., 2011).

Teachers' Self-Efficacy as a Mediating Factor

Teachers' self-efficacy refers to educators' beliefs in their own capabilities to plan, organize, and implement effective teaching strategies, which significantly influence their motivation, resilience, instructional quality, and ultimately, student outcomes (Bandura, 1997; Klassen & Chiu, 2010; Tschannen-Moran & Hoy, 2001). In their study, Zee and Koomen (2016) found that teachers' self-efficacy is positively associated with students' academic adjustment, teacher behaviors and instructional practices related to classroom quality, and teachers' psychological well-being, including personal accomplishment, job satisfaction, and organizational commitment. In this regard, teachers' self-efficacy may be related to their ability to create learning environments that promote experiential learning rather than directly transmitting scientific concepts. Although they need not master complex principles like Archimedes' principle, teachers must possess sufficient scientific knowledge to accurately answer children's questions and guide their curiosity. Inadequate scientific background can lead to the transmission of misconceptions to children, which has the potential to negatively impact their learning in primary education and subsequent educational processes (Davies & Howe, 2003; Perry & Richardson, 2001).

By mastering a clear pedagogical strategy (e.g,. story-integrated 5E) and seeing its positive effects on children, teachers can likely experience an increase in their self-efficacy for science teaching. As Bandura (1997) notes, mastery experiences and observed successes are potent sources of efficacy beliefs. Thus, the theoretical framework assumes a bidirectional reinforcement: improved teacher practice boosts student curiosity and skills, and observing children's success further strengthens teachers' confidence and commitment to science education (Roberts et al., 2001).

Conceptual Framework of the Study

This study assumes that strengthening teachers' science self-efficacy will positively influence children's science process skills and curiosity. The conceptual model can be visualized as layered: at the core lies teacher self-efficacy, surrounded by children's science skills and curiosity. These are supported by the implementation of the story-based 5E model and narrative learning, all grounded in the constructivist learning theory. This layered framework reflects the bidirectional relationship between teacher development and child learning (Fig. 1).

Research Questions:

The following research questions were determined:

How does participation in Story-Based 5E Teacher e-Workshops influence preschool teachers' self-efficacy beliefs in teaching science?

What is the effect of Story-Based 5E Teacher e-Workshops on preschool children's scientific process skills and curiosity?

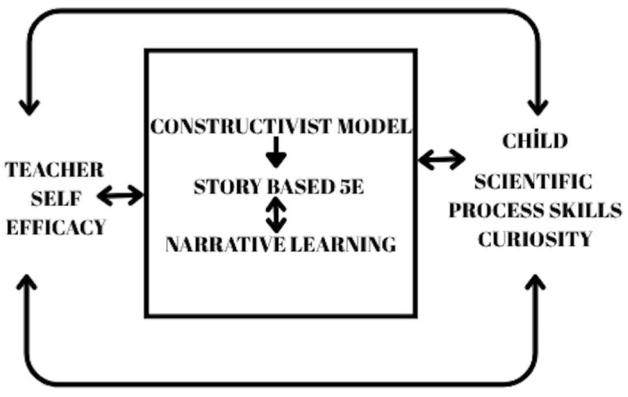


Fig. 1 Conceptual Framework

Method

Design

This study was conducted to examine the effect of Story-Based 5E Teacher e-Workshops, which constitute science education practices based on the story-based 5E model for preschool teachers, on teachers' science education self-efficacy beliefs and the reflections of these beliefs on children's science process skills and scientific curiosity levels. The study was designed within the scope of a quasi-experimental design with the pretest–posttest control group, one of the quantitative research approaches (Cohen et al., 2018; Creswell, 2014). The choice of this design was influenced by the opportunities to evaluate the effect of the intervention in comparison with the control group and to monitor the change over time. In addition, experimental group 2 was included to differentiate the effect level of the story reading process from the effect of the interventions based on structured science education. Including experimental group 1 and experimental group 2 strengthens the research's internal validity and allows the opportunity to distinguish the effects of the intervention from the natural development or attention effect (Hawthorne effect) (Shadish et al., 2002), (Fig. 2).

Ethics

Informed consent was obtained from all teachers and parents involved in the study, and ethics committee approval was obtained from the Marmara University Institute of Educational Sciences Research and Publication Ethics Committee with the decision dated February 7, 2023, and numbered 02—40.

Working Group

After obtaining research permission from the Ministry of National Education and ethical approval from the Marmara University Institute of Educational Sciences, preschool teachers working in independent kindergartens affiliated with the district directorates of national education in Ataşehir, Beşiktaş, Beykoz, Çekmeköy, Kadıköy, Kağıthane, Kartal, Küçükçekmece, Maltepe, Şişli, Ümraniye, and Üsküdar

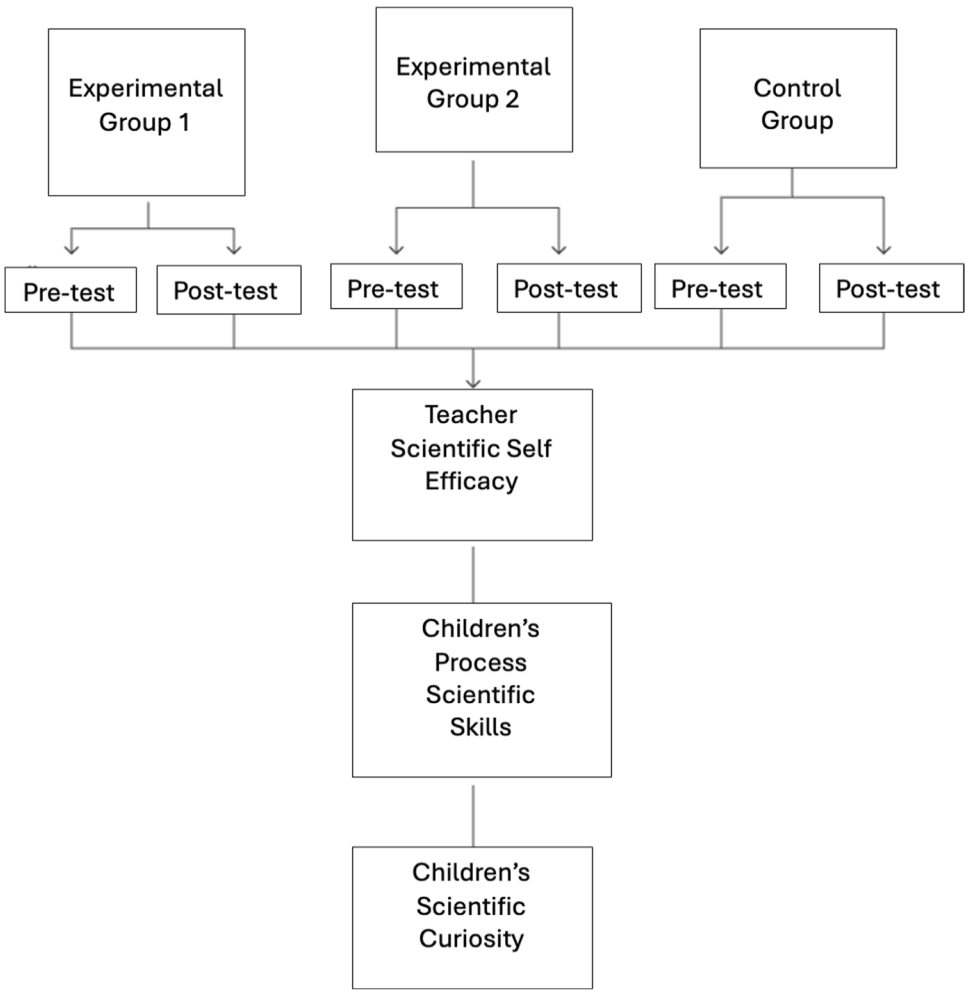


Fig. 2 Experimental Design

were informed about the study. An official email containing a brief description of the project and an online participation form (Google Forms link) was disseminated to teachers through district directorates.

Teachers who voluntarily completed the form and agreed to participate constituted the initial pool of eligible participants. From this volunteer pool, simple random assignment was used to allocate teachers to the two experimental groups and the control group. This procedure was implemented to increase comparability across groups and reduce selection bias, in line with recommended sampling strategies for quasi-experimental designs (Fraenkel & Wallen, 2009; Karasar, 2020).

In total, the final study sample consisted of 118 preschool teachers working in independent preschools and 416 five-year-old children in their classrooms. Teachers were allocated as follows:

Experimental Group 1 (n = 41 teachers / n = 144 children): Within the scope of the story-based 5E teaching model, teachers first attended online workshops, received training, and implemented the model in their classrooms for 10 weeks.

Experimental Group 2 (n = 39 teachers / n = 137 children): Only read science-themed storybooks; no structured education model was applied.

Control Group (n = 38 teachers / n = 135 children): Continued with the current practices in line with the national curriculum (MoNE, 2024); no intervention was made.

When the characteristics of the preschool teachers participating in the study were examined, it was found that the vast majority were women (96.6%, n = 114), while male teachers constituted a small proportion (3.4%, n = 4). Regarding educational background, most teachers held a bachelor's degree (74.6%, n = 88), followed by those with postgraduate degrees (17.8%, n = 21), and a smaller group with associate degrees (7.6%, n = 9). In terms of professional experience, 36.4% (n = 43) of the teachers had 1–5 years of experience, 19.5% (n = 23) had 6–10 years, another 19.5% (n = 23) had 11–15 years, 16.1% (n = 19) had 16–20 years, and 8.5% (n = 10) had 21 years or more of experience.

When teachers' frequency of including science activities was considered, more than half reported doing so sometimes (57.6%, n = 68), while 38.1% (n = 45) indicated that they frequently included science activities, and only a small proportion reported doing so rarely (4.2%, n = 5). With respect to participation in scientific projects, the majority of teachers had not previously participated in such projects (89.0%, n = 105), whereas 11.0% (n = 13) reported prior participation. Finally, in terms of socioeconomic context, most teachers worked in schools with a middle socioeconomic level (63.6%, n = 75), while 28.8% (n = 34) were employed in schools with a lower socioeconomic level.

When the characteristics of the five-year-old children in the preschool teachers' classrooms were examined, 50.1% (n = 209) of the children were girls, and 49.6% were boys. 34.6% (n = 144) of the children were in the experimental group, 32.9% (n = 137) in the placebo group and 32.5% (n = 135) in the control group.

Data Collection Tools

Measurement tools for both teachers and children were used in the study:

For teachers

Science Education Self-Efficacy Belief Scale

The Science Education Self-Efficacy Belief Scale developed by Günşen and Uyanık (2020) to determine preschool teachers' science education self-efficacy beliefs consists of three dimensions and 17 items: faith in the science education process, outcome expectancy in science education, and personal self-efficacy belief in science education. The total Cronbach's alpha reliability coefficient of the 5-point Likert scale is .91. The scale's reliability in this study was calculated as $\alpha = .872$.

For children

Scientific Process Skills Scale

To measure the scientific process skills of five-year-old children, the Scientific Process Skills Scale developed by Turan (2012), consisting of 27 questions, was used to measure the ability to establish cause-and-effect relationships and to predict the consequences of a situation, to group and distinguish some concepts and objects, to classify and sort, to make inferences, to make observations and to think analytically. As a result of the test application, children's answers explaining their scientific process skills were evaluated as 2 points, and their answers of "I do not know" or answers unrelated to the item were assessed as 1 point. In this context, the highest score that can be obtained from the Scientific Process Skills Assessment Tool is 54, and the lowest score is 27. Turan determined the scale's reliability with Cronbach's alpha reliability coefficient $\alpha = .81$. The scale's reliability in this study was calculated as $\alpha = .842$.

Scientific Curiosity Scale for Preschool Children

Science Curiosity Scale for Preschool Children" was developed by Karataş (2021) to determine the curiosity levels of 60—72-month-old children towards science. The scale's content validity was evaluated using the Lawshe technique, which aligns with the opinions of field experts. The Content Validity Index (CVI) was calculated as .93. As a result of the principal component analysis, the scale had a structure consisting of 22 items and seven factors: Space, Living Things/Animals, Experiment, Biology, Living Things/Plants, Earth Science, Engineering and Technology. This structure explains 62.44% of the total variance. The scale's reliability was determined as .76 with Cronbach's alpha coefficient, and the split-half reliability was also found to be .76. The scale's reliability in this study was calculated as $\alpha = .720$.

These instruments have been validated in Turkish early childhood contexts and shown to be sensitive to short-term changes, making them appropriate for the present intervention.

Implementation Process

This study included three groups: Experimental Group 1, Experimental Group 2, and the Control Group. Teachers in Experimental Group 1 participated in the online Story-Based 5E Teacher e-Workshops and then implemented science education activities in their classrooms based on this model for ten weeks. The e-Workshops consisted of 20 structured modules delivered twice a week (approximately one hour per session), covering the foundations of inquiry-based science teaching, the 5E model, story-based science instruction, technology integration, formative assessment, and practical implementation guidance. Throughout the training period, teachers engaged in synchronous online sessions, examined sample 5E lesson plans, and received weekly feedback on their classroom applications through an e-portfolio system embedded in the mobile workshop platform.

To monitor the consistency of implementation across classrooms, several fidelity procedures were used. Teachers in Experimental Group 1 participated in weekly online support meetings where they discussed their planned and completed 5E lessons. After each activity, teachers uploaded e-portfolio entries through the mobile workshop app, including brief reflections, photographs, and notes describing how each phase of the 5E cycle was carried out. The research team reviewed these submissions to verify adherence to the model. When minor deviations were identified—such as omitting a phase or limiting exploration time—targeted feedback was provided during the following week's meeting to support corrective adjustments. These procedures ensured ongoing guidance and enhanced consistency in how the 5E model was implemented.

Teachers in Experimental Group 2 received only the science-themed informational storybooks used in the intervention and were asked to read them to children whenever they wished, without receiving structured training or access to the workshop system during the study. The Control Group continued with routine curriculum activities and did not receive the storybooks or any additional guidance until after post-test data collection.

To maintain consistency, all teachers were informed about general study procedures, and implementation steps were standardized within each group. Teachers in the main intervention group had continuous access to the workshop trainer through weekly meetings, whereas Experimental Group 2 and Control Group teachers were provided with materials only after data collection to avoid contamination. Details regarding the training modules, implementation schedule, and related visuals are presented in Appendix 1, (Fig. 3).

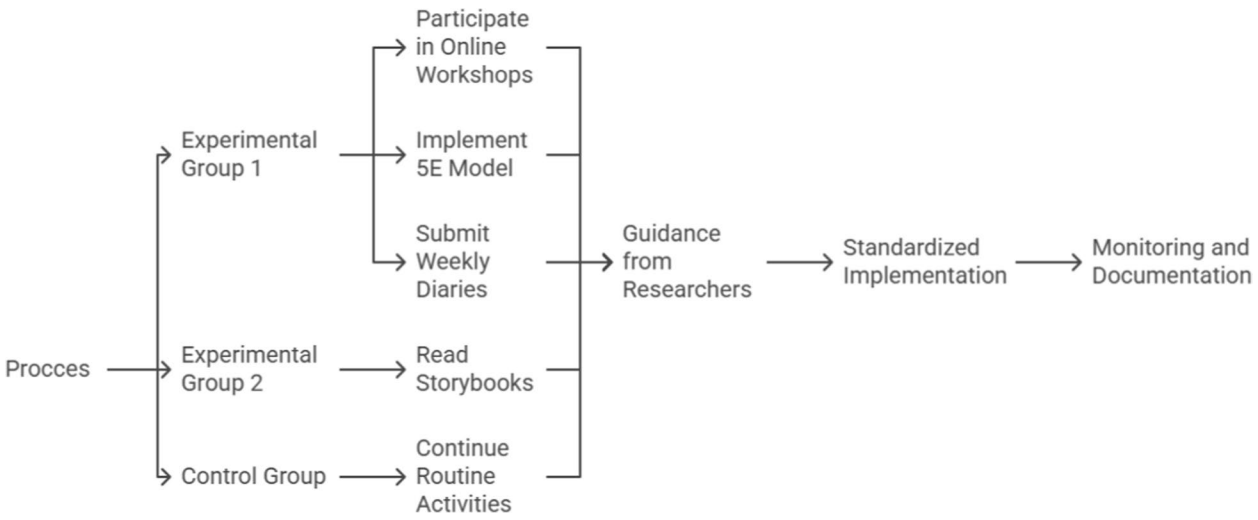


Fig. 3 Implementation Process

Data Analysis

Quantitative data were analyzed using the SPSS 25.0 program. After the assumptions of normal distribution, homogeneity of variance, and linearity were tested, *the Dependent Sample t-test* was used to analyze the change in the pretest and post-test results of the groups*; the Independent Sample t-test* was used for intergroup comparisons, *ANCOVA (One-Way Analysis of Covariance)* was used to evaluate the experimental effect by controlling the pretest scores as covariates, and *Tukey HSD test*, which is a posthoc analysis for multiple comparisons. The significance level was accepted as $p < .05$. Effect sizes were calculated with η^2 and interpreted according to Cohen's (1988) classification: small (.01), medium (.06), and large (.14).

Findings

Findings on Teachers' Self-Efficacy

The following section presents the findings related to preschool teachers' science teaching self-efficacy. These results compare pre- and post-test scores across experimental groups and provide insight into how the Story-Based 5E Workshops influenced teacher development.

As shown in Table 1, the post-test scores of science self-efficacy among teachers in Experimental Group 1 and Experimental Group 2 increased significantly ($p < .001$) compared to their pre-test scores as a result of the experimental process, whereas no statistically significant difference was observed in the control group.

As shown in Table 2, there is a significant difference in teachers' post-test scores based on their group assignment. In order to further examine this difference and determine which experimental group the difference favors, a Tukey test was conducted. The results are presented in Table 3.

Table 3 indicates that teachers in Experimental Group 1 had significantly higher post-test mean scores compared to those in Experimental Group 2 and the control group.

Table 2 ANOVA Test Results for Differences in Teachers' Post-Test Self-Efficacy Scores by Experimental Group

	Sum of Square	d	Mean square	F	p
Between groups	1252,763	2	626,381	6,233	.003*
Within groups	11,456,383	114	100,495		
Total	12,709,145	116			

*$p < .05$

**$p < .01$

Table 3 Tukey test for determining the effect of participation in the experimental and placebo groups on teachers' self-efficacy perceptions

Groups (I)	Groups (J)	Mean Difference (I-J)	Standard Error	p
Experimental Group 1	Experimental Group 2	6,132*	2,242	,020
	Control	7,440*	2,273	,004
Experimental Group 2	Experimental Group 1	-6,132*	2,242	,020
	Control	1,308	2,301	,837
Control	Experimental Group 1	-7,440*	2,273	,004
	Experimental Group 2	-1,308	2,301	,837

*$p < .05$

**$p < .01$

Findings on Children's Scientific Skills and Curiosity

The next set of findings focuses on preschool children's scientific process skills and science curiosity. These outcomes reflect the effects of the teacher interventions on children's learning, as assessed after the 10-week implementation period.

Table 4 shows a significant difference between the children's scientific process skills post-test scores according to the experimental group 1 and experimental group 2 in which the teachers participating in the project were involved ($F = 33.372$, $p < 0.05$). This result indicates that the training groups had a large effect on children's performance ($\eta^2 = 0.145$). Furthermore, children's pretest scores

Table 1 Paired Samples T-Test Results for Teachers' Science Education Self-Efficacy Pre-Test and Post-Test Scores

		N	x̄	S.S	S.D	t	p
Experimental Group 1	Pre-Test Total Scores	41	26,39	5,800	40	-6,326	,000**
	Post-Test Total Scores	41	38,68	12,382			
Experimental Group 2	Pre-Test Total Scores	39	28,90	5,056	38	-5,532	,000**
	Post-Test Total Scores	39	32,79	6,461			
Control	Pre-Test Total Scores	38	31,27	8,248	36	-,181	,857
	Post-Test Total Scores	38	31,51	10,655			

*$p < .05$

**$p < .01$

Table 4 ANCOVA analysis to determine the effect of story-based 5E teacher e-workshops on teachers' self-efficacy perceptions on children's scientific process skills scores

Source	Type III Sum of Squares	Degrees of Freedom (df)	Mean Square	F Value	p Value	Effect Size (η^2)
Adjusted Model	1271,482	4	317,870	27,100	0,000	0,216
Constant Term (Intercept)	6451,445	1	6451,445	550,010	0,000	-
Experimental Group 1 + Experimental Group 2	782,889	2	391,444	33,372	0,000	0,145
Pretest Score (Covariate)	47,468	1	47,468	4,047	0,045	0,010
Error	4609,767	393	11,730	-	-	-
Total	982,071,000	398	-	-	-	-
Adjusted Total	5881,249	397	-	-	-	-

*$p < .05$

**$p < .01$

significantly influenced their post-test scores (F = 4.047, $p < 0.05$), indicating that the covariate was adequately controlled. The model explained 21.6% of the variance in the dependent variable, suggesting that it has a moderate explanatory power. These findings show that teachers in the experimental group 1 and experimental group 2 significantly affected children's science process skills. Since there was a significant difference between the education groups in this result, the results of the Tukey HSD test as a post-hoc analysis to determine which groups differed from each other are given in Table 5.

According to Table 5, the mean difference between the experimental group 1 (teachers who received intensive training) and the experimental group 2 (p = 0.012) and the mean difference between the experimental group 1 and the control group (p = 0.045) were statistically significant, and the differences were in favor of the experimental group 1. In other words, the training of the teachers in the experimental group 1 significantly increased the children's basic science process skills scores compared to the experimental group 2 and control groups. The mean difference between the experimental group 2 and control groups (p = 0.789) was insignificant. As a result, the experimental group 1 teachers who received intensive training had a more significant positive effect on children's basic science process skills.

Table 5 Tukey Test for the determination of the effect on children's scientific process skills scores according to teachers' participation in the experimental 1 and experimental group 2

Groups (I)	Groups (J)	Mean Difference (I-J)	Standard Error	p
Experimental Group 1	Experimental Group 2	2,45	0,78	0,012
Experimental Group 1	Control	1,89	0,82	00,045
Experimental Group 2	Control	-0,56	0,79	00,789

*$p < .05$

**$p < .01$

According to the ANCOVA analysis results in Table 6, there was a significant difference between the post-test scores of children's science curiosity according to the experimental group 1 and experimental group 2 (F = 33.372, $p < 0.05$). This finding shows that the training groups effectively influenced children's science curiosity. The effect size ($\eta^2 = 0.145$) was evaluated as moderate. In addition, children's science curiosity pretest scores significantly affected their post-test scores (F = 4.047, $p < 0.05$), suggesting that the covariate was adequately controlled. The model explained 21.6% of the variance in the dependent variable, indicating that it has a moderate explanatory power. These results show that teachers' experimental group 1 and experimental group 2 significantly affected children's science curiosity. Since there was a

Table 6 ANCOVA analysis to determine the effect of story-based 5E teacher e-workshops on teachers' self-efficacy perceptions on children's scientific curiosity scores

Source	Type III Sum of Squares	Degrees of Freedom (df)	Mean Square	F Value	p Value	Effect Size (η^2)
Adjusted Model	1271,482	4	317,870	27,100	0,000	0,216
Constant Term (Intercept)	6451,445	1	6451,445	550,010	0,000	-
Experimental Group 1 + Experimental Group 2	782,889	2	391,444	33,372	0,000	0,145
Pretest Score (Covariate)	47,468	1	47,468	4,047	0,045	0,010
Error	4609,767	393	11,730	-	-	-
Total	982,071,000	398	-	-	-	-

significant difference between the experimental group 1 and experimental group 2 in this result, the results of the Tukey HSD test as a post-hoc analysis to determine which groups differed from each other are given in Table 7.

According to Table 7, the training provided to teachers had a significant effect on children's science curiosity post-test scores ($F(2, 393)=33.372$, $p<0.001$, $\eta^2=0.145$). It showed that the experimental group 1 teachers (teachers who received intensive training) significantly increased children's science curiosity scores compared to the experimental group 2 ($p=0.012$) and the control group ($p=0.045$). However, no significant difference was found between the experimental group 2 and control group ($p=0.789$).

Table 8 shows a significant difference between the children's science process skills post-test scores according to the experimental group 1 and experimental group 2 in which the teachers participated in the training ($F=4,32$, $p<0.001$). This result shows that the experimental group 1 and experimental group 2 moderately affected children's performance ($\eta^2=0.145$). Furthermore, children's pretest scores significantly influenced their post-test scores ($F=18,42$, $p<0.001$), indicating that the covariate was adequately controlled. The model explained 27% of the variance in the dependent variable, suggesting that it has a moderate explanatory power. These findings indicate that teachers in the experimental group 1 and experimental group 2 significantly affected children's science process skills. Since there was a significant difference between the experimental group 1 and experimental group 2 in this result, the results of the Tukey HSD test as a post-hoc analysis to determine which groups differed from each other are given in Table 9.

Table 7 Tukey Test to determine the effect on children's science curiosity scores according to the status of teachers' participation in the experimental group 1 and experimental group 2

Groups (I)	Groups (J)	Mean Difference (I-J)	Standard Error	p
Experimental Group 1	Experimental Group 2	2,45	0,78	0,012
Experimental Group 1	Control	1,89	0,82	0,045
Experimental Group 2	Control	-0,56	0,79	0,789

*$p<.05$

**$p<.01$

According to Table 9, the mean difference between the experimental group 1(teachers who received intensive training) and the experimental group 2 ($p=0.045$) and the mean difference between the experimental group 1 and the control group ($p=0.020$) were statistically significant, and the differences were in favor of the experimental group 1. In other words, the training of the teachers in the experimental group 1 significantly increased the children's basic science process skills scores compared to the experimental group 2 and control groups. The mean difference between the experimental group 2 and control groups ($p=0.850$) was insignificant. As a result, it can be said that the experimental group 1 of teachers who received intensive training had a more significant positive effect on children's basic science process skills.

Discussion and Conclusion

Teacher Self-Efficacy

The Story-Based 5E e-Workshop had a clear positive effect on preschool teachers' science teaching self-efficacy. Teachers who completed the full training (Group 1) showed significant gains in confidence compared to both the partial-intervention group and the control group. This aligns with Bandura's (1997) theory that mastery experiences (successfully leading inquiry-based lessons) are a powerful source of efficacy. Meta-analytic evidence confirms that well-designed professional development substantially boosts teachers' science self-efficacy (overall effect size $g=0.64$, $p<.01$). In practice, higher self-efficacy is linked to more frequent and higher-quality science teaching. Indeed, a comprehensive synthesis of 40 years of research concluded that teacher self-efficacy is positively associated with classroom quality and students' academic adjustment (Zee & Koomen, 2016). In our study, teachers in the full-intervention group reported observing deeper student engagement

Table 8 ANCOVA analysis to determine the effect of story-based 5E teacher e-workshops on teachers' self-efficacy perceptions on children's basic science process skills scores

Source	Type III Sum of Squares	Degrees of Freedom (df)	Mean Square	F Value	p Value	Effect Size (η^2)
Adjusted Model	680,9	4	170,2	9,79	<0,001	0,27
Constant Term (Intercept)	1250,3	1	1250,3	71,85	<0,001	0,27
Experimental Group 1 + Experimental Group 2	150,2	2	75,1	4,32	0,014	0,13
Pretest Score (Covariate)	320,5	1	320,5	18,42	<0,001	0,08
Error	1800,7	194	9,28	-	-	-
Total	2481,7	198	-	-	-	-

Table 9 Tukey Test to determine the effect on children's basic science process skills scores according to the status of teachers' participation in the experimental and placebo groups

Groups (I)	Groups (J)	Mean Difference (I-J)	Standard Error	p
Experimental Group 1	Experimental Group 2	2,1	0,48	0,045*
Experimental Group 2	Control	2,8	0,52	0,020
Experimental Group 2	Control	-0,3	0,50	0,850

*$p < .05$

**$p < .01$

and achievement, which, consistent with Bandura's reciprocal model further reinforced their confidence. In short, the structured 5E-with-story training appeared to provide teachers with clearer guidance and opportunities for mastery experiences, which may have contributed to increases in both their perceived abilities and their classroom practice (Zee & Koome, 2016; Bybee, 2009; Eisenkraft, 2003; Gelman & Brenneman, 2004; Guo et al., 2012; Zhou et al., 2023). Teachers in experimental group 2, who engaged children solely through reading the stories, demonstrated the limits of content delivery without pedagogical modeling. While stories can spark interest, they do not necessarily lead to deeper learning unless supported by purposeful instructional design. This supports previous findings (Avraamidou & Osborne, 2009; Bruner, 1990; Marian & Jackson, 2020) emphasizing that narratives require guided interaction to become effective educational tools.

Children's Skills and Curiosity

Correspondingly, children whose teachers received the full Story-Based 5E training (Group 1) made the largest gains in scientific process skills and curiosity. This supports the idea that early, guided science experiences can nurture the natural curiosity of preschoolers and translate it into measurable skills. The 5E model fosters curiosity by starting with engaging puzzles and guiding hands-on exploration, then building explanations and extensions – a sequence that reflects Loewenstein's (1994) *information-gap theory* of curiosity. Our findings are consistent with prior work showing that when abstract scientific ideas are embedded in vivid narratives and hands-on inquiry, children learn and remember more effectively (Bybee, 2009; Eisenkraft, 2003; Klassen & Klassen, 2014; Paivio, 1991). As one recent review notes, "listening to and sharing stories with caregivers…can make scientific ideas and inquiry practices meaningful and accessible" for young learners (Haden, et al., 2023). By contrast, children in Group 2 (stories only) showed modest gains, and the control group (business-as-usual curriculum) showed the least change. Together, the results affirm that combining inquiry (5E) with age-appropriate story contexts creates a rich learning environment: the stories spark interest and provide context, while the 5E phases channel that interest into observation, prediction, classification, and reasoning. In practical terms, children in the full-intervention classrooms more often initiated questions, made causal connections, and used science vocabulary – evidence that their scientific thinking and curiosity were substantially boosted by the Story-Based 5E approach (Haenilah et al., 2021; Rehman, 2020). In this study, children's curiosity was nurtured not only by the content of the stories but by how those stories were presented—through engaging, exploratory, and elaborative processes that invited active participation. As the literature suggests, curiosity is the engine of scientific inquiry and lifelong learning (Loewenstein, 1994). The fact that teachers could guide this natural drive through structured activities highlights the potential value of combining storytelling with the 5E model. Moreover, studies show that when children encounter abstract ideas through vivid and relatable narratives—supported by dual coding of visual and verbal input—they are more likely to retain and apply what they learn (Klassen & Klassen, 2014; Paivio, 1990). This study also supports broader educational insights: early and rich exposure to scientific thinking enhances not only immediate learning outcomes but sets a foundation for complex problem-solving skills in later academic stages (Zimmerman & Klahr, 2018). The effective use of the 5E model, framed through stories, allowed teachers in group 1 to consciously plan the learning process—an act that deepened their own professional confidence while enriching the learning environment for children. Strengthening self-efficacy seemed to contribute to improved instructional decisions and classroom interactions, consistent with Bandura's (1997) view that positive experiences reinforce teachers' beliefs in their capabilities. These findings also align with Demircioğlu and Sezgin Selçuk (2016), who emphasized that teachers with high self-efficacy adapt better teaching strategies and create richer educational experiences.

Control Group Outcomes

Importantly, the control-group children (and their teachers) did not experience the same gains. Under the standard curriculum, science is typically underemphasized in preschool settings (many programs devote more time to literacy and social skills) (Gelman & Brenneman, 2004; Greenfield et al., 2009). In line with national reports, teachers often lack time or preparation to teach science (e.g., a Head Start evaluation found science scores lag behind due to teachers' limited time and comfort with science). Thus, the control

group's lower outcomes likely reflect this context: without structured stories or inquiry methods, children's science skills grew little beyond normal development. This pattern indicates that improvements in science learning may require intentional instructional changes rather than business-as-usual practices.

Limitations

Several factors temper generalization of these results. First, the intervention lasted only 10 weeks. A longer program might produce larger or more durable gains (meta-analyses suggest extended PD yields stronger effects on teacher practice) (Zhou, et al., 2023). We were unable to measure whether effects persist over time, which is an important question for future work. Future studies should incorporate delayed post-tests or longitudinal follow-up assessments to evaluate whether the gains observed in this study are sustained over time. Second, the sample was limited to one city's preschools, mostly with similar socioeconomic backgrounds. Teachers also varied in prior science experience (most held bachelor's degrees in education but few had advanced science training). Such teacher differences could influence responsiveness to the workshop and were not fully controlled. Third, we did not measure implementation fidelity in detail, nor account for observer effects (teachers knew they were being studied). Even with random assignment, knowledge of participating in an experiment (a Hawthorne effect) might have influenced teacher behavior (Shadish, Cook, & Campbell, 2002). Additionally, although teachers were randomly assigned to groups after volunteering, voluntary participation itself may introduce a general motivation bias common in educational research; teachers who choose to participate in Professional Development-oriented studies may be more open to innovation or improvement than the broader teacher population. Random assignment reduces this bias across groups but cannot eliminate it entirely. Finally, we did not involve families; parental encouragement can amplify early science learning. Each of these – sample size/context, intervention duration, teacher background, observer presence, and family involvement – should be noted as limitations.

Future Research Directions

Building on this work, future studies should test the Story-Based 5E model in broader contexts. For example, applying the program with older age groups (kindergarten and early elementary) or with different science themes (e.g. physical science, earth science) could show whether similar gains occur. A longitudinal design would clarify if children retain benefits long-term or if teacher efficacy continues to rise with practice. Investigating the role of families – for instance, guiding parents to reinforce the storytelling model at home – could multiply effects (research on informal learning emphasizes family science talk as key) (Haden, et al., 2023). It would also be valuable to compare alternative training modes (e.g. blended in-person and online, or peer coaching) to see what maximizes teacher learning. In each case, formative studies could identify necessary adaptations to different cultures or school systems.

Cultural and Practical Considerations

In terms of context, we emphasize that story-based teaching must fit local cultures. Most evidence on narrative science comes from Western, book-focused settings (Haden, et al., 2023). In communities with strong oral traditions, equivalent gains might require using folk tales or conversation-based storytelling rather than picture books. Recent experts argue for broadening "science in stories" to include culturally relevant oral narratives. Thus, educators should adapt story content and delivery to local values and languages. For instance, teachers might use familiar characters or local examples to explain concepts, and policymakers should support story curricula that reflect community heritage. Examining the social validity of the model – i.e., how acceptable and meaningful it is to teachers, families, and education systems in different regions – will help scale this approach. In short, while our findings are promising, real-world application will require cultural tailoring and stakeholder engagement to ensure the Story-Based 5E model resonates in each setting.

Conclusion

The findings of this study revealed that the Story-Based 5E Teacher e-Workshops developed for preschool teachers significantly increased teachers' self-efficacy beliefs towards science education and that this increase was directly reflected in children in the education process, leading to significant gains in children's science process skills and scientific curiosity levels. This result, which addresses teacher and student development, is noteworthy because it shows that conscious investments in science education in early childhood can simultaneously benefit both levels. This dual effect suggests that structured, pedagogically grounded professional development can positively support both teacher practice and child outcomes within early childhood settings.

The results also indicate that teachers who participated in structured training were more systematic and confident

in planning and implementing science activities, which appeared to benefit children's engagement and understanding. Thus, it was evident that the quality of in-service training and how it is implemented are directly determinative of the effectiveness of the learning process in the classroom. The fact that the teachers in Experimental Group 1—who applied the stages of the 5E model holistically—showed more consistent gains suggests that integrating story-based learning with the 5E framework may support richer cognitive and affective development in children. In this context, it appears that traditional practices such as story reading alone may be less effective unless supported by structured and interactive learning environments.

In conclusion, programs aimed at increasing preschool teachers' self-efficacy beliefs towards science education contribute to teachers' professional development and directly support the development of basic skills such as scientific thinking, observing, establishing cause-effect relationships, and curiosity in early childhood. In other words, this study reveals with concrete data that teacher investment is indirectly reflected in student achievement. These findings highlight the potential value of theoretically informed and practice-oriented training opportunities in early childhood science education. Thanks to such programs, teachers can more easily transfer their theoretical knowledge to classroom practice; therefore, the quality of the education process increases holistically in both teacher and student dimensions. The findings again reveal that the teacher factor is critical in laying the foundations of scientific awareness and thinking in early childhood. This study contributes to the literature by showing the concurrent effects of story-based 5E model implementation on teachers' self-efficacy and children's scientific skills within the specific context studied.

In sum, this study demonstrates that *how* we train teachers matters deeply. A well-structured professional development that combines inquiry and storytelling can simultaneously empower teachers and awaken the scientist in every child. Teachers who learn to weave narratives into the 5E learning cycle gain confidence, and their students respond with more curiosity and skill. These are not just incremental gains – they are mutually reinforcing transformations: as teachers see children flourish in science, their own belief in teaching grows, which in turn creates richer learning environments. Investing in structured, story-integrated science education in preschool has the potential to simultaneously strengthen teaching quality and children's scientific development. When teachers and children learn together in this way, science stops feeling distant; it becomes a shared journey of discovery. By foregrounding curiosity and connection, we cultivate not only scientific skills but a classroom culture of wonder.

Future Endeavors

We hope that these results encourage others to dream bigger for early science education. Imagine expanding this model across cultures and systems, or watching a generation of children grow up thinking of themselves as "little scientists" because of playful stories and questions sparked at age five. Such visions remind us why this work matters – it's about planting seeds of confidence and curiosity that can bloom into a lifetime of learning.

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Declarations

Conflict of interest The authors report there are no competing interests to declare.

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