Evaluating the Impact of Data Visualization Professional Development on Early Childhood Educators

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Abstract

Many early childhood educators (ECE) lack confidence in using data visualization for classroom analysis, despite its effectiveness in making information accessible to young learners. This study examined whether a one-hour online professional development (PD) session could improve data visualization knowledge, self-efficacy, and implementation intentions among 82 ECE participants. Using a pre-post quasi-experimental design with mixed methods, findings revealed a notable paradox; while technical knowledge remained stable, educators' self-efficacy and implementation intentions increased significantly. Qualitative responses showed that educators view data visualization as a tool for inclusion that supports diverse learning styles and creates opportunities for all children to participate in mathematical thinking. This study aligns with the Texas Prekindergarten Guidelines (2022) and addresses the need for accessible, scalable PD for the Texas ECE workforce.

Keywords: *data visualization, early childhood education, professional development, self-efficacy, Texas PreK Guidelines*

During hurricane season in Galveston, Mrs. Hebert faced a familiar challenge in her Head Start classroom. She needed to prepare her multilingual preschoolers for emergency situations, but traditional discussion-based approaches left many children disengaged. Instead, she tried something different. Children voted on emergency supply priorities using picture cards showing water, flashlights, batteries, and first aid kits. Together, they arranged the cards to create a bar graph showing their collective priorities.

What happened surprised her. Every child participated fully in a mathematics activity for the first time that year. Children who rarely spoke up during circle time had strong opinions about which supplies mattered most. Her English language learners engaged confidently because the visual representation required no translation. The resulting graph sparked genuine mathematical discussions about which bar was taller and what that meant. Mrs. Hebert realized that data visualization could bridge language gaps while building mathematical understanding in her diverse classroom.

Despite such successes, a gap persists between the recognized benefits of data visualization and actual classroom implementation (Copley, 2014). Many ECE educators lack the confidence to integrate these tools, even when they understand basic concepts (Kinzie et al., 2015). This study addresses that gap by examining a one-hour online professional development (PD) session delivered via the Texas A&M University AgriLife Promoting Early Education Quality (PEEQ) initiative. PEEQ serves as a vital resource for the Texas ECE workforce, many of whom face geographic isolation and limited access to intensive training. This study evaluates whether such brief, scalable digital interventions can provide a localized solution to state-wide PD needs.

Literature Review

Young children ask questions that naturally lend themselves to data collection and visualization. "How many?" "Which one is more?" "What's everyone's favorite?" These questions reflect children's drive to make sense of their world through comparison and quantification. When educators help children represent these questions visually through graphs and charts, they transform informal curiosity into structured mathematical thinking.

Preschool-aged children work best with concrete, hands-on experiences. Abstract numbers become meaningful when children can see, touch, and manipulate data representations. A child who struggles to understand that "8 is more than 5" can clearly see the difference when bars of different heights represent classmates' snack preferences. Visual representations also reduce language barriers. A child learning English can participate in discussions about which category has the most items even before mastering the vocabulary to express comparative concepts verbally.

Teacher Self-Efficacy and Professional Learning

Bandura's (1977) self-efficacy theory offers a framework for understanding why PD sometimes changes practice and sometimes does not. The theory proposes that individuals' beliefs about their capabilities to perform specific tasks significantly influence whether they will attempt those behaviors. In PD contexts, educators may acquire new knowledge without developing confidence that they can successfully apply that knowledge in their classrooms. Simply providing information about data visualization techniques proves insufficient if educators doubt their ability to implement those techniques with young children. Bandura identified four sources of self-efficacy: mastery experiences (successfully performing the task), vicarious experiences (seeing others succeed), social persuasion (receiving encouragement), and physiological states (managing anxiety or stress) (Bandura, 1997). PD can target these sources by providing hands-on practice opportunities, modeling from experienced educators, supportive feedback, and strategies for managing implementation challenges.

Research supports this connection between targeted PD design and self-efficacy outcomes. Erol and İvrendi (2025) found that a 12-week online STEM PD program significantly increased early childhood teachers' self-efficacy and fostered more constructivist instructional beliefs, with qualitative findings revealing that teachers entered the program feeling inadequate and anxious about complex STEM concepts but left with confidence to implement developmentally appropriate practice. Similarly, Neumayer DePiper et al. (2021) showed that PD focused on visual representations and language strategies boosted teachers' confidence in supporting English learners in mathematics, a finding particularly relevant to ECE contexts where multilingual learners are common. Lipscomb et al. (2022) further established that self-efficacy functions not only as a product of PD but as a predictor of sustained work engagement among Head Start and center-based teachers, suggesting that confidence gains have practical consequences well beyond a single training session.

PD in Early Childhood Education

Effective PD in early childhood education connects new concepts directly to educators' current classroom contexts (Copley, 2014). Adult learners need to see immediate relevance and applicability. Research suggests that sustained, intensive PD produces the strongest effects on teacher practice and student outcomes. However, sustained PD remains inaccessible to many ECE educators due to time constraints, geographic isolation, and limited funding, creating tension between research-based ideals and workforce realities (Sheridan et al., 2020). Can brief interventions produce meaningful change? Under what conditions? These questions motivated the current study.

For dual-language learners and children with diverse learning needs, visual representations of data serve an additional equity function. Nemeth (2017) argues that making mathematics meaningful for diverse learners requires moving beyond verbal explanation to representational modes that reduce language demands without reducing cognitive expectations. When a preschooler who is still acquiring English can point to the tallest bar and declare a winner, mathematical thinking is decoupled from language proficiency. Young and Presser (2021) extend this argument to technology-mediated learning, demonstrating that digital tools – including tablet-based graphing applications – can scaffold young children's early math engagement when used purposefully by teachers who feel confident in their implementation. Together, these perspectives suggest that PD must address not only content knowledge but also educators' confidence in applying inclusive, visually grounded instructional strategies.

This is precisely what Lewis Presser et al. (2023) demonstrated in a preschool data collection and analysis intervention, where a teacher-facing digital app guided educators through supporting children in collecting, organizing, and visualizing data. Children in intervention classrooms showed significantly higher post-intervention scores in target mathematical and computational thinking skills compared to a control group, evidence that when teachers are equipped with accessible, structured tools, young children's data literacy measurably improves. The study reinforces that PD pairing content knowledge with concrete implementation supports can close the gap between educator confidence and classroom practice.

Theoretical Framework

This study draws on two complementary frameworks. Bandura's (1977) self-efficacy theory explains why knowledge alone does not guarantee behavior change. Educators must believe they can successfully implement new practices before they will attempt them. In this study, the one-hour online PD session was designed to target these sources through specific instructional mechanisms:

- Vicarious Experiences: The session included modeled practical demonstrations of creating simple visualizations using classroom materials and sample classroom activities aligned with early learning standards. These allowed participants to observe successful implementation in a context similar to their own.
- Mastery Experiences: During the hands-on practice portion, educators created basic visualizations and discussed potential applications in their own classrooms. This provided an immediate, low-stakes opportunity to perform the task successfully.
- Social Persuasion: Through supportive feedback and collaborative discussion, the session provided the professional encouragement necessary to validate existing knowledge.
- Physiological States: By connecting new concepts directly to educators' current classroom contexts and using familiar materials, the PD aimed to reduce implementation anxiety by showing that data visualization is a practical tool rather than an additional curriculum burden.

Constructivist learning principles inform the PD design itself. Adults construct understanding by connecting new information to existing knowledge structures. The PD session therefore built on educators' current classroom practices to activate foundational knowledge they already possessed.

The Texas PreK Guidelines provide additional grounding, particularly the emphasis on progressing from concrete to pictorial to abstract representations in mathematical thinking (Texas Education Agency, 2022). This developmental sequence informed both the PD content and the conceptualization of age-appropriate data visualization practices. Young children need physical objects to manipulate before they can understand pictorial graphs, which in turn precede abstract numerical representations. Three research questions guided this investigation:

1. *Does a one-hour online PD session significantly improve early childhood educators' knowledge of data visualization concepts?*
2. *Does the PD session significantly increase early childhood educators' perceived self-efficacy in using data visualization?*
3. *Does the PD session influence early childhood educators' intentions to incorporate data visualization into their teaching practice?*

Methodology

Using a pre-post quasi-experimental design to measure changes in participant knowledge, self-efficacy, and implementation intentions, the methodology combined quantitative and qualitative data collection to provide comprehensive insights into the PD session's impact. Respondent-generated identification codes were intended to enable paired comparisons between pre- and post-test responses.

Participants included 82 early childhood educators who attended a one-hour online PD session sponsored by Texas A&M University AgriLife Promoting Early Education Quality (PEEQ) on May 27, 2025. The intervention consisted of a one-hour synchronous online session delivered via Zoom. The session addressed four content areas: (1) introduction to data visualization and its relevance to early childhood education, including explicit connections to the Texas PreK Guidelines, (2) practical demonstrations of creating simple visualizations using classroom materials and digital tools, (3) sample classroom activities aligned with early learning standards, such as voting activities, attendance tracking, and interest surveys, and (4) hands-on practice where participants created basic visualizations and discussed potential applications in their own classrooms.

Instruments

Participants completed identical surveys immediately before and after the PD session. The survey included three components: knowledge assessment, self-efficacy measures, and implementation intentions.

Knowledge Assessment

Five multiple-choice questions assessed fundamental concepts: (1) definition of data visualization, (2) appropriate visualization selection for different data types, (3) interpretation of visual representations, (4) practical classroom applications, and (5) understanding of multiple representation methods. Questions used developmentally appropriate language and realistic early childhood scenarios. Six early childhood educators pilot tested the instrument in April 2025, and questions were refined for clarity based on their feedback.

Instrument Validity and Reliability

Content validity of the survey instrument was established through expert review. A panel of six early childhood education specialists was invited to examine all survey items prior to administration. Reviewers were asked to evaluate each item for clarity, developmental appropriateness, and alignment with the PD content and the Texas PreK Guidelines. Items flagged as ambiguous or misaligned were revised before pilot testing. Following expert review, the instrument was piloted with six additional early childhood educators in April 2025. Pilot participants completed the survey and provided written feedback on item clarity; items were refined a second time based on this feedback.

The Likert-scale items used a 5-point response scale with anchors ranging from 1 (Not likely) to 5 (Definitely). Because this study employed a quasi-experimental pre-post design with independent samples analysis, internal consistency estimates across the full instrument should be interpreted cautiously; reliability of the self-efficacy and implementation intention subscales is reported separately.

Self-Efficacy Measures

Three Likert-scale items ranging from "Not likely" to "Definitely" measured participants' confidence in: (1) creating simple bar graphs, (2) choosing appropriate visualization types for different datasets, and (3) explaining data visualizations to others.

Implementation Intentions

Three Likert-scale items assessed: (1) plans to incorporate data visualizations into lesson plans, (2) beliefs about data visualization's potential to enhance student learning, and (3) likelihood of sharing knowledge with colleagues.

Qualitative Data

The survey included one open-ended question intended for post-test administration only; however, a subset of pre-test respondents (n = 36) also completed it, yielding 96 total legible responses across both administrations. The open-ended question asked participants to describe how they envision using data visualization in their teaching practice and what support or resources would help with implementation. This question provided contextual data about educators' thinking and perceived barriers.

Data Analysis

Data processing utilized Python and the Polars library. Qualitative response patterns were initially summarized using Google Gemini CLI (version 1.0); this tool was used to manage the volume of open-ended responses efficiently. All AI-generated summaries were subsequently reviewed and refined by the researcher to ensure interpretive accuracy. Due to inconsistent completion of respondent-generated identification codes, the majority of pre- and post-session records could not be linked; independent samples t-tests were therefore used in lieu of paired comparisons to assess pre-to-post differences.

Results: The Cognitive-Affective Paradox

The PD intervention produced a notable paradox between cognitive gains and affective shifts.

Knowledge of Data Visualization Concepts

Quantitative analysis of the knowledge assessment, comprised of five multiple-choice questions, showed that the share of correct responses was nearly identical between the pre-test and post-test, holding steady at approximately 82%. This suggests that participants entered the session with a strong foundational understanding but required external validation to translate that knowledge into practice.

Perceived Self-Efficacy and Implementation Intentions

Despite the plateau in knowledge scores, participant sentiment and self-efficacy shifted dramatically:

Self-Efficacy: Educators demonstrated a significant increase in their perceived ability to select appropriate visualizations (d = 0.39) and felt more confident explaining these visuals to others (d = 0.33). Confidence in creating a simple bar graph showed the largest gain among self-efficacy items (d = 0.53, p < .001).

Intentions: Following the session, educators were modestly more likely to plan the integration of data visualizations into their daily lesson plans (d = 0.27), though this change did not reach statistical significance. Educators also reported stronger beliefs that data visualization can enhance student learning (d = 0.52, p < .001). Table 1 presents means and effect sizes for all Likert items.

Table 1

Pre- and Post-Session Means and Effect Sizes for Self-Efficacy and Implementation Intention Items

Measure	Pre M	Post M	Cohen's d	*p*
Self-efficacy				
Confident creating a bar graph	4.20	4.66	0.53	***
Choosing appropriate visualization type	4.10	4.47	0.39	**
Explaining visualizations to others	4.02	4.36	0.33	*
Implementation intentions				
Incorporate into lesson plans	4.36	4.59	0.27	ns
Data visualization enhances student learning	4.43	4.78	0.52	***
Likely to share with colleagues	4.43	4.62	0.25	ns

Note. Scale: 1–5. ns = not significant. * $p < .05$. ** $p < .01$. *** $p < .001$.

Qualitative Findings

Open-ended responses were collected across both survey administrations; all 96 legible responses were included in qualitative analysis regardless of submission timing. Responses revealed four thematic patterns regarding how educators envision implementing data visualization and what would support that implementation.

Shifting perceptions of children's mathematical capacity. Several educators described a meaningful reappraisal of what young children are capable of. One participant wrote: "I learned that we see perspective as adults but didn't think that kids as well have that same perspective as us adults. It's an amazing way to also help kids that learn not only mentally but visually!" This reflects more than a knowledge gain, it represents a reconceptualization of preschoolers as capable of comparative and representational thinking.

Integration into existing routines. The most prevalent theme was educators' intention to embed data visualization into practices already present in their daily schedules. Participants identified specific low-barrier entry points: morning meeting activities (asking about shirt colors or breakfast choices), emotion and attendance tracking, and recurring observations such as daily weather. One educator captured the practical orientation directly: "We can use it in different areas of the day. Helps to give the kids a vision of what they are doing." This pattern suggests participants understood data visualization not as a standalone mathematics lesson but as a representational layer applicable across existing routines.

Inclusion and access across diverse learners. Educators working in linguistically diverse and mixed-ability classrooms described visual representations as a way to lower participation barriers. One participant noted that data visualization supports "all children" regardless of how they learn, while others specifically identified benefits for dual-language learners, for whom image-based charts reduce the language demands of mathematical participation. This inclusive framing – positioning visualization as a vehicle for every child to engage in mathematical thinking, aligned with the equity commitments embedded in Head Start and Texas PreK Guidelines contexts.

Desire for resources, templates, and collegial support. A consistent subset of responses noted the importance of ready-to-use materials and peer collaboration. Educators referenced "simple tools, templates, and brief training," and one described a collaborative vision: "Support from the other teachers so we can be on the same page and pitch new ideas." These responses suggest that confidence gains, while real, may not be sufficient to translate into sustained practice without complementary structural supports, a finding consistent with the broader PD literature on the intention-implementation gap (Sheridan et al., 2020).

Discussion

The study produced a notable paradox. Knowledge assessment scores remained stable between pre-test and post-test, with approximately 82% of responses correct at both time points. This stability suggests that participants entered the session with significant foundational knowledge. Rather than a failure of instruction, this suggests the one-hour format was not intended for measurable cognitive gains but served as a facilitator for current competence.

Despite stable knowledge scores, participant self-efficacy increased substantially. The increase in self-efficacy gains across items offers a theoretically meaningful pattern. The largest effect corresponded to the item most directly practiced during the session: creating a bar graph ($d = 0.53$). Smaller but significant gains in choosing appropriate visualization types ($d = 0.39$) and explaining visualizations to others ($d = 0.33$) reflect items addressed through modeling and discussion rather than direct practice. This pattern suggests that the hands-on bar graph activity functioned as a mastery experience – Bandura's (1997) most potent source of self-efficacy – rather than a vicarious one. Participants who remarked that they had not created a graph since middle or high school were not lacking knowledge; they were lacking recent, successful performance of the task. Brief, concrete practice may therefore be the active ingredient in short-format PD, even when the session as a whole addresses multiple self-efficacy sources.

Implications for Teacher Education Practice

These findings suggest that brief, focused PD can produce meaningful changes in educator confidence even when knowledge remains stable. The paradox reveals that many ECE educators already possess basic knowledge about data visualization but have lacked confidence to use it.
For teacher educators, the implication is clear: PD that validates existing knowledge while providing concrete implementation examples may effectively bridge the gap between theoretical knowledge and classroom practice. This shift from knowing to doing is a critical developmental milestone for early childhood educators.

Limitations

The pre-post design without a control group limits causal claims about the intervention's effects. Observed changes occurred immediately following the session, but alternative explanations such as response bias or social desirability effects cannot be ruled out. A randomized controlled trial would strengthen confidence in causal relationships. The immediate post-test also provides no information about persistence of knowledge gains or self-efficacy improvements over time. The gap between implementation intentions and actual behavior change is well-documented in educational research (Sheridan et al., 2020). Follow-up data collection examining whether participants actually incorporated data visualization into their teaching would strengthen conclusions about practical impact.

Several additional limitations warrant discussion. First, this study relied entirely on self-report data for both knowledge assessment and attitudinal measures. Participants may have responded to post-session items in ways that reflect social desirability rather than genuine change – particularly given the supportive, synchronous format of the PD session. The Hawthorne effect, in which participants alter their responses simply because they know they are being observed and evaluated, cannot be ruled out.

Second, sampling limitations constrain generalizability. Participants were drawn from a single PD session offered through the PEEQ initiative, which may attract educators who are already motivated to improve their practice. This self-selection bias may inflate pre-existing knowledge and self-efficacy scores relative to the broader ECE workforce in Texas. The absence of demographic data on participants, including years of experience, educational attainment, or classroom setting (e.g., Head Start, private center, family home), further limits the ability to characterize the sample or assess differential effects across subgroups.

Third, the inability to link some pre- and post-session records due to inconsistent completion of respondent-generated identification codes required the use of independent samples t-tests in lieu of the more statistically powerful paired comparisons the design intended. This reduces sensitivity to detect change and introduces greater variance into effect size estimates.

Finally, the study measured implementation intentions rather than actual implementation. The intention-behavior gap is well-documented in educational research (Sheridan et al., 2020); expressed plans to use data visualization in lesson planning do not guarantee that such practices will be adopted or sustained. Future research employing follow-up surveys or classroom observations would provide stronger evidence of practical impact.

Longitudinal designs tracking educators over several months would reveal whether knowledge and self-efficacy gains persist and whether implementation intentions translate into classroom practice. Observational studies documenting actual data visualization use would provide evidence about how educators adapt PD content to their teaching contexts. Comparative studies could examine outcomes across different PD formats, durations, and delivery modes – particularly how synchronous and asynchronous online formats compare. These questions would inform practical decisions about PD design and resource allocation.

Conclusion

Mrs. Hebert's experience during hurricane season demonstrates what becomes possible when educators feel confident using data visualization with young children. Abstract mathematical concepts transform into engaging, accessible learning experiences. Language differences become less limiting. All children find ways to participate. PD that builds on educators' existing knowledge while strengthening their confidence to implement new practices can help more teachers create these opportunities in their classrooms.

The stability of knowledge scores alongside the surge in self-efficacy suggests that for the Texas ECE workforce, the barrier to implementation is not a lack of information, but a lack of professional permission. For Texas teacher educators, the implication is that PD should focus less on rote instruction and more on "activation" through modeled mastery experiences. This brief digital model offers a blueprint for state-wide scalability to meet TEA requirements for mathematical representation while respecting the time constraints of active practitioners.

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