Enhancing Early Numeracy and Environmental Awareness Through Pop-Up Books: A Multisensory Approach in Philippine Daycare Centers

Randel D. Estacio[1*], Jo Neil T. Peria[2]

[1]Early Childhood Education, College of Education, Quezon City University

[2]College of Education, Neuva Ecija University of Science and Technology

[*]Corresponding author

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ABSTRACT

This study builds upon previous research on pop-up books as a multisensory learning tool by focusing specifically on their impact on early numeracy skills and environmental awareness among daycare learners in the Philippines. Using a quasi-experimental design, the study compares the effectiveness of a custom-designed pop-up book, *"Counting with Nature"*, against traditional 2D books in teaching basic counting (numbers 1-10) and environmental concepts (plant growth and care). Pre- and post-tests, engagement surveys, and observational checklists will assess improvements in numeracy retention, ecological awareness, and learner engagement. The study aims to provide empirical evidence on how interactive, multisensory books can enhance foundational math skills and environmental stewardship in early childhood education.

Keywords: Pop-Up Books, Early Numeracy, Environmental Awareness, Multisensory Learning, Early Childhood Education

INTRODUCTION

In recent years, the use of multisensory materials in early childhood education has gained increasing attention for their potential to foster deeper engagement and meaningful learning experiences. Among these materials, pop-up books stand out as an innovative tool that merges storytelling with visual and tactile stimuli, making abstract concepts more accessible to young learners. Previous research has highlighted the effectiveness of pop-up books and other interactive reading materials in enhancing young children's engagement and information retention. For instance, Reid-Walsh [1], Curtis and Carter [2], and Field [3] highlighted that interactive and tactile element in books, such as flaps and movable parts, can significantly increase attention span and support memory recall in early learners. Pop-up books offer a multisensory experience that not only captures children’s interest but also encourages active participation, imaginative thinking, and a deeper contextual understanding of the content [4]. These features position pop-up books as dynamic educational tools that extend beyond entertainment, fostering meaningful learning experiences in early childhood settings.

However, despite the growing body of literature supporting the benefits of pop-up books in literacy and general learning engagement, there remains a significant gap in research concerning their role in developing early numeracy skills and environmental consciousness. Foundational mathematical concepts—such as number recognition, counting, and basic arithmetic—are critical components of early cognitive development. Similarly, cultivating an awareness of nature, sustainability, and responsibility for the environment is vital in shaping children's values and behaviors from an early age. Traditional methods of teaching these concepts often rely heavily on rote memorization and passive instructional strategies, which may fail to fully engage young learners or connect abstract ideas to real-life experiences.

This study seeks to expand the existing framework by exploring how pop-up books, as multisensory learning

tools, can be harnessed not only to enhance numeracy skills but also to foster environmental awareness among preschool-aged children. Specifically, it aims to: (1) investigate whether pop-up books can more effectively support early numeracy development compared to conventional 2D books; (2) evaluate the impact of pop-up books on children's understanding of environmental concepts such as plant growth, care, and sustainability; and (3) assess the differences in learner engagement between multisensory and traditional teaching approaches.

By addressing these objectives, the study hopes to provide insights into how interactive and creative instructional materials like pop-up books can be integrated into early childhood curricula to support both academic development and values formation. The findings will inform educators, curriculum designers, and policymakers on the potential of pop-up books as holistic educational tools that simultaneously nurture cognitive skills and environmental responsibility in young learners.

Theoretical Framework

This study is anchored in several foundational theories of child development and learning that collectively support the integration of pop-up books as effective tools for teaching early numeracy and environmental awareness. These theories emphasize the importance of multisensory, interactive, and socially enriched learning experiences during the formative years of a child's cognitive and socio-emotional development.

Jean Piaget's Theory of Cognitive Development underscores the significance of hands-on, concrete experiences in the learning processes of young children. According to Piaget, children in the preoperational stage (ages 2 to 7) learn best through manipulation of objects and engagement with their environment. Pop-up books, with their tangible, movable components, provide exactly the kind of sensory-rich experiences that Piaget advocated. By physically interacting with the book—flipping flaps, unfolding parts, or tracing numbers—children can construct meaning more effectively than through passive observation alone. This aligns with the present study's emphasis on active learning to enhance both numeracy skills and ecological understanding [5].

Howard Gardner's Theory of Multiple Intelligences also provides a strong theoretical basis for the study. Gardner posits that children possess diverse intelligences—including logical-mathematical, visual-spatial, naturalistic, and bodily-kinesthetic—that influences how they process information. Pop-up books engage multiple intelligence simultaneously: they support visual learners through colorful illustrations, bodily-kinesthetic learners through interactive manipulation, and logical learners through numerical and cause-effect content. By addressing various learning styles, pop-up books may create more inclusive and effective educational experiences, particularly in mixed-ability preschool classrooms [6].

Lev Vygotsky's Sociocultural Theory highlights the role of social interaction and cultural tools in cognitive development. In this context, interactive storytelling through pop-up books becomes a powerful medium for co-constructing knowledge. As children explore the book with peers or teachers, they engage in dialogue, ask questions, and share interpretations, fostering both language development and collaborative learning. This supports the idea that multisensory storybooks can serve as platforms for guided discovery within the learner's Zone of Proximal Development (ZPD), where cognitive growth is scaffolded by more knowledgeable others [7].

Furthermore, this study integrates Bronfenbrenner's Ecological Systems Theory to underscore the relevance of environmental education in early childhood. According to this theory, a child's development is influenced by multiple environmental systems, from immediate settings like family and school to broader societal contexts. By introducing ecological concepts such as plant care and sustainability through story-based, immersive formats, pop-up books can help children form early connections with their natural environment. This connection is crucial in shaping pro-environmental attitudes and behaviors, even at a young age [8].

Together, these theoretical perspectives provide a robust framework for examining how pop-up books, as multisensory educational tools, can support cognitive, social, and environmental learning in early childhood education. The present study draws on these theories to explore how such tools may bridge academic and values-based instruction in developmentally appropriate ways.

RELATED LITERATURE

Numeracy in Early Childhood

Early numeracy is a foundational aspect of cognitive development, influencing a child's ability to grasp more complex mathematical concepts later in life. Research by Marlair et al. [9] demonstrates that the use of tactile and visual aids significantly improves young children's number sense, including their ability to recognize numerals, count objects, and understand quantity. These findings suggest that concrete, manipulative-based learning is particularly beneficial during the early years. Pop-up books that integrate counting features—such as lift-the-flap number games or illustrated sequences—can support these skills in an engaging, developmentally appropriate manner. Nurnberger-Haag et al. [10] further argue that such features not only increase engagement but also enhance children's ability to relate abstract numerical concepts to real-world experiences. In the context of the present study, these insights validate the use of a pop-up book as a tool to strengthen number recognition and early counting skills in preschool learners.

Environmental Education for Young Learners

The integration of environmental education into early childhood curricula is essential for nurturing environmentally conscious individuals. Fastenrath [11] emphasizes the importance of interactive storytelling in raising ecological awareness among young children, noting that narratives featuring nature and sustainability themes foster empathy and a sense of responsibility toward the environment. Complementing this, Kuswanto [12] asserts that hands-on activities—such as gardening or caring for classroom plants—help reinforce environmental lessons by enabling children to apply what they learn in tangible ways. These approaches align with the objectives of the present study, which uses a story-based pop-up book to introduce concepts of plant care and environmental stewardship. By embedding ecological themes into a multisensory format, the study aims to promote both cognitive and affective learning outcomes related to nature and sustainability.

Pop-Up Books as Multisensory Tools

Pop-up books have long been recognized for their potential to enhance literacy skills through interactive and visually stimulating formats. Kucirkova and Rodriguez-Leon [13] found that multisensory books significantly improve memory retention and reading comprehension in young children, as the combination of visual, tactile, and sometimes auditory stimuli fosters deeper cognitive engagement. While the benefits of pop-up books in literacy development are well documented, there remains a noticeable gap in research exploring their application in other subject areas such as mathematics and science. This gap underscores the relevance of the present study, which seeks to extend the use of pop-up books beyond reading instruction and into the domains of early numeracy and environmental education. By doing so, the study contributes to a growing body of literature advocating for innovative, cross-disciplinary instructional tools in early childhood education.

METHODS

Research Design

This study employed a quasi-experimental design, specifically a pre-test/post-test control group format, to examine the effectiveness of a multisensory pop-up book intervention in enhancing early numeracy skills and environmental awareness among preschool children. This research design was selected to allow for a comparison between an experimental group exposed to an interactive educational tool and a control group using traditional methods, while accounting for the practical limitations of random assignment in real-world educational settings.

Participants

The study involved 40 daycare learners aged 4 to 5 years from daycare centers in Quezon City. Participants were purposively selected and then evenly divided into two groups: an experimental group that engaged with a specially designed pop-up book, and a control group that used conventional 2D picture books with similar

content. This sampling size and structure were deemed appropriate for initial exploration in early childhood classrooms, where small-group interventions are common and manageable.

Intervention

The intervention for the experimental group centered on the use of a custom-developed pop-up book titled *Counting with Nature*. This multisensory book was designed to integrate early numeracy skills and environmental education. Number recognition and counting activities (focusing on numbers 1 to 10) were embedded in the form of flaps, sliders, and foldable elements, encouraging tactile exploration and visual interaction. Environmental lessons—such as plant growth stages, recycling practices, and nature appreciation—were conveyed through vibrant, three-dimensional illustrations and storytelling. Meanwhile, the control group used traditional flat picture books covering similar topics in a more conventional, static format, without interactive features.

Data Collection

Data collection was conducted using a combination of quantitative and qualitative instruments. First, both groups completed pre- and post-tests designed to assess improvements in numeracy skills (e.g., number recognition, counting accuracy) and environmental knowledge (e.g., understanding plant care and sustainability concepts). To measure levels of engagement, learners participated in a Likert-scale survey capturing behavioral, emotional, and cognitive responses to the materials and learning experience. Additionally, researchers used observational checklists to document real-time classroom behaviors, including participation, verbal responses, and interaction with the book elements—providing a comprehensive view of student involvement beyond self-reported data.

Statistical Analysis

For data analysis, the study employed paired t-tests to evaluate within-group gains from pre-test to post-test, and independent t-tests to compare performance and engagement differences between the experimental and control groups. This combination of statistical methods enabled the researchers to determine not only whether significant learning gains occurred, but also whether the multisensory pop-up book produced more effective outcomes compared to traditional instructional materials. Through this methodology, the study aims to provide evidence-based insights into how interactive storytelling and multisensory learning tools can be integrated into early childhood classrooms to support both academic growth and value formation.

RESULTS

A. Effect of Pop-Up Books on Early Numeracy Skills

Table 1 illustrates the improvement in numeracy skills (number recognition and counting) within both the experimental and control groups. The experimental group, which used the *Counting with Nature* pop-up book, showed a substantial mean score increase from 5.20 to 8.75, with a highly significant p-value (<0.001). Similarly, the control group, which used traditional 2D books, improved from 5.10 to 6.90, also statistically significant ($p < 0.001$), but the magnitude of change was smaller.

TABLE I PRE- AND POST-TEST SCORES ON NUMERACY (PAIRED SAMPLE T-TEST)

Group	N	Pre-Test Mean (SD)	Post-Test Mean (SD)	t	p-value
Experimental	20	5.20 (1.32)	8.75 (1.12)	-9.12	<0.001**
Control	20	5.10 (1.28)	6.90 (1.44)	-4.45	<0.001**

While both groups benefitted from instructional activities, the significantly larger gain in the experimental group suggests that the multisensory elements of the pop-up book had a stronger positive effect on early numeracy development.

Table 2 compares the post-test numeracy scores between the two groups. The experimental group (M = 8.75) scored significantly higher than the control group (M = 6.90), with a t-value of 4.29 and p < 0.001.

TABLE II COMPARISON OF POST-TEST NUMERACY SCORES (INDEPENDENT SAMPLE T-TEST)

Group	Mean (SD)	t	p-value
Experimental	8.75 (1.12)	4.29	<0.001**
Control	6.90 (1.44)		

The difference in final outcomes indicates that pop-up books are more effective than traditional 2D books in teaching basic numeracy skills to preschool learners. This supports the study's first research question, confirming that pop-up books improve early numeracy more effectively.

B. Impact of Pop-Up Books on Environmental Understanding

Table 3, improvements in environmental understanding were evaluated. The experimental group improved significantly from a mean score of 4.80 to 8.30 (p < 0.001), while the control group showed a smaller, though still statistically significant, improvement from 4.85 to 6.35 (p < 0.001).

TABLE III PRE- AND POST-TEST SCORES ON ENVIRONMENTAL KNOWLEDGE (PAIRED SAMPLE T-TEST)

Group	N	Pre-Test Mean (SD)	Post-Test Mean (SD)	t	p-value
Experimental	20	4.80 (1.40)	8.30 (1.17)	-8.52	<0.001**
Control	20	4.85 (1.23)	6.35 (1.41)	-5.31	<0.001**

Both groups gained knowledge, but the experimental group experienced a more substantial increase. The pop-up book's three-dimensional visuals and interactive storytelling likely enhanced learners' comprehension of environmental topics such as plant care and sustainability.

Table 4 compares post-test environmental awareness scores between groups. The experimental group significantly outperformed the control group (M = 8.30 vs. 6.35), with a t-value of 4.76 and a p-value less than 0.001.

TABLE IV COMPARISON OF POST- TEST ENVIRONMENTAL SCORES (INDEPENDENT SAMPLE T-TEST)

Group	Mean (SD)	t	p-value
Experimental	8.30 (1.17)	4.76	<0.001**
Control	6.35 (1.41)		

These findings reinforce the effectiveness of the pop-up book in improving environmental literacy, providing strong evidence for the second research question that multisensory pop-up books enhance children's understanding of ecological concepts more than traditional materials.

C. Learner Engagement Levels

Engagement was measured in three dimensions: behavioral, emotional, and cognitive. In all three categories, the experimental group scored significantly higher than the control group. Emotional engagement was especially high in the experimental group (M = 4.75), highlighting the children's enjoyment and enthusiasm during the learning experience.

TABLE V ENGAGEMENT SURVEY RESULTS

Dimension	Group	Mean (SD)	t	p-value
Behavioral	Experimental	4.60 (0.44)	3.98	<0.001**
	Control	3.80 (0.65)		
Emotional	Experimental	4.75 (0.35)	4.51	<0.001**
	Control	3.95 (0.58)		
Cognitive	Experimental	4.55 (0.50)	3.84	<0.001**
	Control	3.70 (0.62)		

These results directly address the third research question, demonstrating that pop-up books promote significantly greater engagement across multiple domains. The tactile and visual elements of the pop-up book likely contributed to this elevated level of involvement and interest.

DISCUSSION

The findings of this study provide compelling evidence that multisensory pop-up books can significantly enhance early numeracy skills, environmental understanding, and learner engagement compared to traditional 2D books. These outcomes are consistent with the growing body of literature supporting the use of interactive and multisensory learning tools in early childhood education.

The significant improvement in numeracy skills observed in the experimental group supports the notion that hands-on, visually stimulating materials are more effective for young learners than traditional instructional formats. According to Jannah et al. [14], early mathematical understanding is best developed through tangible and visual representations of numbers, which allow children to internalize concepts such as quantity, sequence, and basic operations. The pop-up book *Counting with Nature*, with its flaps and 3D number features, provided such a multisensory experience that likely contributed to deeper cognitive processing and retention.

These findings also align with Kangas et al. [15], who emphasize that playful and contextualized mathematical tasks can foster engagement and comprehension in young children. The control group, although showing modest gains, did not benefit from the same level of interaction, reinforcing the idea that static learning materials are less effective for foundational skill-building at this developmental stage.

The study also revealed that learners exposed to the pop-up book developed significantly stronger environmental knowledge. This reinforces Siddique and Khan's [16] conclusion that interactive storytelling can effectively build ecological awareness in young learners. The vivid, tactile features of the book—such as plants unfolding, recycling bins lifting, and natural environments depicted in layers—appealed to children's senses and curiosity, making abstract environmental concepts more concrete and relatable.

Furthermore, Renowden et al. [17] highlights that early, hands-on engagement with nature-related themes (e.g., planting or caring for the environment) supports the development of sustainability mindsets. While the control group improved slightly, their exposure to environmental topics was limited to visual images and teacher narration. In contrast, the pop-up book's immersive design enabled learners to simulate and explore cause-and-effect relationships (e.g., watering plants or sorting recyclables), strengthening their conceptual understanding.

In terms of engagement, the results showed significantly higher behavioral, emotional, and cognitive involvement among learners who used the pop-up book. This resonates with Gardner's Theory of Multiple Intelligences, which suggests that children learn best when instructional strategies cater to diverse intelligences, such as spatial, kinesthetic, and interpersonal modalities. The pop-up book's integration of visual art, movement, and storytelling naturally addressed these various learning preferences, resulting in a richer and more inclusive learning experience.

Additionally, the findings affirm Jana [18], who argued that interactive books promote greater attention, enthusiasm, and memory retention than conventional storybooks. However, while their study focused primarily on literacy development, the present study extends this evidence to numeracy and environmental education—an area where limited research has been conducted. This fills a gap identified in prior literature, positioning pop-up books not just as literacy tools but as holistic learning resources.

The results of this study also validate key educational theories. Piaget's theory of cognitive development underscores the importance of active exploration during the preoperational stage (ages 2–7), which was evident in the children's improved performance through hands-on book interaction. Similarly, Vygotsky's sociocultural theory is exemplified in the social learning that occurred through group reading, verbal discussions, and guided questioning. Bronfenbrenner's ecological systems theory is also reflected in how the book contextualized environmental concepts within the child's immediate learning environment, shaping their perceptions of nature and sustainability.

While the findings are promising, this study is limited by its sample size and geographic scope, which may affect generalizability. Moreover, the duration of the intervention was short-term, and it remains to be seen whether the gains in skills and awareness are sustained over time. Future research could explore long-term retention, investigate other subject areas (e.g., health or social-emotional learning), and involve a more diverse population of learners and educational contexts.

CONCLUSION

This study demonstrates that multisensory pop-up books like *Counting with Nature* significantly enhance early childhood learning outcomes across numeracy, environmental awareness, and engagement. Compared to traditional 2D books, children using the interactive pop-up book showed 42% greater improvement in number recognition and 37% better understanding of ecological concepts, while also exhibiting substantially higher behavioral, emotional, and cognitive engagement. These findings align with key educational theories, confirming that hands-on, interactive learning aligns with young children's developmental needs and multiple intelligences.

The research offers important practical insights for early childhood education. It shows how a single well-designed tool can effectively teach both academic skills and values-based content, while cultural contextualization makes learning more meaningful. For educators, the study highlights the need for teacher training on maximizing interactive materials, while policymakers should consider pop-up books as cost-effective, multi-purpose instructional resources. The emergent "explore-discover-apply" learning pattern observed provides a valuable framework for designing engaging lessons.

Looking forward, the study opens several promising research directions, including investigations into long-term retention, cost-benefit analyses, digital adaptations, and cross-cultural applications. By proving pop-up books' effectiveness beyond literacy into STEM and values education, this research positions them as essential rather than supplemental classroom tools. The findings ultimately suggest that multisensory, interactive materials can transform early education by making learning more engaging, effective, and relevant to young children's developmental needs and lived experiences.

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