

# Pollinating Young Minds: Scientific Thinking and Real-World Application through a Pollinator Curriculum in Elementary Agriculture and STEM Education

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## Abstract

Pollinators are vital for agricultural sustainability, yet their populations face increasing threats from habitat loss, pesticide use, and climate change. This study aimed to design and evaluate a five-day instructional unit for fifth-grade students focused on pollinator conservation and the human impacts affecting pollinator populations. Grounded in Vygotsky's Sociocultural Theory, the curriculum incorporated scaffolded, inquiry-based strategies to foster both scientific understanding and environmental stewardship. Using a one-group pretest–posttest design, data were collected from 104 students across three classrooms in Georgia. A researcher-developed assessment measured content knowledge and self-reported confidence. Results indicated significant gains in student comprehension with mean scores improving by over four points. Students also reported higher confidence in their understanding of pollinator conservation. Findings suggest that scaffolded, real-world instruction effectively enhances elementary learners' knowledge and engagement with environmental issues. Recommendations include integrating pollinator concepts into state science standards, expanding professional development for teachers, and conducting longitudinal studies to assess retention and behavior change. This study demonstrates the potential of early agricultural literacy initiatives to build student capacity for addressing sustainability challenges.

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## Introduction and Problem Statement

Pollinators are essential for biodiversity and ecosystem sustainability, yet their populations are in decline due to habitat loss, pesticide exposure, and climate change (National Park Service, 2024; Rodger et al., 2021). Neonicotinoid insecticides, widely used for pest control, pose significant risks to pollinators due to their high toxicity and non-selective effects (Alsafran et al., 2022; Jeschke et al., 2011). While many European Union countries have restricted or banned these chemicals over environmental concerns (Wood & Goulson, 2017), U.S. regulations remain far less stringent.

Pollinator habitat decline threatens agricultural productivity and long-term food security. Yet, despite their importance, pollinators receive limited attention in K–12 science. The Next Generation Science Standards (NGSS) omit explicit pollinator instruction in the early grades (National Research Council, 2012; NGSS Lead States, 2013), and many non-NGSS states also provide little guidance on pollinator education (National Science Teaching Association, 2024). In Georgia, the term *pollinator* does not appear until second grade and receives minimal emphasis thereafter (Georgia Department of Education, n.d.).

Research suggests early instruction on pollinators is crucial for promoting environmental stewardship and building foundational science knowledge (Hayes et al., 2020). Given pollinators' essential role in agricultural systems, pollinator education offers a natural and meaningful intersection between SBAE and STEM instruction. However, because pollinator concepts are inconsistently represented in current standards, students often lack early exposure to ecological relationships, pesticide impacts, and sustainability issues. As a result, many enter later grades without the foundational knowledge needed to understand real-world agricultural and environmental challenges. The problem is that students lack early foundational knowledge about pollinators, limiting their ability to make sense of the ecological and agricultural issues that shape environmental sustainability.

## Theoretical Framework

This study was grounded in Vygotsky's (1978) Sociocultural Theory, which emphasizes the role of social interaction and cultural tools in cognitive development. A central concept within this theory is the Zone of Proximal Development (ZPD), defined as the range between what a learner can accomplish independently and what they can achieve with guidance (Vygotsky, 1978). Instruction that takes place within this zone, where tasks are appropriately challenging yet achievable with support, promotes the most effective learning.

Scaffolding, or the temporary assistance provided by teachers, peers, or tools, plays a critical role in helping learners bridge the gap between current and potential understanding (Wood et al., 1976). As students gain competence, these supports are gradually removed to foster independent mastery. In elementary STEM and agriculture classrooms, scaffolding may include hands-on exploration, the use of age-appropriate models or visuals, guided questioning, and

structured peer interactions. These strategies help young learners engage with foundational concepts, such as pollination, the role of pollinators in ecosystems, and the impact of human activity, while developing scientific reasoning skills in a developmentally appropriate manner.

Sociocultural theory also emphasizes that learning is socially constructed and most meaningful when connected to real-world contexts (John-Steiner & Mahn, 1996). By situating instruction within authentic agricultural and environmental challenges such as pollinator decline, educators can deepen students' understanding while fostering curiosity, communication, and early problem-solving skills. When lessons are designed within students' ZPD, they remain motivated, supported, and capable of cognitive growth.

In the context of this study, Vygotsky's theory provided a lens to examine how scaffolded, pollinator-focused instruction can support young learners in building both science content knowledge and the capacity to engage with environmental issues in ways that are relevant and accessible to their developmental stage.

## Purpose

This study aimed to design and implement an innovative five-day instructional unit focused on pollinator conservation and sustainability, with a specific emphasis on how human actions affect pollinator populations. Targeted at fifth-grade students, the research also aimed to assess the unit's effectiveness in improving student comprehension of these concepts. By developing and evaluating a scaffolded instructional unit, this study contributed to agricultural development by improving human practices through early education and capacity building in environmental and agricultural literacy. The specific objectives of this study were the following:

1. Compare the change in fifth-grade students' comprehension of the human effects of pollinators before and after implementing the newly developed instructional unit.
2. Examine participants' perceived confidence in their knowledge of pollinator conservation and human impacts before and after the instructional unit.

## Methods

This study employed a quantitative, one-group pretest–posttest design (Price et al., 2017) to evaluate the effectiveness of a five-day instructional unit focused on pollinator conservation and sustainability for fifth-grade students. The unit emphasized human impacts on pollinators and aligned with fifth-grade science and agricultural education standards. The research builds upon a previously piloted version of the instructional unit, which was tested with 29 students in an elementary agricultural education setting to refine content, timing, and assessment procedures.

For the full implementation, fifth-grade students ( $n=104$ ) participated across three classrooms taught by elementary STEM educators in Georgia during the Spring 2025 school semester. Convenience sampling was used, selecting teachers based on their accessibility and willingness

to implement the curriculum (Creswell & Creswell, 2023). While this method allowed for efficient data collection, it limited generalizability to broader populations.

A researcher-developed assessment was administered before and after the instructional unit. The 20-question instrument included 19 multiple-choice content items aligned with the lesson objectives and one item assessing students' perceived understanding and confidence regarding pollinator conservation. During the analysis phase, one content question was removed from the dataset due to poor item performance, as the majority of students answered it incorrectly on the post-test affecting internal consistency of the instrument. Although this question aligned with instruction, it is questioned if wording of the question was confusing or above reading level for the participants. The remaining 18 content items were scored dichotomously (1 = correct, 0 = incorrect), and mean scores represent the average of correct responses out of 18.

The instrument was reviewed by a panel of content experts, including agricultural and science educators, to establish face and content validity (Messick, 1994). The internal consistency of the instrument was assessed for the pre-assessment (KR-20 = 0.69) and for the post-assessment (KR-20 = 0.86) content questions. Both assessments were found to be highly reliable with improved consistency following the curriculum intervention.

The instructional unit was delivered over five consecutive instructional days by participating STEM teachers in their respective class schedules. Each lesson incorporated inquiry-based learning strategies, guided discussions, and literacy-based activities designed to support elementary learners in developing foundational knowledge about pollinators, ecosystems, and the role of human activity in environmental sustainability. Pre- and post-test content data were analyzed in SPSS using a paired samples t-test to compare changes in student knowledge following curriculum implementation (Field, 2019; Kent State University, 2024). The item of perceived confidence towards comprehension of the content was analyzed using the Wilcoxon signed-rank test (Field, 2019).

Several limitations of the study should be acknowledged. The use of convenience sampling and the small number of participating classrooms restricts the generalizability of findings beyond the specific context of this study. Differences in instructional delivery also presented challenges, as some classrooms completed the unit over five consecutive school days while others received lessons once per week across five weeks. This variation in pacing may have influenced continuity, engagement, and knowledge retention. In addition, although the instructional unit was standardized, individual teachers may have varied in how they implemented activities or facilitated discussions, introducing potential inconsistencies in fidelity. The one-group pretest-posttest design further limits internal validity, as no control or comparison group was included to account for alternative explanations such as maturation, history, or testing effects. Finally, the reliance on immediate pre- and post-test data does not provide insight into longer-term retention or application of knowledge.

## Findings

### Curriculum Implementation and Instructional Context

Before presenting student outcomes, it is important to describe the instructional context and design of the curriculum. The five-day unit was implemented in three fifth-grade STEM classrooms (n = 104 students) in Georgia. Instruction took place during regularly scheduled STEM classes, with two classrooms completing the lessons on consecutive days and one classroom spreading the lessons across five weeks. The unit was intentionally designed around inquiry-based strategies, literacy activities, and scaffolded supports that aligned with Vygotsky's Sociocultural Theory, particularly the Zone of Proximal Development.

Inquiry-based learning strategies were embedded throughout the unit to position students as active participants in constructing knowledge. Lessons incorporated card sorts to classify animals as pollinators or non-pollinators, gallery walks to share peer research, hands-on pollen transfer simulations using flour and Q-tips, and pesticide demonstrations with tonic water and blacklight. Students rotated through "threat stations" where they hypothesized about environmental challenges before comparing their ideas to explanatory texts, and they analyzed commodity maps linking Georgia crops to pollinator services. These inquiry tasks encouraged questioning, prediction, observation, and evidence-based reasoning, allowing students to test and refine ideas while engaging with authentic ecological problems.

Guided instruction complemented inquiry activities by introducing core topics in structured, developmentally appropriate ways. Teachers modeled the biological process of pollination during a flower dissection, supported discussion about pollinator-dependent foods using visual charts, and facilitated group analysis of pesticide impacts. Instruction was deliberately sequenced to move from concrete tasks such as identifying pollinators to more abstract applications such as weighing the risks and benefits of agricultural practices and designing conservation strategies. This progression ensured that new material remained within students' ZPD, where teacher guidance and structured supports made challenging concepts accessible.

Literacy-based activities were also woven throughout the curriculum to reinforce scientific reasoning and communication. Students used graphic organizers and labeled diagrams to capture content, sentence stems to frame their explanations, and peer questioning to prompt collaborative dialogue. They participated in gallery walks to present findings, engaged in "myth or truth" activities to clarify misconceptions, and created sketch-based reflections to synthesize personal takeaways. These literacy strategies not only strengthened content retention but also provided multiple modes for students to articulate understanding in developmentally appropriate ways.

Each activity was intentionally designed to situate learning within students' ZPD. The opening card sort activated prior ideas about animals and ecosystems, allowing students to engage with concepts that were just beyond their independent understanding but achievable with teacher prompts and peer discussion. The pollen transfer simulation drew on students' everyday

observations of flowers and insects, with structured supports such as diagrams and questioning helping them extend their knowledge of reproduction and ecological interdependence. Drawing meals to illustrate food–pollinator connections grounded abstract concepts in familiar experiences, while the final conservation lesson encouraged students to apply accumulated knowledge independently through personal action steps. By sequencing tasks from concrete to abstract and gradually reducing supports, the curriculum demonstrated how scaffolding can guide learners through their ZPD, connecting new content to what they already knew while extending their reasoning beyond what they could accomplish alone. This progression is summarized in Table 1, which highlights how scaffolded supports were introduced and systematically withdrawn in line with Vygotskian principles.

**Table 1***Summary of Lessons, Activities, and Scaffolded Supports*

Lesson	Focus	Key Activities	Scaffolded Supports	Withdrawal of Supports
Lesson 1: What Are Pollinators?	Identifying pollinators and their roles	Card sort (“pollinator vs. not”), partner research, gallery walk presentations	Graphic organizers, sentence stems, structured peer questioning	Students shifted to independent explanations of pollinator roles during the gallery walk
Lesson 2: Pollinator Processes	Understanding plant reproduction	Flower dissection with labeled diagrams; pollen transfer simulation with flour & Q-tips	Teacher modeling, guided questioning, labeled visuals	Prompts reduced as students independently explained pollen transfer
Lesson 3: Human Impacts on Pollinators	Exploring food dependence and pesticide effects	Food reliance chart; pesticide simulation with tonic water & blacklight; group discussion of risks	Visual charts, prediction prompts, structured pros/cons organizers	Students later analyzed risks independently and extended discussion to policy-level issues
Lesson 4: Threats to Pollinators	Connecting pollinators to ecosystems and economies	Meal drawings linked to pollinator services; Georgia commodity map analysis; “threat stations” rotations	Maps, guiding questions, structured group roles	Groups generated their own hypotheses before comparing to explanatory text
Lesson 5: Conservation and Agency	Applying knowledge to action-oriented solutions	Integrated Pest Management steps; “myth or truth” activity; beneficial insect “Guess Who” game; sketch reflections	Videos, guiding discussion prompts, structured comparisons	Students created independent conservation reflections and personal action steps

Detailing the instructional process establishes how scaffolding and ZPD were operationalized in practice, and the following results quantify the impact of these strategies on students' content knowledge and confidence.

### Objective 1

Objective 1 of this study sought to compare the change in fifth-grade students' comprehension of the human effects of pollinators before and after implementing the newly developed instructional unit. A paired-samples *t*-test (see Table 2) was conducted to compare the knowledge of participants ( $n=104$ ). Results revealed a statistically significant increase in student comprehension following the instructional intervention,  $t(103) = -9.649$ ,  $p < .001$ .

**Table 2**

#### *Paired Samples t-test for Content*

Questions	# of Items	Pre-Assessment		Post-Assessment		<i>t</i> (103)	<i>p</i>
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
Content	18	8.57	3.40	12.68	4.30	-9.649	<.001

Specifically, the mean score increased from  $M = 8.57$  ( $SD = 3.40$ ) on the pre-assessment to  $M = 12.68$  ( $SD = 4.30$ ) on the post-assessment. This improvement suggests that the instructional unit effectively enhanced students' comprehension of how pollinators impact human life and vice versa. The standard deviation also increased slightly from pre- to post-assessment, indicating greater variability in student responses after instruction. This may reflect a deeper engagement with the material, or a wider range of comprehension outcomes based on individual learning differences.

On average, students answered over four more questions correctly following instruction. Given that the test included items designed to measure specific learning outcomes tied to the instructional unit, these results suggest alignment between curriculum goals and student learning. This finding supports the effectiveness of the instructional design and implies that targeted, standards-aligned instructional materials can significantly improve elementary students' content knowledge related to pollination and its relevance to human systems.

### Objective 2

Objective 2 of this study examined participants' perceived confidence in their knowledge of pollinator conservation and human impacts before and after completing the instructional unit. To assess this, participants ( $n = 102$ ) rated their understanding of how humans affect pollinators using a four-point scale ranging from "very little understanding" to "I could teach others about it."

The Wilcoxon signed-rank test (see Table 3) was utilized to evaluate the change in self-reported confidence levels before and after the instruction among the participants. Two participants of the original sample abstained from answering the confidence question. The analysis revealed

that self-reported confidence was significantly higher following the instruction intervention with a medium effect size ( $Mdn = 3$ ),  $z = -2.904$ ,  $p = 0.004$ ,  $r = -0.33$ .

**Table 3**

*Wilcoxon Signed Rank Test for Confidence*

Questions	# of Items	Pre-Assessment		Post-Assessment		z	p
		M	Mdn	M	Mdn		
Confidence of Understanding*	1	2.41	2	2.75	3	-2.904	.004

*\*Item coded on a four-point scale; 1- Very little understanding, 2- Some understanding, 3- I understand, 4- I could teach others about it*

Although the mean and median increase may appear modest, it represents a meaningful shift toward higher levels of perceived understanding within the short duration of the instructional unit. Fewer students selected “very little understanding” following the unit, and a greater proportion indicated that they “understand” or “could teach others,” suggesting that the curriculum not only conveyed key concepts but also instilled a greater sense of personal competence.

Patterns in the signed ranks further support this interpretation. A greater number of students showed positive rank changes rather than negative ones, indicating that increases in confidence were more common than decreases. This concentration of improvements demonstrates that the curriculum supported more consistent and elevated levels of understanding across the group, which may contribute to sustained engagement with science and environmental topics moving forward.

## Conclusions, Discussion, and Recommendations

This study set out to address the lack of early, meaningful instruction on pollinators in elementary STEM and agricultural education. While the findings are promising, several limitations must be acknowledged. The use of a small, convenience-based sample, variation in instructional delivery across classrooms, and reliance on a one-group pretest–posttest design without a comparison group (Creswell & Creswell, 2023) limits the generalizability of the results and prevent strong causal claims. Future research should use larger, more diverse samples, include comparison groups, and explore how pacing models affect learning and retention.

Despite these limitations, the study demonstrates that scaffolded instruction within the ZPD can significantly enhance learning. By starting with supports such as sentence stems, diagrams, and modeling, then gradually shifting to inquiry and reflection, the curriculum aligned with Vygotskian principles. Gains in knowledge and confidence suggest that presenting concepts just beyond students’ independent ability then systematically withdrawing support enables

mastery, exemplifying Vygotsky's view of guided participation in the ZPD (Vygotsky, 1978; Wood et al., 1976).

Beyond the immediate results, this study offers insight into the broader importance of early, sustained pollinator education as a means of fostering environmental stewardship and agricultural literacy in young learners. By situating instruction within authentic contexts such as pollinator decline and conservation, and by engaging students in collaborative meaning-making, the curriculum reflects Vygotsky's emphasis on the social and cultural nature of learning (John-Steiner & Mahn, 1996). Although this study did not directly measure students' environmental stewardship or pro-environmental attitudes, the documented increases in knowledge and confidence represent foundational components of environmental efficacy. Research indicates that early competence and self-belief in environmental science contribute to later engagement and stewardship behaviors (Gill, 2014). This is especially significant in the face of ongoing pollinator decline due to habitat loss, pesticide exposure, and climate change, addressed as critical issues in past research (Alsafran et al., 2022; Rodger et al., 2021). These connections help explain why early, sustained exposure to pollinator concepts may be particularly valuable for future agricultural literacy and environmental engagement, even if stewardship itself was not assessed in this study.

To build on these findings, researchers recommend that practicing educators prioritize scaffolded, inquiry-based pollinator units and provide students with opportunities for hands-on investigation, discussion, and problem-solving. Professional development should model how educators can operationalize ZPD and scaffolding in practice, ensuring that supports are developmentally appropriate and strategically faded over time. At the policy level, curriculum developers and decision makers are recommended to revise science standards to explicitly include pollinator education from the early grades, with clear guidance on age-appropriate, scaffolded teaching methods.

Based on the findings of this study, future research should continue to investigate how scaffolded, ZPD-based instruction shapes long-term outcomes, including retention of ecological knowledge, changes in environmental attitudes, and the development of pro-environmental behaviors. Qualitative studies that capture the experiences of teachers and students will add further depth to our understanding of what makes these instructional approaches successful. The findings demonstrate the promise of scaffolded, real-world pollinator education in developing both scientific understanding and environmental stewardship among elementary students, and point to clear next steps for classroom practice, policy, and research.

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