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Zooming into STEM: Designing Curriculum Around Guest Presentations in an Online After-School STEM Program for Title I Elementary Students

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ABSTRACT
The WonderKids program is a virtual after-school integrated science, technology, engineering, and mathematics (STEM) initiative serving K–5 students from Title I schools in South Los Angeles. Designed to increase representation and engagement in STEM, each six-week semester focuses on unique subfields in science as its theme. Each week features guest speakers from diverse backgrounds who are professionals in the given subfields. In Fall 2023, the curriculum development approach was modified to more directly prepare students for these guest presentations. To assess the impact of this shift, we analyzed students' pre- and post-tests and guest speaker surveys on student preparedness. Scores improved significantly from pre- to post, especially for 3rd–5th-grade students, suggesting effective content learning. Additionally, students expressed strong enjoyment across topics and activities and most post-test drawings reflected accurate scientific understanding and increased self-identification with STEM professionals. However, guest speaker survey responses across years revealed no statistically significant differences in their perceptions of students' preparedness or background knowledge, even after the curriculum development approach was revised in an attempt to better prepare students for guest presentations. These findings support the program's effectiveness in fostering early STEM interest but suggest the program could be further improved through continued refinement of how students are prepared for speaker presentations.

Keywords: elementary STEM education, out-of-school time (OST) programs, virtual STEM learning, inquiry-based learning, university-community partnerships

Introduction

Early elementary school is a crucial period for developing students' confidence and identity in science, technology, engineering, and math (STEM). Research suggests that high-quality STEM experiences during the elementary years can positively influence students' long-term interest in STEM disciplines by engaging them in authentic scientific inquiry, engineering design, and problem solving (National Research Council, 2012; Maltese & Tai, 2010). Elementary school also represents a critical window for shaping students' STEM aspirations, as children begin to develop perceptions of who participates in science and whether STEM careers are attainable for them (DeWitt & Archer, 2015). Inquiry-based instruction grounded in the Next Generation Science Standards (NGSS) encourages students to ask questions, develop models, investigate phenomena, and communicate evidence-based reasoning, practices associated with deeper conceptual understanding and increased engagement in science learning (NGSS Lead States, 2013; Bybee, 2013). Furthermore, exposure to STEM career professionals and authentic learning experiences has been shown to strengthen students' science identity by helping them envision themselves as future professionals in these fields (DeWitt & Archer, 2015). Despite these benefits, access to high-quality elementary STEM experiences remains inequitable because of differences in school resources, science-focused instructional time, and access to STEM specialists. Consequently, after-school and informal STEM programs have become an increasingly important component of local STEM learning ecosystem participation by providing hands-on learning opportunities that complement classroom instruction (Bell et al., 2009; National Research Council, 2015). These inequities became even more pronounced during the COVID-19 pandemic, when many students lost access to in-person science experiences, after-school programming, and face-to-face interactions with STEM professionals.

The WonderKids after-school program is one of several K-5 integrated science, technology, engineering, and mathematics (STEM) programs offered through the University of Southern California's (USC) Joint Educational Project (JEP). Since its inception in 2013, the program has served more than 500 elementary students by introducing STEM topics that are often considered too advanced for young learners, including engineering, computer science, audiology, gastroenterology, and osteology/orthopedics (Stiles et al., 2024; Kast et al., 2018). In Fall 2020, educational disruptions caused by the COVID-19 pandemic necessitated that WonderKids transition from an in-person partner program with JEP's Readers PLUS to a fully virtual model (McMahon et al., 2022). Rather than simply moving instruction to Zoom, the program was intentionally redesigned to preserve the core elements of effective elementary STEM education through synchronous, inquiry-based instruction, hands-on investigations using readily available or program-provided materials that were shipped directly to participating students' homes, bilingual support, undergraduate near-peer mentoring, and interactions with STEM professionals from around the world. The virtual format also expanded the program from four guest speakers and four instructional modules to six speakers representing diverse STEM disciplines from across the globe, illustrating how thoughtfully designed online learning environments can increase students' access to experts and career role models regardless of geographic location (Poppick, 2018). While many virtual STEM initiatives have focused primarily on content delivery, virtual WonderKids demonstrates a scalable model that combines inquiry-based elementary science instruction, university-community partnerships, near-peer mentoring, and global STEM engagement within a sustainable after-school program (Kast, 2026). By documenting both the instructional model and implementation strategies, this paper contributes practical guidance for educators, universities, and community organizations seeking to expand equitable access to high-quality elementary STEM enrichment through adaptable virtual programming. The impact of these experiences is reflected in students' own words. After participating in the neuroscience module, one third-grade student wrote, *"I drew a drawing about the neuroscientist because it was one of my favorite subjects. I drew Mr. Lehnen behind her. I loved neuroscientists so much that I might be one!!!"* (Allison, Grade 3). This reflection illustrates how early exposure to STEM professionals and authentic learning experiences can help students begin to envision themselves pursuing future STEM pathways.

WonderKids modules emphasize hands-on activities based on the Engage, Explore, and Explain phases of the 5E instructional model (Duran & Duran, 2004) while incorporating the science and engineering practices outlined in the NGSS, including asking questions, developing models, carrying out investigations, and constructing explanations (NGSS Lead States, 2013). One of the primary lessons from WonderKids has been that a program like this need not be created entirely from scratch to be impactful. A major factor in launching and sustaining the program was partnering with schools and after-school organizations that already had the infrastructure, relationships, and access to students. WonderKids complemented these existing programs by providing an inquiry-based STEM curriculum centered on hands-on learning experiences. Program quality has been maintained by investing in training partner program staff so they feel confident facilitating activities, fostering shared ownership, and strengthening the program's long-term sustainability. Another important lesson has been the value of collecting simple pre- and post-assessment data. Even brief assessments or student reflections can document growth, inform curriculum improvements, and demonstrate the program's value to partners and funders. Taken together, these experiences suggest that others seeking to develop similar STEM enrichment programs may benefit from identifying clear learning goals, partnering with organizations that already serve their target population, building facilitator training into implementation, and incorporating simple evaluation methods from the outset. This foundation supports sustainable program growth while expanding access to meaningful STEM learning opportunities for elementary students.

A major factor in getting the program started and sustaining it over time was partnering with schools and after-school programs that already had the infrastructure, relationships, and access to students. WonderKids contributed to their existing efforts through the STEM curriculum with hands-on activities. Program quality has been maintained by investing in the training of partner program staff so that they feel confident facilitating activities, which helps create shared ownership and has strengthened the program’s long-term sustainability. Another important lesson has been the value of collecting simple pre- and post-assessment data. Even brief assessments or reflections can help document growth, improve the curriculum, and demonstrate the program’s value to partners and funders. Taken together, these experiences suggest that others hoping to build a similar program may benefit from identifying a clear goal (what you want students to learn or experience), finding a partner who already has access to your target group, and beginning programming with a few well-designed, hands-on activities.

From there, build in partner training and simple evaluation methods early on. That foundation makes it easier to grow something sustainable over time. Together, these elements create a scalable model that can be adapted across a variety of educational settings while expanding equitable access to meaningful elementary STEM experiences.

Program Overview

A graduate JEP STEM Education Fellow designs the curriculum and hosts the program online with support from 1-2 undergraduate assistants. To increase accessibility, the program is advertised directly to families via staff at various partner schools who act as coordinators and post information to their schools' parent/guardian portals. Additionally, the program and materials are offered free of charge, so a student only needs access to a device capable of videoconferencing to participate. This is because WonderKids is supported through a combination of grant and institutional funding, which has helped sustain the program over time. Grant support from USC's Good Neighbors Campaign covers program staffing and activity supplies, while institutional funding from the USC Dornsife College of Letters, Arts, and Sciences supports the graduate fellow who helps coordinate WonderKids part-time (20 hours per week) through the program's STEM Education Fellowship. This fellowship provides graduate school funding, including a living stipend, tuition remission, and health insurance for 1-2 semesters, depending on the accepted students' time commitment. The program's overall combination of funding sources has remained consistent for more than six years, including through periods of broader budget constraints, and has allowed WonderKids to continue offering free programming and materials to participating students.

Each week, students attend two 1-hour sessions, with separate sessions offered for K-2 and 3-5 grade groups. The first session offers a hands-on lesson about the weekly theme, using materials shipped directly to participating families. Beginning in 2023, this first session was designed to prepare students directly for the guest speaker portion of the second weekly session. This second session features guest speakers from diverse social and cultural backgrounds. Each guest speaker is a professional whose career aligns with that week's focus. These speakers present their work and offer insights into their daily activities, such as sharing research photos or providing video tours of their workspaces. This design not only educates students about specific scientific fields, careers, and concepts but also provides diverse role models from traditionally underrepresented groups in STEM, often with backgrounds similar to students'. This aligns with the core principles of presenting students with effective role models in STEM, especially in contexts where role models are portrayed as competent authorities whose success is attainable by students (Gladstone & Cimpian, 2021). Altogether, the program is designed around the ultimate goal of inspiring students to envision careers in STEM.

WonderKids serves young learners from Title I schools in South Los Angeles, a community primarily composed of Hispanic/Latino families. This term saw the enrollment of 19 students in grades K-2 and 21 students in grades 3-5. The student demographics for this semester were reported as 72% Latino, 4% Black, and 28% Asian, underscoring the program's success in engaging students from underrepresented backgrounds. Spanish-speaking ELL students were supported with bilingual program materials, and communication with parents was available in both English and Spanish. Mirroring the backgrounds of the participating students, 71% of speakers were BIPOC. This approach is intentional, grounded in the understanding that representation and mentorship are critical in nurturing STEM aspirations.

Fall 2023 Curriculum

Fall 2023 themes are presented below in Table 1, followed by detailed descriptions of each week's activities. Materials for each activity, including printouts, can be found in the supplementary resources at the end of the article (see Supplementary Materials).

Table 1
Fall 2023 Eight-Week WonderKids Curriculum

Week	Theme	Lesson 1	Lesson 2	Guest Speaker
1	Introductions	What is STEM?	STEM Careers	None
2	Ecology	Food Chains & Webs	Natural Selection	Charles Lehnen
3	Geospatial Sciences	Topographic Map	Room Map	Dr. Laura Loyola
4	Neurobiology	Brain Hat	Neurons firing	Alisha Cayce
5	Entomology	Parts of an insect	Insect life cycles	Dr. Austin Baker
6	Cellular Biology	Cells	DNA	Dr. Catherine Diadhiou
7	Kinesiology	Muscles	Motion Capture	Andrea Rivera Aslan and Marisa Loo
8	Family Showcase	What have you learned?	Family Showcase	Families

Note. The lesson 1 topic and activities were presented on Tuesday of the given week. The lesson 2 topic and activities were provided on Thursday, and this lesson included guest presentations.

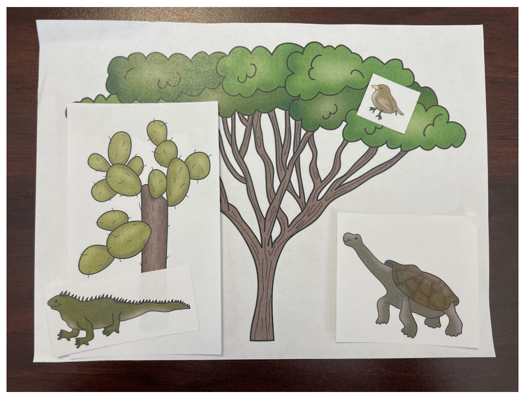
Week 2 - Ecology

The ecology week focused on helping students understand ecosystems and their complex relationships. The curriculum introduced concepts such as prey-predator balance, adaptive radiation, the founder effect, and how ecologists use trophic ecology and biogeography to track and support endangered species. The first day's lesson centered on food chains and webs, engaging students in a predator-prey computer simulation (*Figure 1, left*).

Students explored the dynamics of rabbit, wolf, and grass populations, forming hypotheses and observing how varying population sizes and traits affected outcomes.

On the second day, Charles Lehnen, the graduate JEP STEM Education Fellow and a Ph.D. Candidate in ecology and evolutionary biology at USC, presented his research. Through photos and videos, he showcased his field research in the Galapagos Archipelago of Ecuador on the introduction of Española Giant Tortoises (*Chelonoidis hoodensis*) to Santa Fe Island and the resulting cascading effects on the ecosystem. This included a recorded video tour of his field basecamp. He then guided an activity in which students used paper cutouts of various Santa Fe Island plants and animals to construct their own ecosystems, depicting species interactions with arrows (*Figure 1, right*). Students also received plastic toys depicting Galápagos flora and fauna, allowing them to further engage with the concepts discussed.

Figure 1
Ecology Activity Examples



Note. On the left is a screenshot from a predator/prey simulation used to teach students about the importance of a balanced ecosystem (www.phet.colorado.edu/sims/html/natural-selection/latest/natural-selection_all.html). On the right are paper cut-outs students used to make their own balanced ecosystem with Santa Fe Island plants and wildlife.

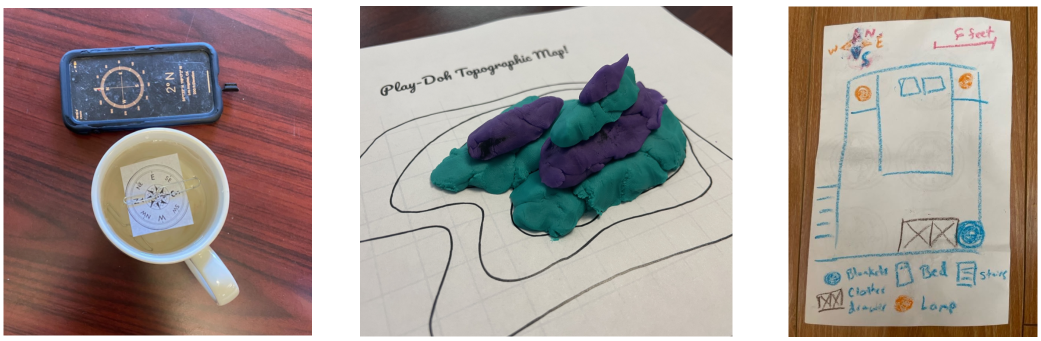
Week 3 - Geospatial Sciences

During the week of geospatial sciences, students learned about cardinal directions and essential map components, establishing a foundation for understanding how geospatial scientists use cartography to examine environmental changes and their effects on wildlife, such as monkeys. On the first day, after learning about maps, students created their own compasses using magnets, paperclips, paper cutouts, and water (*Figure 2, left*). Older students (grades 3-5) were introduced to topographic maps, learning to read them and creating 3D models with Play-Doh (*Figure 2, center*).

The second day featured Dr. Laura Loyola, a USC professor in Geospatial Sciences. Dr. Loyola presented her research on Red Colobus Monkeys (*Piliocolobus spp.*) and the impact of human-altered rivers on these primates. Photos of her fieldwork tracking monkeys in Kenyan forests using GPS units demonstrated real-world applications of the concepts from day one.

Following her presentation, Dr. Loyola led an activity in which students created maps of a chosen room, incorporating critical elements such as compass roses, scale bars, and legends (*Figure 2, right*). This exercise, using their homemade compasses, allowed students to practice geospatial skills and understand the importance of accurate mapping in scientific research.

Figure 2
Geospatial Sciences Activity Examples



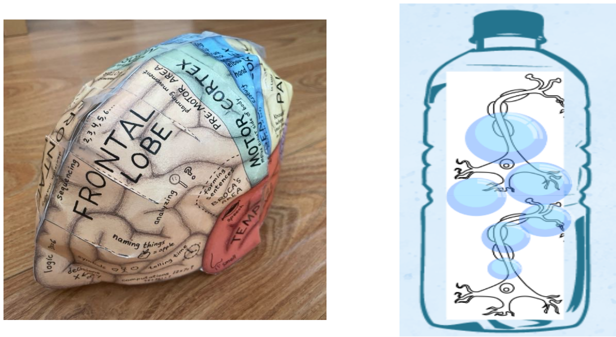
Note. On the left is a homemade compass activity with magnet, paper-clip, compass cut-out, and cup of water. In the center is an activity in which students made 3D Play-Doh models based off of topographic maps. On the right is an activity where students made a map of a room of their choosing utilizing important map aspects (compass rose, legend, and scale bar).

Week 4 - Neurobiology

The neurobiology week introduced students to the human brain, its components, and the critical functions of neurons and neurotransmitters. Students began by learning about various parts of the brain and creating and wearing paper brain hats (*Figure 3, left*). They then identified different brain regions by touching specific parts of their hats while performing activities primarily associated with those areas, such as remembering, using their senses, or dancing. This helped them connect brain regions with specific cognitive and physical functions.

On the second day, Alisha Cayce, a second-year Ph.D. student in Neuroscience at USC, shared her insights and ongoing research. Cayce's work focuses on Mesial Temporal Lobe Epilepsy, a complex condition often resistant to medication. She explores the efficacy of various drug compounds on extracted hippocampal tissue. To help students imagine their own lives as neuroscientists, Cayce provided an immersive tour of her lab. After discussing the challenges of treating epilepsy and her research efforts, she guided students through the "Neurons in a Bottle" activity. This experiment used plastic water bottles, paper neurons, and bubbling food-coloring tablets to simulate neurotransmitter-mediated information transmission across neurons, illustrating brain-body communication (*Figure 3, right*).

Figure 3
Neurobiology Activity Examples



Note. On the left is a paper brain hat students folded, taped, and wore to learn about which parts of their brains are primarily associated with different actions (e.g., remembering, dancing, using their senses). On the right is a diagram of the "Neurons in a Bottle" activity.

Week 5 - Entomology

During entomology week, students learned to distinguish between insects and bugs, studied insect anatomy, and explored insect life cycles. The curriculum also demonstrated how entomologists conduct field studies. On the first day, students focused on insect anatomical features, using plastic insects to identify body parts. They then crafted their own insects using Play-Doh and a paper guide, ensuring they included essential components such as antennae, thorax, abdomen, and legs (*Figure 4, left*). The second day featured Dr. Austin Baker, a Postdoctoral Fellow in the Entomology Department at the Natural History Museum (NHM) of Los Angeles County. Dr. Baker presented his work on collecting DNA barcodes of California insect species, emphasizing the importance of documenting insects for conservation efforts. He shared a recording of the museum's extensive insect collections, showcasing specimens from around the world. Following the presentation, Dr. Baker guided students in creating models of insect life cycles using pasta on paper plates (*Figure 4, right*). To encourage further exploration, students received magnifying containers and were advised to collect insects under adult supervision.

Figure 4
Entomology Activity Examples

Note. On the left are Play-Doh insect students made to learn about the parts of an insect. On the right is an insect life cycle activity where students placed pasta on a paper plate in the correct order to simulate metamorphosis.

Week 6 - Cellular Biology

The cellular biology week introduced students to DNA, animal cell components, viruses, and gene-editing techniques such as CRISPR-Cas9, which cellular biologists use to combat diseases such as HIV. On the first day, students explored DNA structure and base pairing (adenine with thymine and guanine with cytosine) using gummy bears, licorice, and toothpicks (*Figure 5, left*). They were also introduced to CRISPR-Cas9 concepts in preparation for the guest presentation. Students then "edited" their candy DNA strands, simulating CRISPR-Cas9's function. The second day focused on cell components, including DNA storage locations. The guest speaker, Catherine Diadhiou, a PhD candidate at the Keck School of Medicine of USC, presented her work on engineering B cells to produce anti-HIV antibodies. She personalized her presentation by sharing her journey from Dakar, Senegal, to her current research position. Diadhiou provided a virtual tour of her lab, offering students insight into a cellular biologist's daily life and work environment. She then led an activity where students constructed animal cell models using craft supplies on paper plates (*Figure 5, right*).

Figure 5

Cellular Biology Activity Examples

Note. The left shows a candy DNA model in which students matched nucleotide base pairs (based on the colors of the gummy bears). Students then "edited" their candy DNA strands to learn about the CRISPR-Cas9 system. On the right is a paper plate model of an animal cell that students made to learn about the parts of a cell.

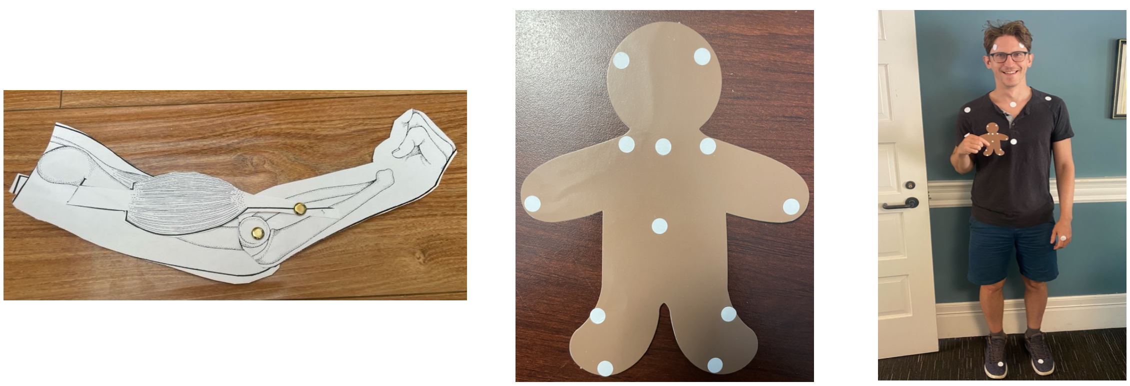
Week 7 - Kinesiology

The kinesiology week in the WonderKids program introduced students to muscle function and motion capture technology used in clinical settings, animation, and athlete recovery. Students first explored muscle function at the cellular and physiological levels, learning about its components. They then constructed a paper model of a bicep to illustrate muscle contraction and movement (*Figure 6, right*).

The second day focused on practical applications of studying movement using motion capture technology, a system of cameras and sensors that track, record, and digitize body movement. Guest presenters Andrea Rivera Maza and Marisa Loo from VICON shared their unique career paths. Rivera, with a background in dance and kinesiology, and Loo, experienced in sports biomechanics and visual effects, offered perspectives on the intersection of movement science and technology. They demonstrated VICON's equipment at their lab, showcasing applications in life sciences and visual effects.

Students participated in an interactive session by verbally directing a real-life actor's movements on a motion-capture stage to animate a digital gingerbread person in real time. This showcased state-of-the-art technology and its relationship not only to science but also to art. Students also engaged in a hands-on exercise with paper dolls (*Figure 6, center*) and had the option to apply stickers to their bodies (*Figure 6, right*) to mimic the motion-capture process. This activity highlighted the importance of accurate motion-capture marker placement. Finally, using Zoom filters, they animated their own avatars, bringing the week's lessons to life.

Figure 6
Kinesiology Activity Examples



Note. On the left is an example paper bicep muscle students made to learn how skeletal muscles work through contraction and relaxation. The center shows a paper doll on which students placed stickers to learn about the accurate placement of motion capture (mocap) markers by kinesiologists. On the right, students placed stickers on their own bodies in the same places where they had placed them on their paper dolls.

Methodology

One of the key goals of WonderKids is to help students envision themselves as scientists. To support this goal, guest presenters are selected to reflect a wide range of backgrounds, cultures, and scientific fields. These speakers are encouraged to share what their day-to-day work actually looks like and highlight the collaborative nature of scientific research to help science feel more accessible. JEP staff and graduate fellows pull from their networks to identify and contact researchers who could meet our recruitment objectives. As new graduate fellows from different fields manage the program, they contribute to a growing list of scientists who can be contacted either for the current semester or for future years.

In Fall 2023, to better prepare students to engage with guest speakers and the material they present, WonderKids introduced a new curricular approach that focuses more heavily on preparing students for guest speaker presentations than on broadly covering the weekly theme. The aim of this approach is to enhance students' ability to derive educational value from each guest presentation while offering a more targeted and cohesive learning experience. This change involves working closely with each guest speaker to understand the key points of their upcoming presentations, which informs the development of the interactive lessons at the beginning of each week. Speakers are encouraged to meet with the graduate fellow and undergraduate assistant on Zoom for 30 minutes to 1 hour during the planning stages of the semester, before materials are purchased. During this meeting, they review what they plan to present so that the graduate fellow and undergraduate assistant can design the lesson around that content. We also discuss ideas for hands-on activities so that speakers can suggest modifications or propose their own. In Fall 2023, four of the six speakers chose to meet on Zoom in advance, while the other two shared their ideas over email. Both approaches worked well, and which is better may depend more on the teaching style of the individual speaker. One week before presenting, speakers were asked to send their slides so that the graduate fellow and undergraduate assistant could finish tailoring the first lesson of the week to best prepare students for the presentation later that week. On the day of the presentation, speakers were expected to arrive on Zoom 30 minutes early so that we could set up screen sharing, presentations, and audio if needed, and review the hands-on activity once more. Speakers then presented in two back-to-back one-hour sessions, for a total Zoom time commitment of approximately 2.5 hours.

Following their lessons, feedback from guest speakers was collected via Google Forms (see *Table 2* below), with questions identical to those used in past semesters. This allowed us to quantify the effect of this new approach on the perceived reception of guest presentations. By comparing this semester's data with that from previous semesters, we aimed to measure the effectiveness of the curriculum's new approach of preparing students directly for guest speaker presentations. Throughout this article, we present and evaluate the program's effectiveness. Paired T-tests were used to compare survey results prior to and following this modified approach.

To assess the effectiveness of meeting with presenters to design curricula with the goal of directly preparing students for speaker presentations, we collected and analyzed a variety of data. To gauge students' conceptual understanding and perceptions of scientists across various fields/subfields, we administered pre- and post-tests using drawings developed in past semesters because low literacy rates prevented effective use of the Zoom chat feature (*McMahon et al., 2022*). These types of assessments, or draw-a-scientist tests (DASTs), have been utilized by other programs since the 1980s (*Chambers et al., 1983*). In order to avoid bias, students were asked to draw a specific type of scientist, such as “Draw an entomologist,” at the start of each week before any lessons were conducted. These drawing activities were then repeated at the end of each week, allowing us to compare changes in students' comprehension and viewpoints. Additionally, at the beginning and end of the semester, students drew what they thought a scientist does in general, providing broader insights into their shifting perceptions. Our analysis focused on the accuracy of these depictions as well as noting the diversity of backgrounds students attributed to scientists. These were graded on a simple binary system: 1 point for accuracy and 0 points for inaccuracy or ambiguity. We also recorded whether they depicted scientists who were meant to resemble themselves or not. Unpaired T-tests were used to compare the accuracy of drawings pre- and post-weekly lessons.

During the first lesson of Week 8, students were polled using Zoom's built-in survey feature. They were able to select their single most-preferred theme for the semester. Then they could select their three favorite activities from a radio button list. ANOVAs were conducted to assess student preferences for the various themes and activities.

Table 2

Speaker Survey Questions

Speaker Survey Questions:
Which subject were you a guest speaker for?
Have you been a speaker for Wonderkids before?
Overall, how do you feel your lesson went?
What information did you share with the students to inspire their interest in your field?
What 'hands-on' activities (projects, experiments, etc.) did you do to engage the students in your field? Please describe.
Did the students seem to have background knowledge of some of the topics addressed in your lesson?
Were the students engaged in the lesson and did they seem to enjoy it?
Were the Wonderkids staff helpful in preparing you and with online classroom management?
What went particularly well?
What went not so well?
We love quoting our speakers in newsletters and articles relating to Wonderkids. Is there a quote you'd like to submit about the program?

Results

Speaker Survey Analysis

In the weeks following their presentations, speakers were provided with a survey about their experience (*Table 2*). Average response values for quantitative questions are provided (*Figure 7*), which were on a scale from 1 to 10. Original values were either on a scale of 1 to 5 or 1 to 10, so the former were multiplied by 2 to improve interpretability. However, after implementing the new approach of meeting with speakers to design lessons tailored to their presentations, there was no significant change in speaker responses to the question about student background knowledge ("Did the students seem to have background knowledge of some of the topics addressed in your lesson?") (*Figure 8*). Ratings for Background Knowledge before (mean = 8.29, n = 7) and after (mean = 7.14, n = 7) were not significantly different (p = 0.233) according to an unpaired t-test. On average, the presenters' impressions of their experience were highly favorable, including student engagement (9.71 ± 0.76), Wonderkids staff helpfulness (10.00 ± 0.00), and overall experience (9.86 ± 0.38).

Figure 7

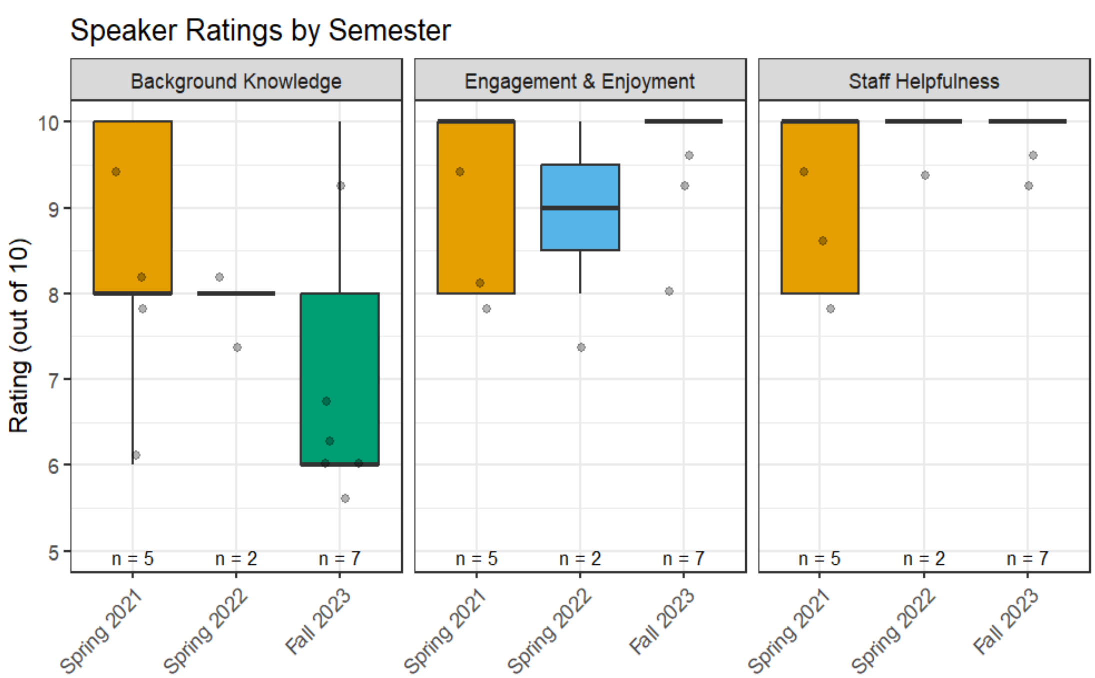
Mean Scores for Quantitative Responses with Standard Deviations

Fall 2023 Speaker Feedback

Survey Question	Mean[1]	Std Dev[1]	n
Background_Knowledge	7.14	1.95	7
Engagement_Enjoyment	9.71	0.76	7
Overall_Rating	9.86	0.38	7
Staff_Helpfulness	10.00	0.00	7

Figure 8

Box-and-Whisker Plots Comparing Speaker Survey Results Across Semesters.



Student Learning Outcomes

The simple pre- and post-tests, in which students were asked to draw scientists from specific fields, revealed a significant improvement in students' ability to accurately understand what scientists in those fields do after Wonderkids lessons during the Fall 2023 semester.

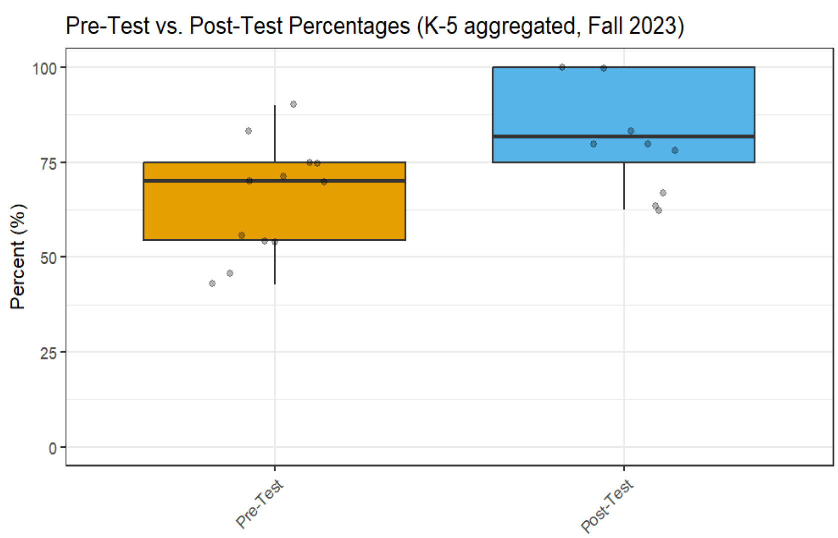
Unpaired T-tests, commonly used to compare the average scores between two groups, were used to compare pre- and post-test scores. These tests indicated that the mean post-test score (81.67) was 16.7% higher than the pre-test score (70.00; $p = 0.005$). For 3-5 students, post-test scores (80.56) were 29.4% higher than pre-test scores (62.27, $p = 0.001$), indicating strong learning gains. Meanwhile, K-2 students demonstrated a 27.3% increase from pre-test (70.71) to post-test (90.00), but this trend was not statistically significant ($p = 0.098$).

These trends of increased post-test scores are shown in the box-and-whiskers plot in Figure 9. Plots show data for aggregated K-5th grade (*Figure 9 (Top)*) and disaggregated between the K-2nd grade and 3-5th grade groups (*Figure 9 (Bottom)*). Unlike the unpaired T-test, which utilizes the mean, in box-and-whisker plots, the central line inside each box represents the median score. The top portion of each box above the center line represents the 75th percentile. Similarly, the bottom portion is the 25th percentile. The straight vertical lines above and below each box, a.k.a the "whiskers," extend to the smallest and largest values within 1.5 times the top and bottom of the boxes. Raw data points are superimposed over the plots, and points beyond the whiskers represent potential outliers.

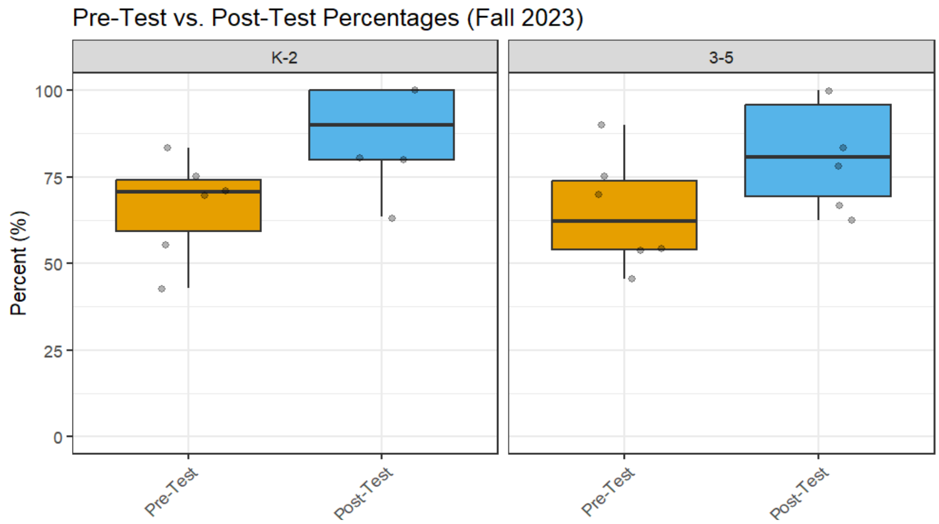
Figure 9

Box-And-Whisker Plots Comparing Pre- and Post-Test Score Distributions Overall (Top) And Disaggregated By Grade Band (Bottom).

Top



Bottom



Note. Overall, median post-test scores shifted upward relative to pre-test scores. When disaggregated by group, both K-2 and 3-5 students showed this same upward trend.

Notably, as shown in the examples below (*Figure 10*), students frequently drew themselves as the scientists and accurately portrayed the science subfield from that week's lesson in their post-test drawings. This suggested not only increased familiarity with the topic but also personal identification with the role. Drawings often included features such as similar hairstyles, skin tones, clothing styles, and gender, indicating that students were beginning to imagine themselves actively participating in scientific work.

Figure 10

Examples Of Student Post-Test Drawings in Which Students Drew Themselves as Scientists

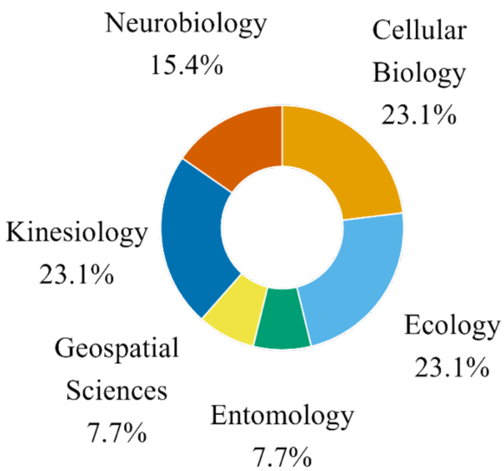
Note. The top-left and top-right drawings show ecologists. The bottom-left depicts a geospatial scientist. The bottom-right shows an entomologist.

Content Analysis

Although students appeared to favor the themes Ecology, Kinesiology, and Cellular Biology, with each receiving 23.1% of total votes (*Figure 11*), a Chi-squared goodness-of-fit test, which is commonly used to compare categories to determine whether they differ from random chance, indicated no statistically significant differences in preference across themes ($\chi^2(5) = 2.23, p = 0.82$). This suggests that student interest was relatively the same across all topics.

Figure 11

Distribution of K-5 Students' Favorite Topics

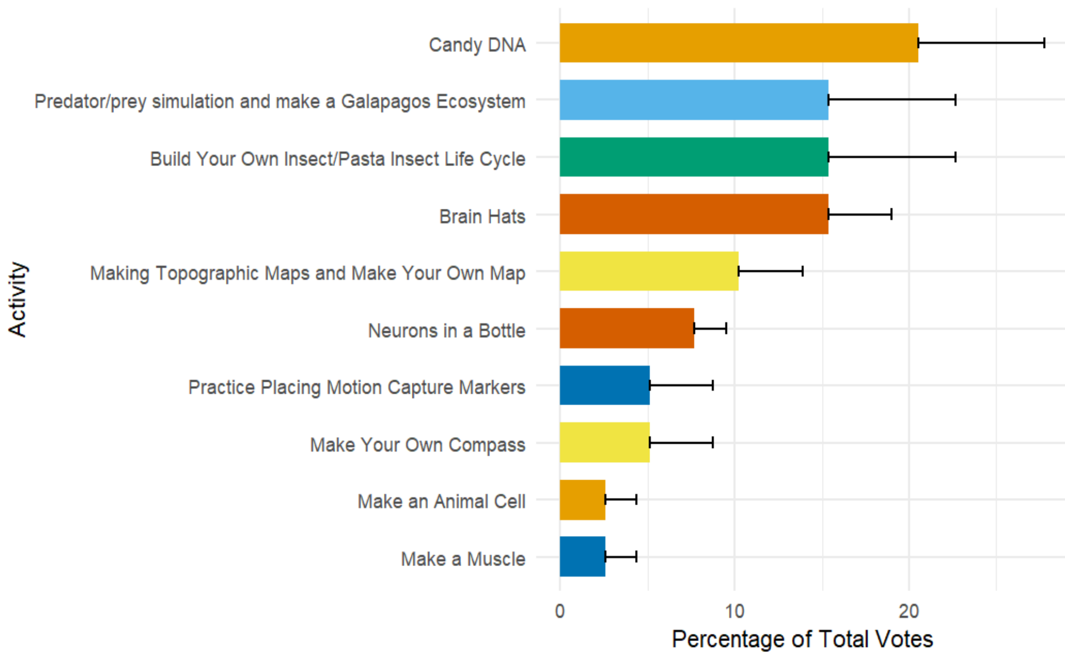


Note. The Chi-squared goodness-of-fit test indicated no statistically significant differences in the number of votes across topics ($\chi^2(5) = 2.23, p = 0.82$), suggesting that student preferences were relatively evenly distributed.

Of the 16 students who responded to the favorite activity prompt, students could select up to three activities, resulting in 39 total votes. Because of this, the percentages shown in *Figure 12* reflect the percentage of total votes rather than the percentage of students. For example, 2.6% represents one student vote, 5.1% represents two votes, and 20.5% represents eight votes. As far as simple ranking is concerned, the "Candy DNA" activity may have ranked highest simply because students had the opportunity to eat candy afterward. As for the three activities that tied for the second place rank, each of those activities involved toys ("predator/prey simulation and make a Galapagos ecosystem," "build your own insect/pasta insect life cycle," and "brain hats" with plastic Galapagos wildlife figures, a plastic insect and a magnifying jar to view insects in, and a colorful hat respectively) that might lend themselves better to free play outside of the activity as compared to the other hands-on materials from other activities. This may have contributed to their higher ranking. However, an ANOVA indicated no statistically significant difference in preference across activities ($p = 0.551$), suggesting that although some activities received slightly more votes, students were broadly engaged across the full set of activities.

Figure 12

Percentage of Votes for K-5 Students' Favorite Activities Per Topic



Note. Error bars indicate the standard deviation of responses for each activity. An ANOVA test found no statistically significant differences in voting across activities (p = 0.551), suggesting relatively even engagement across different learning experiences.

Discussion and Implications

Although tailoring preparatory lessons to individual speaker presentations did not produce measurable gains beyond the previously used approach, the overall improvements in student learning suggest that scientist-led virtual outreach remains an effective strategy for increasing elementary students' awareness of diverse STEM disciplines. These findings extend the growing literature demonstrating that scientist-led outreach can broaden participation in STEM by providing authentic interactions with STEM professionals and increasing students' exposure to STEM careers (Abramowitz et al., 2024; Miller et al., 2018). They also support research suggesting that virtual interactions with STEM role models can expand access to authentic STEM experiences, promote students' sense of belonging, and encourage them to envision themselves in future STEM pathways, particularly when in-person opportunities are limited (Skov & Lykke, 2022).

Lessons, activities, and speaker presentations were effective in improving students' pre- to post-test scores, indicating that the after-school program helped students accurately represent the different subfields of science related to each week's theme. However, meeting with speakers to design a curriculum to better prepare students for their presentations did not appear to affect students' background knowledge, as perceived by the speaker, compared with having an impact on student background knowledge as perceived by the speaker over the previously used method of teaching about the weekly topic in general. It may be worthwhile to continue this approach, as a larger sample size may reveal a different trend. Another point to consider is the subjectivity in interpreting the background information survey question, which may have prevented an accurate measurement of changes in students' perceived background knowledge. To clarify, self-report measures are susceptible to response-shift bias when participants' understanding of the construct being measured changes over the course of an educational intervention (Drennan & Hyde, 2008). In future semesters, student-generated questions for guest speakers could also serve as a useful indicator of preparedness, as could brief oral reflections completed immediately after the presentation. Collecting these data alongside speaker surveys may provide a clearer picture of how well students are prepared for guest presentations. Likewise, family feedback surveys could be reintroduced (*McMahon et al., 2022*) as another metric for gauging students' preparedness. At the same time, other methods for improving preparedness may continue to be explored, such as having students prepare questions for speakers in advance or asking speakers to provide an introductory slide for use during the first lesson of the week.

Other lessons were also gleaned throughout the Fall 2023 semester, providing valuable learning opportunities to improve the program going forward. Because Wonderkids is a virtual program, internet disruptions remained a significant hurdle, with frequent connection losses affecting both presenters and students. Connectivity challenges are a well-documented barrier to effective online learning and virtual instruction (Dhawan, 2020). To mitigate this, each Zoom session was staffed by three personnel: a graduate fellow, an undergraduate assistant, and a JEP staff member in a support role, alongside the guest speaker. This redundancy allowed the program to continue seamlessly even when the primary speaker's connection faltered. Similar staffing strategies have also been employed in virtual STEM outreach programs to maintain continuity and provide technical support during synchronous events (Prizlow et al., 2022). Additionally, students experiencing connectivity issues could quickly rejoin sessions thanks to dedicated staff monitoring the chat and waiting room, and missed material was accessible via recorded sessions on YouTube and Facebook.

The varying environments from which students joined, such as playgrounds, buses, or cars, underscored the role of the digital divide in shaping students' online learning experiences. Although internet access is essential for successful distance education (Hosszu & Rughiniş, 2020), equitable participation also depends on having appropriate learning spaces, technology, and materials. These challenges reflect the first level of the digital divide, which concerns access to internet infrastructure and the ability to remain connected (Robinson et al., 2015). To reduce these inequities, WonderKids implemented proactive muting controls managed by staff and mailed backpack-friendly packets containing all necessary activity supplies, including common items such as tape and crayons, enabling students to participate more equitably regardless of their learning environment. A significant takeaway was the benefit of providing a "lab notebook" to help students manage and organize their materials, especially those in transient settings. Another aspect that emerged was the participation of siblings or cousins, often merged into a single session for family convenience. This approach, which involved accommodating older students in lower grade levels when requested, worked well and could be proactively offered in future sessions.

To ensure smooth presentations, it proved beneficial to require speakers to join the Zoom room 15 minutes early to finalize and test their materials. Similarly, other virtual STEM outreach programs have recommended that presenters and activity leaders join meetings before participants to troubleshoot technical issues and ensure events run smoothly (Prizlow et al., 2022). Offering speakers the option to pick up or receive activity materials before their presentation may further increase engagement by allowing them to participate alongside students. It was also valuable to maintain contact with additional potential speakers who could serve as back-ups in the event of scheduling conflicts, a strategy that proved necessary during the program. These considerations may benefit other organizations implementing virtual STEM outreach programs by improving program reliability, minimizing disruptions, and creating a more engaging learning experience.

When polled about future topics, students expressed interest in mycology, forestry, engineering, oceanography, mathematics, astronautical science, vocology, paleontology, and volcanology. With ample interest from students in a variety of new themes, a large network of potential speakers through connections to USC, and the incorporation of new ideas into an already effective science communication program, the WonderKids program is well-positioned to continue providing after-school science education to Los Angeles' K-5 students. Ultimately, providing students with opportunities to connect personally with scientists and see themselves represented in STEM is essential for fostering a lasting sense of belonging, curiosity, and confidence to pursue future educational and career pathways in science.

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Supplementary Materials

Supplementary resources can be found by following the links provided in the table below. These links include 1) PDFs of all lesson PowerPoints, 2) a list of materials and links to print-outs for all activities, 3) a YouTube playlist of edited versions of all virtual WonderKids lessons from 2020 to the present day (2025), and 4) a GitHub repository of all R and Python code used for statistical analysis presented in this article.

Resource Description	**Permalink**
Presentation PDFs of individual lessons	https://drive.google.com/drive/folders/1-1Dj84sa59nFREHzQsNyFpOtb99DnH20?usp=drive_link
Materials procured for activities, including links to printable worksheets	https://docs.google.com/document/d/1bMnPNNPKg1B-4Ylws-qbbaJUzLTmcHwwj3nOsv1xsh0/edit?tab=t.0
YouTube Videos of lessons	https://www.youtube.com/watch?v=XcHUq3_X74U&list=PLU0ue4Xv_K1udN1Nd_DUlmonps7cAh9EG
Raw code for analyses	https://github.com/CharlesLehnen/WonderKids_2023