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Young Children's Self-Regulated Learning Benefited from a Metacognition-Driven Science Education Intervention for Early Childhood Teachers

Shiyi Chen [1,*], Rebecca Sermeno [1], Kathryn (Nikki) Hodge [1], Sydney Murphy [1], Ariel Agenbroad [2], Alleah Schweitzer [3], Ling Ling Tsao [1] and Annie J. Roe [1]

[1] Margaret Ritchie School of Family and Consumer Sciences, University of Idaho, Moscow Idaho, ID 83843, USA; serm7353@vandals.uidaho.edu (R.S.); hodg6069@vandals.uidaho.edu (K.H.); murp5065@vandals.uidaho.edu (S.M.); ltsao@uidaho.edu (L.L.T.); aroe@uidaho.edu (A.J.R.)
[2] Community Food Systems & Small Farms, University of Idaho Extension, Boise Idaho, ID 83714, USA; ariel@uidaho.edu
[3] Student Wellness Center, Dartmouth College, Hanover, NH 03755, USA; alleah.e.schweitzer@dartmouth.edu
* Correspondence: shiyic@uidaho.edu

Abstract: The two goals of this study are to examine the impact of an early childhood teacher's metacognition-driven, place-based science teaching professional development (PD) intervention and to explore the association between science teaching and environment quality and children's self-regulated learning. A total of 110 children (Mage = 60 months) and 20 teachers from preschools and kindergartens in rural regions of Idaho, U.S., participated in this mixed-methods study between August 2022 and May 2023. Children's and teachers' pre-test and post-test data were collected using validated observation tools, surveys, and reflection journals. The results from repeated measures ANOVA and linear mixed regression show that there were statistically significant increases in children's self-regulated learning scores and teachers' science teaching efficacy and metacognitive knowledge, but not metacognitive regulation skill scores post-PD. Thematic analysis revealed evidence about children's learning interests and inquiry skills, and that science activities supported children's learning in other subjects and developmental domains (e.g., literacy, mathematics, and social-emotional skills). Our results indicate the potential for supporting young children's self-regulated learning by training teachers to implement a developmentally appropriate, hands-on science curriculum that focuses on reflective thinking and a holistic understanding of science concepts and process skills.

Keywords: early childhood; science education; self-regulated learning; metacognition; professional development

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1. Introduction

1.1. Self-Regulated Learning

In an age of information technology characterized by an abundance of rapidly evolving knowledge, cultivating self-regulated learners is becoming increasingly important [1]. Self-regulated learning (SRL) is an umbrella term that includes cognitive, metacognitive, social–emotional, and motivational aspects of learning [2,3]. Self-regulated learners have a proactive and adaptive approach to learning, which equips them with the skills and mindset to navigate complex education settings and beyond [4]. Self-regulated learners master their own learning by setting goals, applying effective learning strategies, and pressing on in the face of challenges [2]. Research has linked self-regulated learning to school outcomes from childhood to adolescence across several subject areas [5,6].

Early childhood is a prime time window for fostering SRL, given young children's rapidly developing cognitive faculties [7,8]. Teachers' instructional support and learning

environment play an important role in nurturing children's SRL [9]. In particular, teachers' support during science inquiry learning activities may have great potential to support children's SRL [10–12], given that the inquiry learning cycle (i.e., ask, investigate, create, discuss, reflect) mirrors the SRL model [13,14]. Therefore, this present study aims to examine the effect of an early science education intervention on children's SRL.

1.2. Young Children's SRL and Metacognition

Zimmerman's theoretical model of SRL [15], although widely adopted, does not account for young children's cognitive limitations [16]. Preschool- and kindergarten-aged children's SRL is still developing; as a result, they may have challenges in effectively regulating their learning processes [16]. Some of these challenges include limited cognitive control, difficulty with goal setting, and limited understanding of one's cognitive processes, which could be due to young children's immature executive functioning (i.e., a collage of cognitive abilities such as working memory, cognitive flexibility, and inhibitory control [17]). Therefore, this study adopted a theoretical framing of SRL more suited for young children, as proposed by Bronson and Bronson [18], and Whitebread and colleagues [19]. This framework includes four categories of SRL: emotional (e.g., regulate one's emotions, especially when facing challenges), prosocial (e.g., collaborate with others and being aware of others' feelings), cognitive (e.g., aware of oneself and strategies), and motivational (e.g., initiative and task persistence).

A defining characteristic of SRL is the ability to regulate one's own cognition and motivation during a learning episode [15], and the prerequisite for SRL is metacognition [20]. Metacognition is a cognitive function that involves being aware of and controlling one's mental processes [21,22]. Metacognition researchers agree on the three core components of metacognition [22–25]: metacognitive knowledge (i.e., knowledge about the person, task, and strategies), monitoring (i.e., gauging one's cognition during a goal-oriented task), and control (i.e., using information gathered during metacognitive monitoring to adjust subsequent actions to facilitate problem solving).

Whether and to what extent young children (e.g., age 3–5 years) can think metacognitively is debatable in the fields of education and psychology [26–29]. Early metacognition researchers claim that metacognition does not emerge until middle childhood [29]. This notion is partly due to the measurement limitation—many relied heavily on the participants' language ability to report their mental processes, which young children lack [9,30]. More recent research has used developmentally appropriate methods to assess young children's metacognition, such as play-based observation tools [19,23], interviews [31], and simple computer tasks [32]. In general, researchers found that young children could reflect on their own thinking; however, they tend to overestimate their task performance and struggle with calibrating their decision making based on cognitive monitoring [33]. These results echoed recent neuroscience findings: the neural correlates of metacognition seem to reside in the anterior cingulate cortex—a brain region that connects the prefrontal cortex with the limbic system and plays an important role in motivation, decision making, and error monitoring but which is far from maturing during early childhood [34,35]. Therefore, adults' facilitation and enriched environments are necessary to leverage metacognition and SRL to promote young children's learning and development [36,37].

1.3. Foster Young Children's SRL

SRL can be improved through the direct teaching of learning strategies [38], interactions with others [37], and enriched learning environments [5]. Ample studies have examined effective SRL strategies that are teachable and applicable in education settings, such as setting learning goals, concept mapping, reciprocal teaching, and cognitive reflection [39–41]. Yet, the majority of these studies are conducted with older children and adults [42–44]; as a result, many SRL strategies do not apply to the early childhood age group (i.e., preschool- and kindergarten-aged children). Given young children's rapidly evolving mental capabilities, developmental appropriateness is the key when it comes to

supporting their learning and development [16,45,46]. Some commonalities across studies on pedagogical practices that foster young children's SRL and metacognition are adults' dialogic support, modeling, and learning context [20,37,47].

1.3.1. Teachers as Agents and Learners of SRL

Teachers have a dual role in fostering children's SRL as agents and learners of SRL [48]. First, teachers operate as agents of SRL by providing instructional support to children. Research studies shed light on ways that early childhood teachers can support young children's SRL, such as directly teaching SRL strategies (e.g., setting learning goals and reflecting on learning experiences), scaffolding, promoting learners' autonomy, providing constructive feedback, and creating a learning environment that values explorations and collaboration [20,49]. These teaching strategies are linked to children's learning gain and growth in SRL [47]. However, much less empirical attention is paid to the teachers' second role as learners of SRL. To help children develop their SRL, teachers must first become competent self-regulated learners themselves [50]. The four SRL competence components are teachers' SRL knowledge, skills, self-efficacy, and motivation/value [48]. Purposeful training, such as teachers' preparation and professional development programs, is pivotal to enhancing teachers' SRL competence [51].

1.3.2. SRL and Early Science Learning

SRL can be supported by an array of subject domains in early childhood classrooms, such as literacy and mathematics [4,49]; however, we argue that early childhood science activities, with proper support from teachers, provide a prime context to foster young children's SRL. Children are born inquisitive and eager to learn through hands-on exploration [52,53]. Science learning activities capitalize on young children's innate curiosity, promote autonomy, and foster metacognitive thinking and problem-solving skills, all of which are essential components of SRL [54]. Additionally, with the absence of standardized testing, early childhood teachers have a higher degree of freedom to pursue science activities driven by children's interests as compared to their counterparts in higher grades, making science learning uniquely suited for early childhood education [55].

1.4. Science Learning in Early Childhood Classrooms

1.4.1. Science Learning Starts Early

Contrary to the notion that science only takes place in laboratories led by highly trained scientists, young children, as young as infants, possess rudimentary scientific reasoning skills [53,56,57]. In Walker and colleagues' study [57], 18–30-month-old children were capable of discovering the association between sounds and different buttons on a box through trial and error, indicating that very young children could detect patterns of conditional probability and exhibited a rudimentary form of causal reasoning. Indeed, young children possess some domain-general learning skills and are already "experts" in learning through experimentation—the core of scientific discoveries [58].

Science learning does not only start early; scientific exploration is also developmentally appropriate for supporting children's learning [59,60]. During preschool and kindergarten, children's symbolic thinking emerges, and abstract reasoning becomes more and more explicit [28]. This transformation is aided by adults' support and hands-on learning materials, which allow children to manipulate and experiment while engaging multiple senses [61]. Science activities often involve experiential learning, and it is through interacting with hands-on materials that young children form abstract understandings of a scientific concept from concrete representations [62].

1.4.2. Developmentally Appropriate Early Childhood Science Education

Research findings in neuroscience and cognitive and developmental psychology shed light on possible reasons that integrative science learning is developmentally appropriate for young children. Brains process information from different sensory modalities such as

visual, audio, and tactile information in a coordinated manner [63]. Integrative learning, such as learning mathematics and language while engaging in hands-on science activities, stimulates various areas of the brain to generate a more comprehensive understanding of information [64,65]. This is especially important for young children, to whom experiential learning transforms concrete objects into abstract understanding [45,66]. Also, early childhood is a sensitive period in human development, where children's brains are constantly organizing synaptic connections in response to the environment and experiences (i.e., brain plasticity) [7]. Adults' support (e.g., asking open-ended questions, activating prior knowledge) is particularly important for early science learning because it can offset young children's cognitive limitations and boost science learning outcomes [46]. Therefore, providing young children with individualized support and environments enriched with science learning opportunities is crucial for their knowledge gain as well as for later development [67].

Early childhood science teaching traditions include various approaches aimed at introducing young children to scientific concepts and scientific process skills [50]. Examples of these traditions include outdoor exploration (i.e., observing and interacting with natural elements in the outdoors), hands-on experiments (i.e., allowing children to test their hypotheses by interacting with science materials), storytelling (i.e., learning science concepts in a narrative format), sensory learning (i.e., engaging children's senses during science exploration), child-led inquiry (i.e., giving children opportunities to ask questions and investigate), and integrative science learning (i.e., incorporating science in everyday activities like cooking and gardening) [68]. Overall, these traditions prioritize active engagement and children's curiosity, promote science concept learning, and foster a sense of appreciation for science [69].

Research studies on developmentally appropriate early childhood science education focus on understanding how young children develop general scientific skills, attitudes, and concepts in specific domains (e.g., weather and seasons; plants and animals; living and nonliving things) [70]. There are several trends in current research on early childhood science education. There is a notable emphasis on integrating science learning with other subject areas such as technology, engineering, art, and mathematics (i.e., STEAM) in children's daily lives [71]. Moreover, early childhood science education seems to deviate from the traditional teacher-centered approach to child-centered approaches, such as problem-based learning and inquiry-based learning [61]. Family and community engagement are also recognized as a crucial component of early childhood science education [72].

1.4.3. Current State of Science Learning in Early Childhood Education Settings

Despite the multifaceted benefits of early science education, science is a much less emphasized subject area in early childhood education [62,71]. Research investigating early childhood teachers' instructional time allocations found that teachers spent much less time on science activities than on literacy, language, mathematics, and social study activities [73,74]. Relatedly, early childhood teachers' perceived confidence and capacity in teaching science is lower than in other subject areas, which may lead to fewer science learning opportunities in the classroom [73,75]. Previous research also indicates that some early childhood science activities are hands-on but not "minds-on"; in other words, teachers tend to pay more attention to the pragmatics of the science activity than how children can make sense of what is being performed [76,77]. Inquiry-based science learning activities, for example, require learners to propose predictions by drawing on existing knowledge and form conclusions by comparing hypotheses with evidence gathered during investigations [54]. The cognitive skills involved in inquiry based learning are still developing in preschool and kindergarten children [16], which may impede their ability to construct accurate understanding from inquiry learning activities [68]. Young children's cognitive limitations underline the importance of teachers' effective support during science learning activities via approaches such as questioning and activating prior knowledge [78]. How-

ever, early childhood teachers' science learning support seems to be sporadic rather than purposeful [79].

Researchers have identified several challenges that may have hindered early childhood teachers' capacity and willingness to conduct science activities, for instance, the lack of developmentally appropriate science pedagogical content knowledge [79], poor resources [80], and classroom management issues [81]. Further, many early childhood curricula and learning standards emphasize literacy and mathematics more than science [73], which can partially explain the unbalanced instructional attention [53]. Additionally, early childhood teachers tend to be anxious about conducting science activities because they doubt their ability to answer children's questions [82]. This issue indicates teachers' belief that they must have comprehensive knowledge about certain science topics in order to lead an activity [81]. However, teachers should adopt and model the mindset that science is a dynamic discovery process; a gap in their understanding is not embarrassing, rather, it affords an opportunity for learning with children [82].

1.5. Professional Development Programs

To nurture children's SRL using science activities, teachers must become competent self-regulated learners who possess the necessary knowledge and positive attitudes towards science [83]. Well-designed education interventions, such as teachers' PD programs, can help teachers become self-regulated learners [68,69]. It is important to note that not all PD programs are education interventions by default [84]. For a PD program to become an education intervention, it must have a purposeful education and research design, evidence-based activities, targeted areas of improvement, and empirical data that can support the effect of the PD program [85]. A recent meta-analysis on effective education intervention targeting children's SRL and metacognition indicates that contrary to popular beliefs, teacher-administered education interventions yielded a larger effect than researcher-led ones [86]. This might be because trained classroom teachers, as compared to researchers, were able to provide more immersive interventions and encouraged the transfer of the learned skills to other domains [37]. Therefore, training teachers through PD programs could have a positive downstream effect on their students' learning.

1.6. Empirical Gaps

First, although the SRL framework reflects the iterative, trial-and-error nature of scientific discovery, there is very limited research on the application of SRL and metacognition in science learning during early childhood [13,30]. The relation between metacognition and learning is well established among older children and adult learners [85,87], but more research is needed to investigate how to use science activities to foster young children's metacognition and SRL [30]. The second empirical gap is the lack of research on the features of effective teachers' PD programs designed to support teachers' and children's metacognition and SRL [9]. The quality of teachers' PD programs targeting early science education varies greatly from one-time online workshops to experiential, systematic training over a prolonged period of time [67,88,89]. The development of cognitive skills such as SRL and metacognition require sustained, targeted efforts [90]; however, it is not very clear what kind of PD design facilitates the transformation of teachers' pedagogical knowledge to instructional practices that will eventually benefit children [91,92].

1.7. The Present Study: Aims, Research Questions, and Hypothesis

Informed by the existing literature and empirical gaps, we created a ten-month science education intervention that focuses on SRL and metacognition—Farm to Early Care and Education (Farm to ECE). Farm to ECE adopts a progressive online training plus an in-person coaching model with supplementary curricula that allows teachers to enact their training in real-world scenarios. The goals of this study are twofold: (1) to examine the effect of Farm to ECE on children's SRL and (2) to explore the association between science

instructional environment quality and changes in children's SRL. The specific research questions and hypotheses are as follows:

- RQ1: Does the education intervention lead to a significant gain in teacher-level outcomes, as measured by teachers' science teaching efficacy and metacognitive awareness? We hypothesize that the teacher-level outcomes will improve after the education intervention.
- RQ2: Does the education intervention lead to a significant gain in children's SRL scores? We hypothesize that children's SRL will increase after the educationintervention.
- RQ3: To what extent are changes in young children's SRL related to science teaching and environment quality? We hypothesize that better science instructional environment quality is associated with greater improvements in children's SRL.
- RQ4: What insights can be gained from teachers' reporting of children's learning during the education intervention? We hypothesize that teachers' reports will provide authentic information on various aspects of children's learning experiences.

2. Materials and Methods

This mixed-methods study was approved by the Institutional Review Board (IRB) at the lead author's university (IR protocol code 21-233). The data presented in this paper were collected between August 2022 and May 2023.

2.1. Participants

The targeted sample sizes in this study were based on a priori power analysis conducted using the software Optimal Design. The results indicated that 22 teachers and 132 children were needed to detect a statistical significance with an alpha of .05 and a power of .80. Eligible participants were preschool and kindergarten teachers and children (age = 4–6 years, typically developing) within two hours driving distance from the lead author's university from rural regions of north Idaho, U.S. Trained research assistants contacted potential participating teachers via phone calls, emails, and a recruitment event at a regional child development conference in the summer of 2022. Participating teachers then distributed parental consent forms to eligible children in their classrooms. For each teacher, approximately six children were randomly selected for data collection from all the consented children.

A total of 21 teachers consented but one dropped out due to not having eligible children in the classroom ($N_{teacher}$ = 20) (Table 1). On average, the teachers' age was 36.74 years old (SD = 10.34, range = 22–57), they were predominately White (75%), 60% had a Bachelor's degree and above, and their teaching experiences ranged from 3 to 29 years (SD = 6.69). The child sample consisted of 110 children and had slightly more boys than girls (N_{boy} = 62, N_{girl} = 48), with an average age of 60 months (SD = 7.76, range = 44–87).

Table 1. Participants' demographic information.

		N	M/Percent
TEACHER			
Gender:	Male	1	5%
	Female	19	95%
Age (yrs.)		20	36.74
Ethnicity/Race:	Hispanic	3	15%
	Non-Hispanic White	15	75%
	Other	2	10%
Grade:	Preschool	17	95%
	Kindergarten	1	5%
Have a certification		8	40%
Have a CDA		6	30%
Degree:	GED	3	15%
	HS	2	10%

Table 1. *Cont.*

		N	M/Percent
	AA	2	10%
	BA/BS	12	60%
	MA/MS	1	5%
Experience (yrs.)		20	9.35
CHILD			
Gender:	Boys	62	56%
	Girls	48	44%
Age (mo.)		110	60
Ethnicity/Race:	Hispanic	8	7.3%
	Non-Hispanic White	95	86.4%
	Bi- or Multi-racial	7	6.3%

Note. AA = Associate degree, BA/BS = Bachelor's degree, CDA = Child Development Associate Credential, GED = General Education Diploma, HS = High School, MA/MS = Master's degree, mo = month, yrs = years.

2.2. PD Intervention Design and Implementation

This year-long education intervention was in the form of a teachers' PD program and was divided into the spring and fall seasonal segments. In Farm to ECE, teachers were not only learning science background knowledge and developmentally appropriate science teaching practices (e.g., activating prior knowledge, open-ended questions, and sensory learning) via an online learning platform (i.e., Canvas) but also receiving monthly curricula and activity materials (i.e., "Harvest of the Month" toolkit) to facilitate the transformation of pedagogical knowledge into instructional practices and to enrich their science learning environment [67,89].

A typical training module included an introduction video (overview of the curriculum and teaching strategies introduced in that curriculum), a detailed explanation and demonstration of the teaching practices introduced in a given curriculum, and digital resources that complement the curriculum (e.g., song, recipe, dance).

The "Harvest of the Month" toolkit (Figure 1) was distributed to teachers at the beginning of each month. It included seasonal vegetables/grains/fruits (e.g., plums, beets, lentils, microgreens) purchased from local farms, a plant-themed children's book, detailed lesson plans, vocabulary cards, and family engagement newsletters.

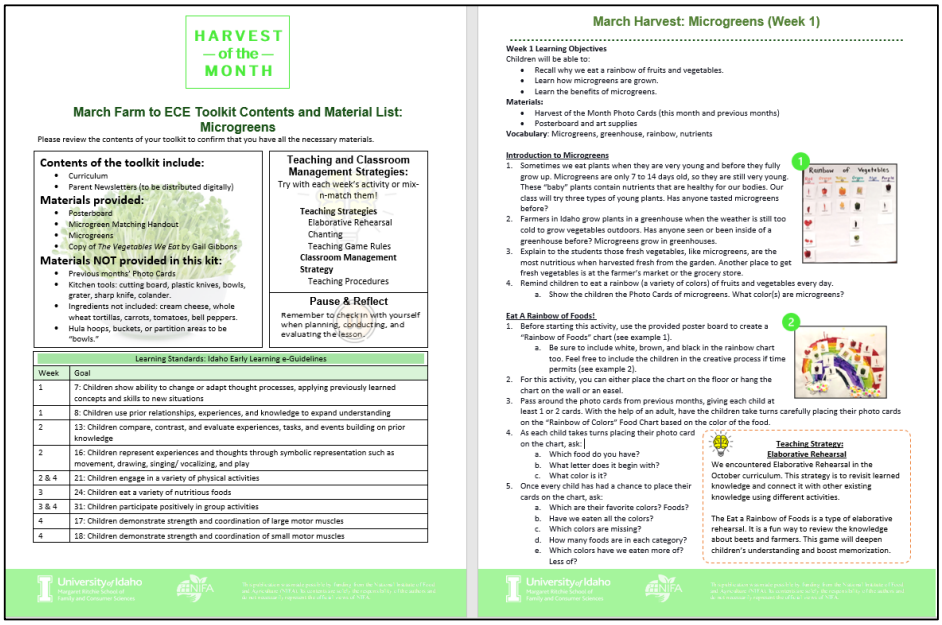


Figure 1. Harvest of The Month toolkit example: March microgreen curriculum.

The monthly curriculum included four lesson plans that were supplementary to teachers' primary curriculum—this was to avoid adding too much work into teachers' existing workload. A unique teaching practice (e.g., concept map, scripted reflective prompts) was incorporated into each lesson plan. Teaching practice textboxes were added next to each activity with detailed explanations of the learning science behind the teaching practice. The design of activities was aligned with the Idaho Learning e-Guideline and was developmentally appropriate for 3-to-6-year-old children. The content of the Farm to ECE curriculum was also aligned with the core components of the National Farm to School program.

Each month's activities (see Figure 2 for examples) centered on the basic plant science concepts related to the featured vegetables/grains/fruits while crosscutting several science teaching traditions such as hands-on experiments, storytelling, sensory learning, and child-led inquiry learning traditions [43,45]. For example, week 1 activity typically included an introduction, where teachers presented the real vegetables/grains/fruits to children and encouraged children to explore with all their senses. Week 2 activities usually included more in-depth investigation using science experiments (e.g., sink-or-float experiments with apples and pears) and observation (e.g., beans germination). Week 3 activities were typically shared book reading (e.g., "A Fruit is a Suitcase for Seeds"). The purpose of the week 4 activity was to review what they had learned in the previous weeks using physical movements. For instance, in the "Fruit Tree Yoga" activity, children were asked to recall the lifecycle of a fruit tree and use yoga poses to demonstrate their understanding. The lesson plan of each week's activities details the activity materials, procedures, and scripted open-ended questions that teachers could use to introduce vocabulary words (e.g., beets, rhubarb, hypothesis, investigate), encourage children to make predictions/hypotheses (e.g., "Will the apple sink or float?"), investigate the phenomenon (e.g., "Let us fill the bucket and find out which one sinks and which one floats."), observe and collect evidence (e.g., teachers will record children's hypotheses and the experiment results on a large Post-It easel pad), and discuss the experiment results (e.g., "Take a look at your hypotheses, did you guess it right?", "Why do you think the apple floats but the pear did not?").

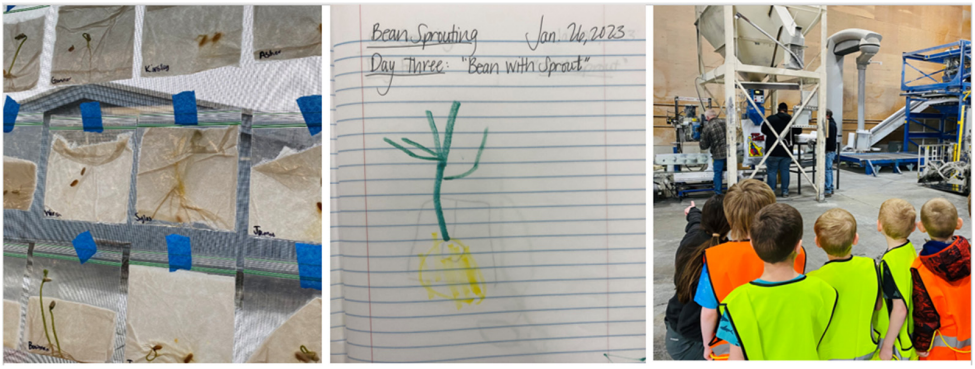


Figure 2. Photographs of the PD program implementation. Note. Left to right: bean germination experiment, bean germination journal, and visiting a local granary.

Metacognitive knowledge (i.e., knowledge about the person, teaching strategies, and teaching tasks [25]), was incorporated into the PD in various forms based on previous research on metacognition intervention. For instance, teachers were required to complete quarterly self-reflection journals and pre- and post-PD assessments [86]. Also, teachers were explicitly taught about metacognition, SRL, science content knowledge related to the curriculum, and science teaching practices (e.g., problematizing modeling, questioning, concept map) using monthly online training modules [91]. Moreover, metacognitive skills (i.e., planning, monitoring, and evaluation) [14] were translated into the PD as journal reflection, workshop, and in-person observation by a trained research assistant [93].

2.3. Procedure

Farm to ECE is a three-year project, and the data presented in this paper were from the year-1 cohort. The year-1 project spanned from September 2022 to May 2023. At the beginning of the PD program in August 2022, teachers participated in a two-and-half hours orientation workshop, led by the first author. The orientation covered topics such as the Farm to ECE curriculum, PD training syllabus, early science learning, metacognition and its application in children's learning, data collection schedule, and Canvas tutorial. Before and after the PD program (i.e., August 2022 and May 2023), teachers completed a series of online and in-person assessments for their science teaching efficacy, metacognitive awareness, science teaching and environment quality, and SRL rating scales. In particular, teachers were required to complete an SRL rating scale for each of the six randomly selected children (with parental consent) in their class during pre- and post-test. During the first week of each month, every teacher received a "Harvest of the Month" toolkit (the toolkit content is described in a previous section) and was required to complete the monthly online training module prior to implementing the curriculum activities by reviewing the online training materials. Teachers' online engagement statistics (e.g., page viewing frequency and duration, etc.) were monitored by the research assistants. The fidelity of the implementation data were collected using an observation tool—Science Teaching and Environment Rating Scale (STERS, [94], α = .94)—at two different time points in November 2022 and April 2023. For each STERS data collection session, trained research assistants observed one Farm to ECE curriculum activity in the classroom and interviewed teachers about their lesson planning and instructional decision-making process after the observation on the same day. The observation field notes and interview transcripts were then independently scored by two trained research assistants using a validated rubric. Upon program completion, each participating teacher received ninety PD credits and a USD 1500 stipend.

2.4. Measurement Instruments

2.4.1. Children's SRL

We measured children's SRL using the Children's Independent Learning Development checklist (CHILD; α = .97; [19]; Appendix A). CHILD is a teacher-reported rating scale that measures children's SRL behaviors. The instrument contains four subscales: cognitive (seven items, e.g., the child adopts previously heard language for own purposes), motivational (five items, e.g., the child plans own tasks, targets, and goals), prosocial (five items, e.g., the child shares and takes turns independently), and emotional subscale (five items, e.g., the child can monitor progress and seeks help appropriately). Each subscale uses a four-point Likert scale ranging from Never (1) to Always (4). Given the time commitment of the entire teacher- and child-assessment battery, we did not include the Emotional and Prosocial subscales to avoid overwhelming teachers.

2.4.2. Science Teaching and Environment Quality

Science learning environment quality was measured by the Science Teaching and Environment Rating Scale (STERS; [94], α = .94; Appendix B). STERS assesses the quality of science teaching and environment in early childhood classrooms by drawing on classroom observation and teacher interview data. Trained research assistants observed the classroom science learning environment and a science learning activity from the Farm to ECE curriculum twice a year in the spring and fall semesters. The research assistants then interviewed the teachers about their instructional decision making using a structured interview protocol (Eight questions, e.g., What have you learned about children's understanding of this topic up to this point? Do you use this information for planning, if so, how?). In total, there were 40 observation field notes and 40 interview recordings (average length: eight minutes).

Observation field notes and interview transcripts were scored on a 4-point validated rubric (1 = deficient to 4 = exemplary) across eight indicators: (1) creates a physical environment for inquiry and learning (e.g., provides access to science learning materials), (2) facilitates direct experiences to promote conceptual learning (e.g., engages learners and

assists their learning), (3) promotes the use of scientific inquiry (e.g., intentionally facilitates science process skills), (4) creates a collaborative climate that promotes exploration and understanding (e.g., fosters a science learning environment where children's ideas are valued), (5) provides opportunities for extended conversations (e.g., promotes multi-turn discussion), (6) builds children's vocabulary (e.g., introduces new words), (7) plans in-depth investigations (e.g., provides sufficient time for exploration), and (8) assesses children's learning (e.g., uses on-going assessments). Two trained research assistants scored the observation and interview data independently (κ = .91). Each teacher's STERS score was derived from two sets of observations and interviews collected in the fall and spring semesters. RAs resolved the scoring differences by discussing the scoring results with the lead author.

2.4.3. Teachers' Science Teaching Efficacy

Teachers' science teaching efficacy was measured by the Science Teaching Efficacy and Beliefs (STEB; [95], α_{STEB} = .90; Appendix C) and Science Teaching Outcome Expectancy (STOE; α_{STOE} = .93) subscales in the Elementary Teacher Efficacy and Attitudes toward STEM Surveys (T-STEM; [95]). STEB and STOE are five-point Likert scales that include 40 items in total. An example of a STEB scale item is "When a student has difficulty understanding science concept, I am confident that I know how to help the student understand it better". An example of a STOE scale item is "Students' learning in science is directly related to their teacher's effectiveness in science teaching".

2.4.4. Teachers' Metacognitive Awareness

The Metacognitive Awareness Inventory for Teachers (MAIT; [96]; Appendix D) was used to measure teachers' metacognitive awareness. The MAIT involves 24 items on a five-point Likert scale ranging from strongly disagree (1) to strongly agree (5). The three subscales that measure metacognitive knowledge are declarative knowledge (α = .63, e.g., I am aware of the strengths and weaknesses in my teaching), procedural knowledge (α = .61, e.g., I try to use teaching techniques that worked in the past), and conditional knowledge (α = .63, e.g., I use different teaching techniques depending on the situation). The three subscales that measure metacognitive regulation are planning (α = .73, e.g., I organize my time to best accomplish my teaching goals), monitoring (α = .71, e.g., I ask myself questions about how well I am doing while I am teaching), and evaluating (α = .76, e.g., I ask myself if I could have used different techniques after each teaching experience).

2.4.5. Qualitative Data Collection

For the qualitative data collection, teachers completed four online quarterly reflection journal entries on Canvas. Each entry included five writing prompts that required teachers to reflect on and provide examples of children's activity engagement, things that went well, challenges they encountered, and teaching strategies or science background knowledge that they wished they knew more about (e.g., How was children's engagement? What did not go as planned and how did you resolve it?).

2.5. Data Analysis

We first conducted descriptive analysis to examine the normality of the data and test the assumptions for the subsequent analysis. A series of repeated measures analyses of variance (ANOVA) [97] were used to test the first two hypotheses. Teachers' and children's outcome variables were entered as the dependent variables in each model, respectively. To test the third hypothesis, we used linear mixed models to account for the data's nested structure (i.e., children were clustered in classrooms/teachers). Individual children's scores were centered at the group level to improve the results' interpretability [98]. Fully unconditional models were run before adding predictors [99]. Intraclass correlation (ICC) indicated that the common variance shared at the cluster level (ICC_{cog} = .12, ICC_{mot} = .24) warranted the use of linear mixed modeling [99]. Child-level variables were then entered

at level-1, and teacher-level variables were entered at level-2. Software R (Version 4.3.1) and R package lme4 [100] were used.

Qualitative data were analyzed using a thematic analysis method to identify recurring patterns in the data [101]. A trained graduate research assistant combed through teachers' reflection journal entries and assigned open codes to emerging phenomena. The research assistant then conducted axial coding by further grouping open codes into larger categories (i.e., axial codes) and identifying the relations between the axial codes. For the final step, the leader author and three research assistants held a meeting to discuss axial coding results and emerging themes. Detailed memos, peer debriefing, and the involvement of multiple coders enhanced the credibility of the qualitative data analysis [102].

3. Results

In this section, we describe the data analysis results organized by using the research questions. We first present whether and to what extent the PD program impacted children and teachers' outcomes, and then discuss the relation between science teaching and environment quality improvement to children's SRL scores. Finally, we review the qualitative evidence of teacher-reported children's learning and challenges related to the PD program implementation.

3.1. PD's Impact on Teachers' Metacognitive Awareness and Science Teaching Efficacy

A series of repeated measures ANOVA were used to answer RQ1: Does the education intervention lead to a significant gain in teacher-level outcomes, as measured by science instructional environment quality, teachers' science teaching efficacy, and metacognitive awareness? We did not control any covariates because this study adopted a within-subject repeated measure experimental design; therefore, potential covariates such as teachers' degrees and years of teaching experience were already controlled. Although our sample was slightly smaller than the target sample size, the data analysis results showed some positive effects of the PD program on teachers' outcomes (Figure 3), which partially confirmed our first hypothesis. Specifically, after the PD program, there was an increase in teachers' science teaching efficacy beliefs ($F_{efficacy}(1, 19) = 11.12$, $p = .003$, $\eta^2 = .37$, average score increase post-PD: 4.15) and science teaching outcome expectancy ($F_{expectancy}(1, 19) = 4.33$, $p = .05$, $\eta^2 = .19$; average score increase post-PD: 2.55). Also, teachers' metacognitive knowledge awareness showed meaningful improvement after the PD program ($F_{awawre}(1, 19) = 6.90$, $p = .02$, $\eta^2 = .27$, average score increase post-PD: 2.65). Contrary to what was expected, teachers' metacognitive regulation skills were not statistically different before and after the PD ($F_{reg}(1, 19) = 1.76$, $p = .20$).

3.2. Children's SRL

To answer RQ2—Does the education intervention lead to a significant gain in children's SRL scores?—we conducted linear mixed modeling with child outcomes at level-1. There was no predictor added at level-2, which only accounted for the unobserved variance explained by the class/teacher differences. The cognitive and motivational subscales showed satisfactory reliability in our sample ($\alpha_{cog} = .96$, $\alpha_{mot} = .90$). The results indicate that there was an increase in teacher-reported children's cognitive skills ($F(1, 109) = 20.08$, $p < .001$, $\eta^2 = .16$), with an average of 1.68 points increase after the PD. There was also a significant improvement in children's learning motivation ($F(1, 109) = 13.50$, $p < .001$, $\eta^2 = .11$), with an average of .14 points increase post-PD (Figure 3). The data analysis results confirm our second hypothesis.

3.3. The Association between Science Teaching and Environment Quality and Children's SRL

To answer RQ3—To what extent are changes in young children's SRL related to science teaching and environment quality?—linear mixed modeling was used with children's cognitive and motivation gain scores (i.e., post-test scores minus pre-test scores) at level-1 and teachers' science teaching and environment quality at level-2. Note that the science

teaching and environment quality scores were not used as pre-test and post-test scores because data were collected in November 2022 and April 2023 for fidelity monitoring and PD coaching purposes. The science teaching and environment quality scores were derived from data collected at both time points in order to better represent the quality of the science instructional environment. The results showed that gain scores in the cognitive ($t(14) = 2.33$, $\beta = .24$, $p = .02$) and motivational ($t(14) = 2.16$, $\beta = .15$, $p = .03$) aspects of SRL were significantly associated with the quality of science instructional practices and learning environment. In other words, children tended to have better SRL skills when their teachers had better science teaching practices and when their classroom environment was conducive to science learning.

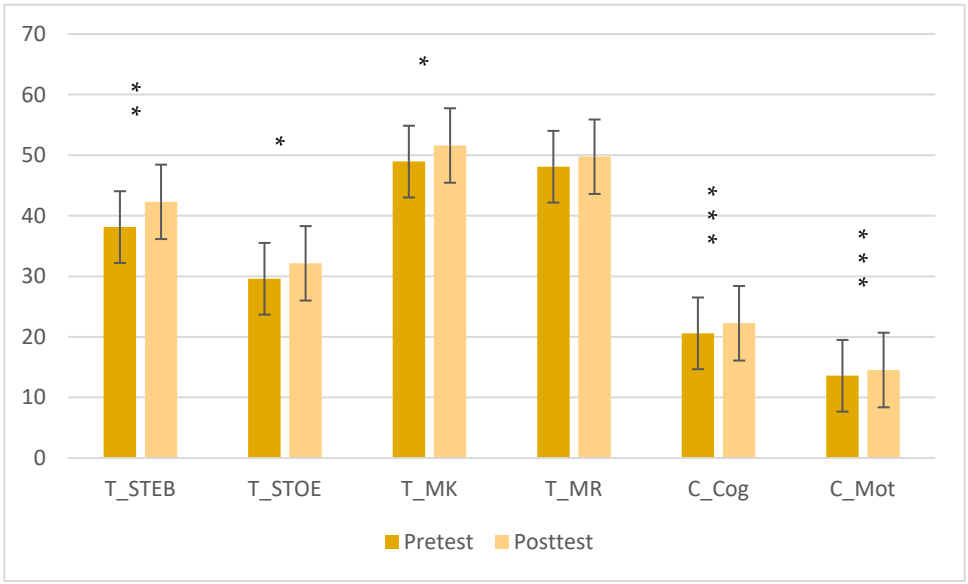


Figure 3. Teacher's and children's pre-test and post-test results. Note. * $p < .05$, ** $p < .01$, *** $p < .001$, C = child, Cog = cognition, MK = metacognitive knowledge, Mot = motivation, MR = metacognitive regulation, STEB = science teaching efficacy beliefs, STOE = science teaching outcome expectancy.

3.4. Qualitative Evidence

To answer RQ4—What insights can be gained from teachers' reporting of children's learning during the education intervention?—we used a thematic analysis method to analyze teachers' structured reflection journals. The results are discussed by themes below.

3.4.1. Children's Learning Interests and Engagement

Teachers' written reports revealed evidence of children's strong interests in the curriculum materials, particularly those hands-on activities (e.g., bean germination experiment, learning games, and fruits/vegetables/grains exploration). For example, a teacher wrote: "*Overall, their engagement was exceptional. Each child had an excitement in the fruits and vegetables being discussed and we were all able to connect over different home/life experiences with the material and the lesson*". Another teacher reflected: "*My preschoolers loved learning about fruits and vegetables during September and October. . .. having the actual fruits and vegetables to see, smell, feel, and taste was very fun for them!*". However, several teachers mentioned that younger preschool children tended to lose interest quicker than older children.

3.4.2. Science Activities Support Learning in Other Subject and Developmental Domains

The Farm to ECE curriculum primarily focused on the teaching of basic plant science concepts; however, qualitative data analysis showed evidence that this curriculum also supported children's learning in other subject domains (e.g., literacy, mathematics) and developmental domains (e.g., inquiry skills and self-regulation skills). For example, a teacher reflected on teaching children thinking vocabulary (i.e., predict, observe, compare):

> *In week one of September, the "thinking vocabulary" was very beneficial for myself and my students. We explicitly went over each of the vocabulary terms, and then we dove right into the lesson. During the lesson, I repetitively used the words "predict, observe, and compare", and I could tell that my students felt like little scientists, which is exactly what they were!*

A teacher reflected on children's inquiry and mathematics skills during the bean germination experiment: "*My class enjoyed playing, sorting, and weighing beans. We germinated them as instructed in plastic bags first then transferred them to bigger containers. We started measuring and taking notice of how fast or slow each plant grew*". Another teacher wrote about how children document evidence in the bean germination experiment: "*The child loved to watch the different beans grow and then be able to draw the progress on their journal. They would always ask to see how much the beans have sprouted!*". The same teacher also reflected on how children were motivated to initiate new investigations: "*The best highlight is the children asking if we could plant our own seeds from our apples and what other vegetables we could grow in our garden*". A different teacher described children's self-regulation skills during a small-group activity: "*The children patiently waited their turn and followed directions well when we planted their bean plant*".

4. Discussion

The goal of this ongoing three-year study is to examine the effect of a metacognitive-driven, experiential early science instructional intervention on children's SRL and to explore the relation between science instructional environment quality and the improvement in children's SRL. Quantitative and qualitative analyses of the year-1 data showed that the PD program yielded positive impacts on teachers' and children's outcomes, such as science teaching efficacy, metacognitive awareness of teaching, and children's SRL. We also found a small but significant correlation between science instructional environment quality and the children's improvement in SRL. In this section, we discuss our research findings, limitations, and future directions.

4.1. Early Science Education and Children's SRL

As expected, we found a statistically significant increase in both the cognitive and motivational aspects of young children's SRL after the PD program (controlling for children's age), and this improvement was positively associated with the quality of science teaching and environment quality. Our quantitative finding was supported by teachers' qualitative reports of children's learning interests and inquiry skills (e.g., observe, document, initiate new investigation). The connection between children's SRL skills gains and early science teaching and environment quality could imply that early science learning promoted young children's SRL [55]. The positive association between science teaching environment quality and children's SRL in our study, although interesting, did not warrant causation. We encourage future researchers to employ a randomized control trial to investigate the potential causal relation between early childhood science education and SRL, as well as to unpack why this relation exists.

Despite the benefit of early science learning, science is an overlooked subject area in early childhood classrooms. For instance, on average, preschool teachers dedicated only 9% of classroom learning time to science, which is significantly lower than literacy (30%) and math (19%) [74]. The current state of early science learning could be due to insufficient teacher training about science pedagogical content knowledge [79] and the lack of resources [80], in particular the lack of developmentally appropriate science curriculum that also touches on other subject and developmental domains (e.g., literacy, math, social-emotional development).

The Farm to ECE curriculum filled the gaps described above by integrating literacy and mathematics contents in the science curriculum while promoting children's self-regulation skills. For example, in the "Peaches & Plums" unit, children not only learned science concepts about fruits (e.g., lifecycles and growing conditions) but also new vocabulary words

(e.g., pit, fuzz, and ripe). In the "Radishes" unit, children gained mathematic competency by measuring and weighing radishes and exercising their self-regulation skills in a small group activity where children used scientific tools (e.g., magnifying glasses and scales) to explore radishes. Moreover, this curriculum uses locally sourced fruits/vegetables/grains as children's place-based hands-on learning materials, which were connected with rural children and teachers' lived experiences. Our finding is supported by the results from a recent meta-analysis study: teacher-administered interventions targeting children's SRL yielded a bigger effect than those administered by interventionists, possibly due to teachers' extensive knowledge about their children and the ability to conduct immersive training that encouraged knowledge transfer [86]. Given the positive impact of early science learning on children's SRL, as indicated by our data analysis results, future researchers and early childhood policymakers should create and fund evidence-based, integrative early science curricula; such curricula should also be supplemented by teacher training to maximize its benefit [71].

4.2. The PD's Impact on Teachers' Outcomes

As for the teacher-level outcome, our data analysis results showed that the metacognition-driven early science learning PD meaningfully improved early childhood teachers' science teaching efficacy. It is worth noting that we observed an increase not only in teachers' science teaching efficacy beliefs but also outcome expectancy post-PD. Previous research has shown that early childhood teachers' training did not necessarily lead to positive changes in the outcome expectancy aspect of science teaching efficacy [103]. In other words, teacher training that focuses on content knowledge and pedagogy may increase teacher-perceived science teaching ability but not the perceived impact of their teaching. A plausible explanation is that science teaching outcome expectancy involves many factors beyond teachers' control, such as children's learning interests and contextual factors (e.g., resources and behavior management) [104]. We credit the increase in teachers' science teaching outcome expectancy in our program to the immersive, hands-on curriculum. The Farm to ECE PD program uses a year-long supplementary curriculum to accompany the monthly online training, and this combination possibly aided the translation of pedagogical content knowledge to classroom teaching practices, therefore leading to increased science teaching outcome expectancy. Future work is needed to understand the multifaceted factors that contribute to teachers' knowledge transformation to classroom practices (e.g., PD training regimen, curriculum, teacher attitudes, and class sizes).

Our results also showed an increase in teachers' metacognitive knowledge about their teaching practices; however, the PD did not have an effect on their regulation skills regarding teaching (i.e., planning, monitoring, and evaluation). The Farm to ECE program adopted several ways to enhance teachers' metacognitive awareness for teaching. For instance, we added "Teaching/Classroom Management Strategies Boxes" to each curriculum activity to explain the science behind these evidence-based instructional practices and how to use them with young children. These practices were explained in greater detail in teachers' monthly training videos on the online PD platform. The curriculum activities allowed teachers to practice using the teaching/classroom management strategies taught in the PD. In addition, teachers were asked to write quarterly reflections about their classroom implementations. The Farm to ECE PD design echoed previous successful PDs that aimed to enhance teachers' and students' metacognition [105–107].

As to the null finding on teachers' metacognitive regulation skills, a possible explanation is the need for more teachers' autonomy in our program. The current Farm to ECE PD program was prescribed to teachers—the lesson plan, learning goals, activities, and materials were predetermined in the monthly curriculum. As a result, there was not much room in the curriculum for teachers to proactively exercise their planning, monitoring, and evaluation skills. Future PD programs could consider using a semi-structured PD framework to allow teachers to co-design the PD with researchers in order to promote teachers' autonomy and metacognitive regulation skills [83]. Another possible explanation for the null finding

is related to measurement. The MAIT explores a teacher's self-reported measurement and is not designed for any specific grade level or content area [96]. Therefore, MAIT items may not accurately reflect early childhood teachers' metacognition related to science teaching, and teachers' responses may be subject to social desirability [108]. Content-specific direct measurements of teachers' metacognition are needed in order to provide reliable data on teachers' awareness of their content and pedagogical knowledge. Future researchers could consider developing such measurements using a response-contingent signal detection approach (i.e., type-2 signal detection). Başokçu and Güzel [109] successfully created this type of instrument to measure elementary teachers' mathematics teaching metacognition. Such a measurement approach could be expanded to other grades and content areas.

4.3. Limitations and Future Directions

In this section, we discuss several limitations and how future research may overcome these limitations and advance studies on metacognition and early science teaching and learning. First, the participants in our study were predominately White and from rural areas of Northern Idaho, and the sample size was slightly underpowered. Therefore, our sample was homogenous and is not representative of the larger population in the U.S. The results from this study should be interpreted within their context. Future research should consider recruiting a larger sample from a more demographically diverse population (e.g., urban, inner city). Secondly, a number of measurements used in this study were self-reported and teacher-reported instruments (e.g., CHILD, STEB, STOE, and MAIT), which may have introduced social desirability bias and rater's bias [108]. Future researchers who are interested in a similar topic should consider using or creating direct measurements of children's SRL [110] and teacher's metacognitive awareness in teaching [109]. Third, the outcome of the PD was measured immediately after the program, and we do not have data to demonstrate the long-term impact of this program. Future PD studies should examine delayed effects as well as acute effects in order to investigate the possible lasting impact and transfer effects of a PD program. Fourth, the qualitative data collected in this study (i.e., reflection journals) lacked richness. Additional qualitative data, such as teachers' interviews, will enable a more in-depth interpretation of results from this mixed-methods study. Fifth, child-level outcomes were limited to SRL, and measurements that assess children's science learning conceptual changes were absent. Future studies should measure not only changes in children's learning skills but also knowledge retainment as well. The sixth limitation is related to the PD design. Although we created curriculum activities that promote sensory learning and child-directed exploration, there is a lack of immersive problem-based learning. To improve the current design, we plan to create more open-ended inquiry learning tasks (e.g., germinating and growing beans, creating compost) to better instill the idea that science is a dynamic discovery process. Last but not least, we only used the cognitive and motivational subscales of CHILD. We decided to not include emotional and prosocial subscales to lessen teachers' workload, given their existing tasks. Future work is needed to examine the relation between science learning and all aspects of SRL.

5. Conclusions

Self-regulated learners are competent at setting learning goals, selecting effective learning strategies, monitoring and evaluating task performances, and persevering despite challenges [4]. We argue that early science learning might be an overlooked prime context to supporting children's self-regulated learning (SRL) because science activities capitalize on children's innate curiosity and allow children to exercise the motivational (meta)cognitive and self-regulation aspects of SRL. Our research findings show the potential of supporting children's SRL by training early childhood teachers to conduct science activities using a combination of professional development and experiential curriculum. Particularly, children's improvement in SRL could in part be attributed to teachers' skillfulness in leading science activities (e.g., promoting children's inquiry learning and sense-making) and the quality of the science learning environment (e.g., a classroom containing developmentally

appropriate science materials that afford exploration and learning). Overall, the Farm to ECE program supported children's SRL, holistic understanding of basic plant science concepts and science process skills, and teachers' science teaching efficacy and metacognitive awareness as well.

Our study also has implications regarding the unique challenges and strengths related to conducting education research with rural populations in the U.S. Idaho ranks 44th of the 50 states in population density, averaging 22.3 per square mile [111] As a result, we were only able to enroll 20 childcare centers. The majority of the childcare centers in this study were located in dispersed rural areas within a 2 h radius from the lead author's university, which inevitably increased the cost of delivering PD materials and instructional coaching. However, the teachers seemed to be very enthusiastic about the PD content, and only one teacher dropped out due to not having enough eligible children in her classroom. We attribute our high retention rate to the fact that early childhood teachers, especially those in remote rural areas, receive very limited financial and training support and are eager for content-rich PD and curriculum that are related to their lived experiences in rural areas (i.e., agriculture, gardening). Early childhood teachers in rural areas are one of the least studied populations, and future researchers should be mindful of the challenges and strengths associated with conducting research with this population. In particular, place-based PD (e.g., PD centered on the farm culture) seemed to gain traction among rural teachers. Future researchers and policymakers should continue to create and support place-based, experiential PD and curriculum for early childhood teachers and children in rural communities.

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Informed Consent Statement: Informed consent was obtained from all participants involved in the study.

Data Availability Statement: Data will be made available upon request.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A. Children's Independent Learning Development Checklist

Based on your recent observation of the child in the past two months, this child:

Self-Regulated Learning Skills		Always	Usually	Sometimes	Never
Emotional					
1.	Can speak about own and others' behavior and Consequences.				
2.	Tackles new tasks confidently.				
3.	Can control attention and resist distraction.				
4.	Monitors progress and seeks help appropriately.				
5.	Persists in the face of difficulties.				

Self-Regulated Learning Skills	Always	Usually	Sometimes	Never
Prosocial				
1. Negotiates when and how to carry out tasks.				
2. Can resolve social problems with peers.				
3. Shares and takes turns independently.				
4. Engages in independent cooperative activities with peers.				
5. Is aware of feelings of others and helps and comforts.				
Cognitive				
1. Is aware of own strengths and weaknesses.				
2. Can speak about how they have done something or what they have learned.				
3. Can speak about future planned activities.				
4. Can make reasoned choices and decisions.				
5. Asks questions and suggests answers.				
6. Uses previously taught strategies.				
7. Adopts previously heard language for own purposes.				
Motivational				
1. Finds own resources without adult help				
2. Develops own ways of carrying out tasks				
3. Initiates activities				
4. Plans own tasks, targets, and goals				
5. Enjoys solving problems				

Appendix B. Science Teaching and Environment Quality

Note. Only the interview protocol is shown in Appendix B due to the size of the full instrument and copyright issues. Interested users can contact the Educational Development Center https://edc.org/ (accessed on 6 May 2024) for the full instrument and training.

Introduction Script

Today is_____ (month/day/year), I'm with _____ (teachers' name), ID number_____. I just observed the _____activity featuring _____ (fruit/veggie/grain). I have 4 questions about the activity you did today. There are no right or wrong answers, we are simply interested in your opinion.

Interview Questions

1. Reflect on the activity you did today, how did you prepare for this topic? How did you introduce the children to this topic?
2. What have you learned about children's understanding of this topic up to this point?
   a. How have you learned this?
   b. Do you document learning in any way?
   c. How do you keep and use your information about children's science learning? "Science" here refers to the food and agriculture knowledge in the Farm to ECE curriculum.
   d. Do you use this information in planning? If so, how?
3. What additional materials and activities do you plan to provide related to this topic and why?
4. What are the most important strategies you use to support children's science learning? "Science" here refers to the food and agriculture knowledge in the Farm to ECE curriculum.

Appendix C. Science Teaching Efficacy Beliefs and Outcome Expectancy

There are no right or wrong answers in this list of statements. It is simply a matter of what is true for you. Read every statement carefully and choose the one that best describes you.

	Strongly Disagree (1)	**Disagree (2)**	**Neutral (3)**	**Agree (4)**	**Strongly Agree (5)**
Science Teaching Efficacy Beliefs					
I am continually improving my science teaching practice.					
I know the steps necessary to teach science effectively.					
I am confident that I can explain to students why science experiments work.					
I am confident that I can teach science effectively.					
I wonder if I have the necessary skills to teach science.					
I understand science concepts well enough to be effective in teaching science.					
Given a choice, I would invite a colleague to evaluate my science teaching.					
I am confident that I can answer students' science questions.					
When a student has difficulty understanding a science concept, I am confident that I know how to help the student understand it better.					
When teaching science, I am confident enough to welcome student questions.					
I know what to do to increase student interest in science.					
Science Teaching Outcome Expectancy					
When a student does better than usual in science, it is often because the teacher exerted a little extra effort.					
The inadequacy of a student's science background can be overcome by good teaching.					
When a student's learning in science is greater than expected, it is most often due to their teacher having found a more effective teaching approach.					
The teacher is generally responsible for students' learning in science.					
If students' learning in science is less than expected, it is most likely due to ineffective science teaching.					
Students' learning in science is directly related to their teacher's effectiveness in science teaching.					
When a low achieving child progresses more than expected in science, it is usually due to the extra attention given by the teacher.					
If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child's teacher.					
Minimal student learning in science can generally be attributed to their teachers.					

Appendix D. Metacognitive Awareness Inventory for Teachers

There are no right or wrong answers in this list of statements. It is simply a matter of what is true for you. Read every statement carefully and choose the one that best describes you.

	Strongly Disagree (1)	**Disagree (2)**	**Neutral (3)**	**Agree (4)**	**Strongly Agree (5)**
▪ I am aware of the strengths and weaknesses in my teaching.					
▪ I try to use teaching techniques that worked in the past.					

	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
▪ I use my strengths to compensate for my weaknesses in my teaching.					
▪ I pace myself while I am teaching in order to have enough time.					
▪ I ask myself periodically if I meet my teaching goals while I am teaching.					
▪ I ask myself how well I have accomplished my teaching goals once I am finished.					
▪ I know what skills are most important in order to be a good teacher.					
▪ I have a specific reason for choosing each teaching technique I use in class.					
▪ I can motivate myself to teach when I really need to teach.					
▪ I set my specific teaching goals before I start teaching.					
▪ I find myself assessing how useful my teaching techniques are while I am teaching.					
▪ I ask myself if I could have used different techniques after each teaching experience.					
▪ I have control over how well I teach.					
▪ I am aware of what teaching techniques I use while I am teaching					
▪ I use different teaching techniques depending on the situation.					
▪ I ask myself questions about the teaching materials I am going to use.					
▪ I check regularly to what extent my students comprehend the topic while I am teaching.					
▪ After teaching a point, I ask myself if I'd teach it more effectively next time.					
▪ I know what I am expected to teach.					
▪ I use helpful teaching techniques automatically.					
▪ I know when each teaching technique I use will be most effective.					
▪ I organize my time to best accomplish my teaching goals.					
▪ I ask myself questions about how well I am doing while I am teaching.					
▪ I ask myself if I have considered all possible techniques after teaching a point.					

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