

# Localized Land-Grant Partnership for STEM Integration Through AFNR: High School Teachers' Experiences

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## Abstract

*Agriculture, Food, and Natural Resources (AFNR) provides authentic and relevant contexts for applying STEM concepts to solve real-world challenges. Land-grant institutions have expertise, mission-aligned values, and infrastructure to make local connections with K-12 teachers and students to support the integration of AFNR in STEM teaching. This study leveraged existing capacities of the land-grant system to develop a localized education partnership within the tripartite mission of teaching, research, and Extension. This exploratory qualitative study described high school teachers' perceptions and experiences of the LOCAL STEM Model that led to teachers' experience at a local research station and conducting a STEM-AFNR project with their students. The immersive professional development workshop prepared teachers to work across disciplines and use the hydroponics topic to teach their classes. They collaborated internally during the professional learning community and were supported by partners from the land-grant university. Regarding the showcase event, teachers discussed students' career exposure, career readiness skills, real-world experiences, and the pedagogical values of the event. For the overall experience, teachers discussed their professional growth, teaching ideas, farm-based experience, how they expanded and connected to resources, and how they engaged others in the project. This study described how the model can serve as a transferable example to help local high schools contextualize STEM using AFNR context with support from local partners at a local research station, Extension, and industries. Our findings have practical implications for program developers in terms of teacher development, student engagement, the model implementation, and future partnerships.*

## Introduction

Localized education partnerships can develop high school students' agricultural STEM—science, technology, engineering, and math literacy and career interests (Monk et al., 2014; National Research Council [NRC], 2009). In this study, a U.S. land-grant institution (Purdue University), local high schools, and community organizations formed mutually beneficial partnerships to address two dimensions of the workforce education issues: (1) the need for high school teachers to provide students with relevant and engaging learning experiences as well as preparing them to use knowledge and skills from different disciplines to solve real-world problems; and (2) the need for land-grant institutions to integrate teaching, research, and Extension missions and be locally relevant in addressing the needs of community partners (i.e., high school teachers and students).

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## **Challenges and Opportunities in Teaching STEM**

Professionals use interdisciplinary content to solve real-world problems, yet many education systems teach content areas as independent disciplines in high schools (Herschbach, 2011). This challenge can be addressed by using STEM integration, a curriculum reform strategy that purposely empowers students to solve real-world problems using knowledge and skills from different disciplines (Bryan et al., 2016; Du et al., 2019; English, 2016; NRC, 2014; Scherer et al., 2019). In this study, we employed a holistic definition of integrated STEM education which blends multiple academic and vocational disciplines “to help students meaningfully learn and apply academic content through real-world problems,” which are “framed in designed complex systems and grounded in career and technical contexts that facilitate multidisciplinary, interdisciplinary, or transdisciplinary learning for the development of life-long and workforce development connections and skills” (Wang & Knobloch, 2023, p. 253). As STEM integration gains popularity, more teachers are adopting it. Although some teachers reported that they use integrated STEM approaches, there is still a need for further investigation into their teaching strategies because different instructional methods can yield a diverse level of effectiveness (Smith et al., 2015; Swafford, 2018; Wang et al., 2020).

Despite the desire to respond to 18,400 anticipated annual job opportunities in AFNR—agriculture, food, and natural resources relating to STEM in the U.S. (Fernandez et al., 2020), teachers struggle to provide students with relevant and engaging experiences to prepare them for future careers in these disciplines (Bryan et al., 2016; Holdren et al., 2010; NRC, 2009). An effective way to address these challenges is for education professionals to provide a strong foundation in STEM aptitudes and knowledge and increase students’ likelihood of pursuing STEM careers by using practical real-life applications to teach these STEM subjects (Wang & Knobloch, 2023; Moore et al., 2020). Localizing and contextualizing real-life applications will help students connect these subjects and solve problems that are relevant to their interests, their daily lives, and societal problems (Holdren et al., 2010; Kelley & Knowles, 2016; Toheri et al., 2020; Wang et al., 2020; Wang & Knobloch, 2023). AFNR can serve as an authentic context to engage students in applying STEM concepts in the real-life applications (Knobloch & Wang, 2024) because the strength of local communities, economic development, social stability, and ultimately national and global security depends on agriculture, food, and environmental conditions (Mercier, 2015). Teachers are not typically prepared to teach their students how to solve complex problems using systems and interdisciplinary thinking (Wang et al., 2020); therefore, this study promoted the integration of the AFNR context into STEM lessons through “targeted teacher preparation, professional development, and instructional resources” (NASEM, 2021, p. 18).

High school teachers must acquire the skills to integrate different disciplines to develop high-quality integrated STEM instruction, including restructuring content and implement strategies to help students make interdisciplinary connections in solving food systems problems (Knobloch & Wang, 2024; Wang & Knobloch, 2023). Teachers were open to learning about STEM integration in their agricultural education programs due to their dedication as life-long learners committed to professional development and continuous improvement of their curricula (Stubbs & Myers, 2016). Stubbs and Myers recommended teacher educators and researchers collaborate with community partners to support high-quality STEM education in agricultural education programs. The alignment between contextualizing learning and community partners is grounded in the assumptions of land-based learning, which McKim and his colleagues (2019) defined as “learners valuing locally-produced knowledge and participating in the creation of local knowledge” (p. 175). McKim et al. posited that land-based learning could generate positive student outcomes such as academic engagement, development of 21<sup>st</sup> century skills, and pro-environmental behaviors, and strengthening the relationships among community partners and the local school.

## **Conceptual Framework**

We conceptualized a localized education partnership using a land-grant university's infrastructure. Land-grant institutions were established in the United States to serve the needs of local stakeholders by providing practical education to the future workforce with an intention to be relevant with people's daily lives as well as the realities of an agricultural and industrial society (APLU, 2012; Croft, 2022). Since the Morrill Act was passed in 1862, the land-grant system established facilities and programs based on a collaborative model of applied research, demonstration work, and integrated education that helped farming communities address needs and solve real-world problems (APLU, 2012; Seevers et al., 2007). Research stations (i.e., agricultural experiment stations), typically located throughout a state, were established as a key component of the land-grant system to conduct applied research and generate useful information to the community (APLU, 2012; NRC, 1995). These research stations demonstrate applied research in localized geographic areas and serve as local demonstration plots for the residents. All these infrastructure components were designed to support the land-grant university's tripartite mission of teaching, research, and Extension. However, it must be noted that these missions are not always integrated, but rather separated due to different administrations, constituents, or incentives (King et al., 2022).

This study leveraged the university's infrastructure and built relationships and networks with the industry and community partners to integrate all three missions (Lyons et al., 2018; McDowell, 2003). Local partnerships through land-based learning helps students see the interconnections of people and develop a sense of place within a local system (Flanagan et al. 2019; McKim et al., 2019). Fundamentally, the infrastructure of land-grant institutions has a capacity to respond to various 21<sup>st</sup> century challenges and work with the school system locally to provide students with exposure and spark their interests in the topics and careers related to both STEM and AFNR (Croft, 2022; NRC, 1995, 2009). The college of agriculture has expertise in AFNR topics, which can offer relevant contexts for teaching STEM integration by helping students engage the subjects with their health, the environment, and the economy (Chase & Grubinger, 2014; Roberts & Ball, 2009). Specifically, the college has a unique opportunity to help teachers make connections with AFNR resources locally and help them apply the context in teaching integrated STEM through K-12 outreach and teacher education.

The Land-grant Outreach for Community-based Agricultural Learning for Science, Technology, Engineering, and Mathematics Education (LOCAL STEM) project is a grant-funded K-12 educational outreach project that leveraged the localized AFNR resources from Purdue University. LOCAL STEM used a localized education partnership (Table 1) as a theory of change to design the learning opportunities for high school teachers and students. The partnership included three organizations within the land-grant system: (1) our team consisted of on-campus faculty and a graduate student in *the college of agriculture* conducting K-12 outreach and engagement. We managed the project and operationalized an integrated STEM approach (Kelley & Knowles, 2016; Stronge, 2007); (2) a local *research station* provided immersive and land-based learning experiences for teachers and students by encouraging exploration and utilization of real-world contexts (Lloyd et al., 2018), local resources for class activities, and venue for all partners to share knowledge and experiences; and (3) the specialists and educators of the *university Extension* provided practical research results, demonstration work, and consultation. We also engaged K-12 teachers from *local high schools*, who are not typically an active partner in this type of project despite the important role they have on students' literacy and career interests (Goodlad, 1993; Smith et al., 2016). Teachers actively participated in professional development opportunities and worked together to implement the project with their students and shared the lesson plans and laboratories with the local communities. Lastly, *local community organizations* were involved throughout the project for direct agriculture knowledge and educational resources from the industry. Connecting teachers with other partners helped them discover new knowledge from the field at the local level without having to travel to the university main campus located further away.

**Table 1**

*Localized Education Partners and Their Roles in the LOCAL STEM Project*

<b>Collaborative Partners</b>	<b>Partners' Roles</b>
Land-grant Institution Infrastructure (e.g., Purdue University)	
1. College of Agriculture (Learning)	Operated the project and provided professional development, technical knowledge, and pedagogical support for teachers
2. Research Station (Discovery)	Provided immersive and place-based learning experiences, agricultural research, local resources, and venue for partners to share knowledge and experiences
3. Extension System (Engagement)	Provided practical research results, demonstration work, and consultation
Local High Schools	Teams of teachers participated in professional development and implemented the project with their students and shared what they developed with the local communities
Local Community Organizations	Shared direct agriculture knowledge and educational resources from the industry

**Theoretical Framework**

Teachers' experiences and interpretations of those experiences when designing and implementing integrated STEM lessons should be studied using transformational learning by using a real-world design challenge (Knobloch & Wang, 2024), which aligns with Steffy and Wolfe's (2001) reflection, renewal, and growth model. Teachers reflect on their practice, redefine their assumptions and beliefs about teaching, and enhance their self-worth. Adults learn from critically reflecting on one's experiences (Mezirow, 1990), which are shaped by their cognitive frames (Mezirow, 2000) and how they interpret knowledge (Hofer, 2000). We chose this framework because we were interested in how teachers interpreted their learning experiences through multiple land-based learning contexts (Peeters et al., 2014) that may have been informed by different disciplinary perspectives.

The purpose of this study was to describe high school teachers' perceptions and experiences of their professional development and interpretations of learning outcomes regarding a localized land-grant university educational partnership model as a theory of change. The researchers were guided by the following questions, "How did the components of the LOCAL STEM Model support or not support the development of teacher outcomes and how they perceived student learning outcomes?"

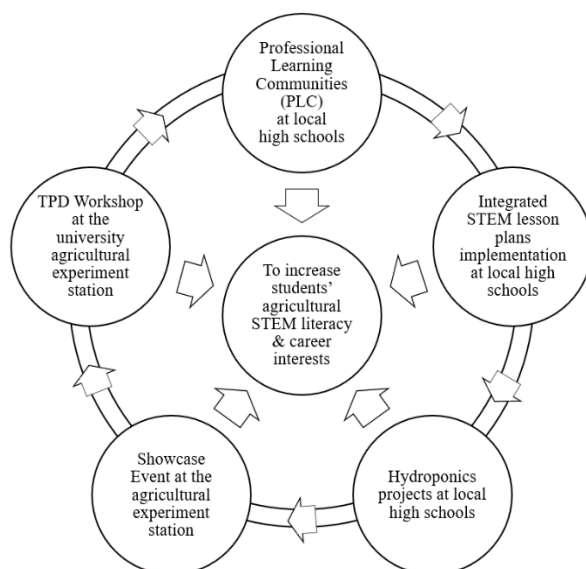
**Methods**

This study used a localized education partnership to develop teachers' capacities to implement a project-based learning strategy to engage students in integrated STEM education using local AFNR resources. An exploratory descriptive research design was chosen to describe high school teachers' perceptions and experiences within the partnership when we implemented the LOCAL STEM Model (Figure 1) that led to teachers' immersive learning experience at a local research station and conducting an integrated STEM-AFNR project with students at their schools. We described how teachers' perceptions and

experiences played a role in providing real-world applications of STEM subjects and making learning more relevant to students.

**Figure 1**

*The LOCAL STEM Model*



### Participants and Context

We recruited 14 high school teachers who taught agriculture ( $n = 4$ ), science ( $n = 6$ ), mathematics ( $n = 3$ ), and social science ( $n = 1$ ) from four schools. Teachers from three schools participated in the first year and two of the schools continued to participate in the second year. A new team of teachers was added in the second year. These teachers had two to 32 years of teaching experience. They reported having collectively taught 136 lesson plans to 1,931 students for the project over two years. The schools were located in rural communities located nine to 29 miles from a research station in the northwestern region of Indiana. School 1 had 1,970 students who were 25% nonwhite and 45% had free/reduced lunch support. School 2 had 451 students who were 19% nonwhite and 43% had free/reduced lunch support. School 3 had 1,081 students who were 13% nonwhite and 37% had free/reduced lunch support. School 4 had 455 students who were 11% nonwhite and 36% had free/reduced lunch support.

### Components of the LOCAL STEM Model

To describe the five components of the LOCAL STEM Model (Figure 1), first, teachers attended a one-week workshop of teacher professional development (TPD) at the research station during the summer. The workshop sessions were led by university professionals in the disciplines of agricultural STEM education, physics, chemistry, and engineering who engaged in horticultural and agronomic research and educational research (i.e., integrated STEM learning, learner-centered teaching, and student motivation). Teachers reviewed a hydroponics curriculum developed by faculty members as an integration of biology, physics, chemistry, and engineering content in an agricultural context. The immersive learning experiences provided teachers with connections of careers and local communities for their students. During the workshop, teachers formed a team to later implement this project at their school. Teachers were provided prompts to reflect on what went well, suggestions for improvement, benefits, and concerns. Second, after the workshop, teachers participated in a nine-month professional learning community (PLC) during the school year to plan and implement integrated STEM lessons in AFNR context that could solve a design

challenge of extending a growing season. Third, teachers continually received interactive support from the faculty and Extension specialists. Simultaneously, they had access to resources and consultation at the research station as well as from the university K-12 outreach and engagement program.

Fourth, teachers identified, adapted, or developed lesson plans in different subject areas to teach integrated STEM curriculum in their courses. All teams used hydroponics as a topic to integrate AFNR into their responsible content areas and assigned design challenges to students to improve their abilities to apply STEM concepts in AFNR context. The lessons focused on increasing students' integrated STEM through AFNR content knowledge, agricultural literacy, career interests, and 21<sup>st</sup> century skills. Teachers taught lessons about seed planting and germination; hydroponics design process and construction; model building; lighting; photosynthesis; nutritional needs; plant anatomy; osmosis; and sustainability. Finally, at the end of each school year, we organized a showcase event for teachers and students to establish relationships with the local context, facilities, project activities, and personnel who worked at the research station. Teachers took students to the event for two main purposes: (1) to expose students to STEM-AFNR literacy and increase their career interests through integrated and immersive learning experiences; and (2) to showcase students' hydroponics project designs, knowledge, and experiences with the local community partners.

There were 10 students, 6 teachers, and 19 community partners in the first year of the showcase event. This event held a demonstration of an agricultural robot, a tour of a high tunnel, a project recognition, and a visit with local businesses for food tasting, interacting with baby goats, starting microgreens, and learning about hydroponics, vertical aeroponics, and local shrimp farming. Each teacher had a display of the progress on their lesson plans. There were 70 students, nine teachers, and 18 community partners at the second-year showcase event. Participants rotated through four learning stations to learn about: (1) precision agricultural practices using farm machinery; (2) horticultural and agronomic research studies; (3) career opportunities and agriculture-related majors; and (4) the geography and role of the research station. Afterwards, each high school showcased their hydroponics designs, what they did and learned in the classroom, and the content knowledge for specific subject areas that incorporated STEM-AFNR. Participants networked with local scientists, Extension educators, and agricultural professionals from local organizations (e.g., a regional food council, an agricultural management company, a nearby farm, Extension office, and university faculty and graduate students).

### **Data Collection**

The authors collected qualitative data to describe teachers' perceptions and experiences in the partnership. Data were collected from: (1) a teachers' reflection after the TPD workshop, (2) notes from communications throughout the project, and (3) teachers' post-project interview manuscripts. We focused on how teachers perceived the components of the LOCAL STEM Model: (1) TPD workshop and PLC; (2) the showcase event; and (3) the overall experience. Open-ended reflection prompts were provided for teachers to share their thoughts. For example, we asked about what went well at the workshop and what needed improvement; their concerns participating in the project; and their interactions with partners. At the end of each project year, teachers participated in 60-minute semi-structured interviews conducted by the first and the third authors. Ten teachers were interviewed in the first year. In the second year, five teachers from the first year were interviewed along with the four second-year teachers. Teachers were asked about their perceptions regarding students' learning outcomes and their personal experience with the LOCAL STEM Model.

### **Data Analysis and Trustworthiness**

Qualitative data were coded using *in vivo* and concept coding (Saldaña, 2016) by the first author and verified by the second author through independent review and peer debriefing (Shenton, 2004). The first author had non-formal teaching experiences in the food systems context. The second author had formal

teaching experience in agricultural education. The third author had formal and non-formal teaching experience in STEM integration. The second and the third authors were internal to the program design and delivery, but the first author was involved in the program as a graduate assistant. All authors had degrees from and currently work at land-grant universities. In the first cycle, the first author used *in vivo* coding method to minimize bias. We identified codes using the three components of the LOCAL STEM Model: TPD and PLC, Showcase Event, and Overall and used color-coding method in Microsoft Word. In the second cycle, codes were grouped into concepts, and then concepts into themes through peer debriefing between the first and second authors (Shenton, 2004) using mind mapping software—Miro. For example, an *in vivo* code, “it’s [Purdue research farm] closer than I thought” fit the concept of local resources and was grouped under the theme—*expanding resources*, which helped teachers make an impact on students’ learning. Transcripts, coding schemes, and a visual collaboration platform were used to demonstrate an audit trail to ensure confirmability (Shenton, 2004).

### Findings

We share teachers’ perceptions and experiences and how the components of the LOCAL STEM Model supported or did not support the development of learning outcomes. The model components (Figure 1) are presented as three major experiences, where teachers directly interacted with the localized education partners, namely TPD workshop and PLC, showcase event, and the overall experience. There were three emergent themes regarding the TPD workshop and PLC, four themes regarding the showcase event, and six themes regarding the overall experience (Table 2).

**Table 2**

*Summary of Themes for LOCAL STEM Model Components*

LOCAL STEM Model Components	Emergent Themes
TPD Workshop and PLC	<ul style="list-style-type: none"> <li>a. Usefulness of the workshop</li> <li>b. How the workshop made teachers comfortable and ready to teach</li> <li>c. Internal collaborations during PLC</li> </ul>
Showcase Event	<ul style="list-style-type: none"> <li>a. Students’ opportunities for career exposure</li> <li>b. Career readiness skills that students developed</li> <li>c. Students’ real-world experiences</li> <li>d. Pedagogical values of the event</li> </ul>
Overall Experience	<ul style="list-style-type: none"> <li>a. Teachers’ professional growth</li> <li>b. Teaching ideas</li> <li>c. Farm-based experience</li> <li>d. Expanding resources for teachers</li> <li>e. Connecting resources to enhance students’ learning</li> <li>f. Teachers engaging others and making this project public</li> </ul>

### TPD Workshop and PLC

Teachers reflected on *the usefulness of the workshop*. Their overall perceptions were positive. Teachers reported that the workshop was a space to discuss with experts in the field, ask questions, clarify their confusions, and find support for teaching. They also learned new approaches, perspectives, and ideas.

Upon interacting with scientists, teachers valued learning how to integrate different disciplines and to highlight their discipline specifically. They found that exchanging information with scientists made difficult concepts relatable and easier to grasp. A teacher wrote, “Interacting with scientist(s) is the single biggest thing missing from my professional career. I wish our administrators would bring in speakers like you all.” Teachers shared they had an opportunity to refresh the knowledge they do not normally teach. Collectively, teachers wrote that the keys to the project’s success included the scientists’ knowledgeable, approachability, and willingness to help. In addition, the workshop provided contact information for teachers to later build a relationship with the experts when implementing the lesson plans.

Teachers reported that the workshop made them *comfortable and ready to teach* because it increased their confidence to use integrated STEM/AFNR lessons and be more open to try innovative teaching strategies after reviewing the integrated STEM in agricultural context. Teachers challenged themselves to design and manage a controlled growing system and potential problems they might face growing plants hydroponically. They did a lot of learning to “know well enough to be able to assist [students].” Teachers shared that it was not necessary for them to have all the technical knowledge regarding hydroponics to facilitate problem solving and open inquiry experiences for their students. The week of time given in the summer during the workshop helped teachers become more ready to implement the project by forming a team, restructuring the plan, building the project, and growing some plants before the school year started.

Throughout the PLC, teachers reported they *collaborated internally within their schools* by working: (1) across disciplines; (2) across years of teaching experiences; (3) to define collaborative roles on the project; and (4) to seek support outside of the project. The PLC was beneficial for developing knowledge and motivating teachers to try new teaching ideas. A teacher said, “[The] collection of the minds and group think[ing] really drives us towards something better.” Teachers also grew to understand other subjects they did not typically teach, which helped them integrate and see how those subjects would fit in with the project. They “bounced ideas off of each other” with teachers from different disciplines. A teacher said, “Talking with other teachers definitely helps me get ideas as far as how things relate.” The PLC helped newer teachers work with more veteran teachers and learn about best practices while they also offered fresh ideas to view things differently in return. Teachers saw different perspectives including teaching philosophy from their peers and found that they wanted to do more team teaching. For this project, they divided the roles to lead lectures and hands-on activities.

PLC helped sustain conversations about the project among the team. A teacher admitted that gathering even for only once a month was beneficial. Additionally, informal communications, including “hallway conversations,” helped teachers make progress. In contrast, at one of the schools, teachers did not have time to meet. Only the agriculture teacher led an afterschool program and recruited a few students to run the hydroponics project. Without the PLC time to plan and collaborate, teachers from different disciplines were rarely involved. Finally, PLC helped teachers seek support outside of the project. At one school, the team asked a colleague for supplies. They shared, “We go and ask [the physics teacher] for weird supplies.... And then [she] just kind of pops her head in and sees what we were using her stuff for.” At another school, a teacher shared, “I talked to [the science teacher] about the grow cart and any questions about biology and I went to him. [Another teacher] gave me the red worm poop for fertilizing. My mom [who used to be a teacher] gave me ideas about growing the potatoes.”

### Showcase Event

Teachers were interviewed about the showcase event. They discussed four themes: (1) students’ opportunities for career exposure; (2) career readiness skills that students developed; (3) how students gained real-world experiences; and (4) the pedagogical values of the event.

*Students gained career exposure* through the event in several ways. A teacher estimated that 80% of students at his school thought of doctors and lawyers as their potential careers with a misunderstanding that agriculture-related careers only include riding tractors or milking cows. At the event, students learned about different agriculture-related college majors they did not typically know. As a result, they viewed agricultural careers differently and were encouraged to think of “a wider career scope.” Teachers helped students become more aware of careers in STEM and AFNR. For instance, a teacher pointed out that “not a lot of people think of biochemistry as an agriculture career.” A student reported that she reconsidered her career choice because of her interest in being outdoors and seeing more career options. As part of becoming aware of new careers, an agronomist at the event offered summer job positions at his local business, to which several students from two schools had applied and one was already accepted for a position at the time of the interview.

At the showcase event, *students developed career readiness skills*. For example, students took a leadership role in implementing the project utilizing an open-inquiry approach. Students at two schools also prepared and led the presentation. Their teacher said, “I think the fact that we had our kids present, that was important to us because it was a student-based project.” Another teacher added, “I wanted to make sure they felt ownership towards their part.” A teacher from another school shared, “[Students] were a little upset with us because we [teachers] didn't do a good enough job of telling them that they'd be in front of that many people talking. They think [it's a] ‘science fair.’ They're going to be at a table and one person's going to walk up and ask two or three of them a question.” Students were told that this event was similar to how scientists present their work at professional conferences by sharing ideas collaboratively in front of a crowd. A teacher also highlighted to their students that giving speeches does not “only belong in English classes,” but that the integration approach also provided the same opportunity in agriculture, math, and other classes. Teachers from two other schools regretted that they did not adequately prepare their students and the teachers were the ones presenting.

Another skill that students developed included working across disciplines. At each school, students from different content areas and classes worked together on the project under topics that the teacher team taught even without meeting regularly. A teacher said, “[Students] saw each other every once in a while, but the topics that we were covering all worked together...then [students] finally see how the whole project looks like at the showcase event.” One group of students designed the hydroponics system and another group worked on the water issues of the system. Students then recognized that the presentation helped show integration of multiple subjects as well as how complex agriculture is and how various things happen in an agricultural system. The showcase event helped these students see how the project came together in a whole picture, which indirectly exposed them to thinking in a systems thinking way, encouraging a higher-order thinking skill.

*Students gained real-world experiences*. Visiting the research station was a new experience for many students. Several of them did not know of the university research station, which is also a working farm. Teachers said that it was an unexpected experience. A teacher reported, “I think [students] were caught off guard with how much goes into everything. I think they were just expecting cows and riding a tractor around.” Although a few students were already interested or involved in agriculture, at least half of the students did not have a background or interest in agriculture. Another teacher said, “It was totally new for them...I think getting to see a little bit more of [the farm] would have been good for them.” After the experience, students learned that these resources existed in their local communities including machinery, research studies, soils, and different types of greenhouses.

The four learning stations were set up in rotation for students to be exposed to farm machinery, research studies, agriculture-related career pathways, and the research station. Teachers reported that “the kids loved the food, the tours. They liked everything.” Although many students prefer getting out of class, there were conditions: (1) they disliked a trip that conflicted with their personal times; and (2) “they were

burnt out on [so many] field trips.” There were several students who reported the farm machinery and equipment station being too technical and irrelevant. A teacher expressed confusion from interacting with scientists. She said, “It’s like the researchers start talking up here about what they’re doing, and the kids are like, ‘Ah, I don’t get it.’ ...Some of us who don’t concentrate on the ag[riculture] stuff as much, that might be a little harder.” Another teacher shared, “A lot of those kids who went, agriculture isn’t their biggest interest. Learning about farm machinery, they were polite and they listened, but I’m not sure how much they got out of it.” Conversely, a teacher suggested that this station could be longer and “go into a little more detail” because seeing farm equipment was “probably the kids’ favorite part.”

Students had a chance to compare different projects and experiences. A teacher reported, “They like to see the other schools’ projects. They were astonished that most of it was teacher-driven.” Students from the schools who did not present were overwhelmed and felt inadequately prepared. Their teacher reported, “That might be on me. Like, just not preparing them and telling them what to expect as much.” On the other hand, students who presented had been given the time to prepare for the presentation on their part of the STEM project. Their teacher said, “The groups that dealt with lighting could talk about the light. [So was] the group that was soil chemistry... So, they just liked how we had our own set area.” The groups compared their approach on the hydroponics systems with each other, such as “a different form of water.” Generally, students compared different examples to their own school-based experiences as well as comparing the different types of greenhouses that their school and the research station had.

Overall, teachers saw the importance of taking students to the event based on the *pedagogical values of the event* they perceived. Teachers provided examples of their favorite parts including what students got to see, what teachers were exposed to, and the tangibles for abstract concepts. They reported that their students saw different perspectives, learned about career choices, and were exposed to agriculture. They also discussed the benefits of the event to their teaching. A teacher reported that they loved the tour and seeing what would help them be able to answer questions in classes, “because a lot of people don’t know very much about what farmers actually do. What ag[riculture] actually is.” Teachers talked about hydroponics components that complemented abstract concepts. A teacher commented that the project helped engineering students, agriculture teachers, and environmental students work collaboratively on an abstract concept such as water potential, “[The project] brought in something real for them to focus on when we were talking about an abstract concept.”

For teachers’ perceptions, they talked about pride, benefits, and impacts of the showcase. Teachers were proud that their students did the presentation well. A teacher shared an impact on students who took ownership, cared about the project, and presented it at the showcase. She said it was impactful to see students grow, “To watch these kids, who wouldn’t say anything at the beginning of the year, be able to stand up in front of you guys.” The teacher continued, “Seeing that transition, [I] was like, ‘not only are you smarter about the topic but you’re now a better person for the future.’ So that it did work really well with what I tried to achieve.” For teachers, the event was not merely a field trip, but it was a learning experience that students also contributed via the showcase presentations. Moreover, it was also an integrated learning experience that connected students to the real world, professionals in the field, and other schools as discussed above.

### **The Overall Experience**

Throughout the project, we used the LOCAL STEM Model to support teachers’ project implementation to help their students increase STEM-AFNR literacy and career interests. At the end of each year, we interviewed teachers for their perceptions and experiences regarding the LOCAL STEM project. We found six themes that helped us better understand the descriptive impact of the localized education partnership: (1) teachers’ professional growth; (2) teaching ideas; (3) farm-based experience; (4)

expanding resources; (5) connecting resources; and (6) teachers engaging others and making this project public.

Teachers shared how this project encouraged their *professional growth*. They made mistakes, overcame challenges, experienced hydroponics as an unfamiliar topic, and learned to consider or incorporate other disciplines. A teacher, who went through trial and error setting up a hydroponics system, said, “In order to be very purposeful and use these things in school, you needed to learn as well.” Another teacher reported that continuing the project in the second year had helped the team accomplish several things. He shared, “Last year was a giant learning curve and it gave us the opportunity to kind of get a sense of everything.” At another school, a math teacher talked about being uncomfortable with other disciplines. He said, “It’s a lot of science and I’m not the best at science...I had to learn it before I could figure out anything. [Biology teacher] and [agriculture teacher] know it like the back of their hand.” An agriculture teacher from another school reacted to building the STEM project similarly. He said, “[The project] actually helped me understand the math, how it meant, and the math will fit in better...I feel like I can talk to [math teacher] about some of the things that she’s doing, and I sound somewhat intelligent.”

Teachers developed various *teaching ideas* from conducting the project, attending presentations at the research station, and working with their team and other schools. These ideas made them look at teaching differently. A teacher shared how this project changed the way they taught, “...because it’s all hands-on... It’s just a different way of us presenting to those kids, which was cool for us and it was probably cool for them too to learn it, [and] relearn it.” Problems that occurred in the preparation phase were teachable moments for students and became inquiry, project-based learning opportunities. A teacher shared that the challenges they faced are going to be a lab “planting seeds, getting them to sprout, struggling with pH... [The project]’s making me much more interested in the open inquiry method.” Another teacher, who was also motivated by the project, added, “I think there were more possibilities out there that our kids could have thought of, but we gave them some parameters that we wanted to.”

Teachers participated in the showcase event and meetings with other teachers in the project. They were inspired by new ideas and would use them in the future. They listed new topic ideas they wanted to use such as scaling, modeling, breaking down complex information, and finding the patterns to increase students’ analytical skills rather than merely memorizing the content. In addition, a teacher talked about how the commonly used rockwool is easier for the hydroponics system but terrible for the environment. She wanted her students to build on designs that are more environmentally friendly. She said, “It was nice for [students] to get to see that we can still build these projects but think about the planet as we’re doing it.”

The partnership provided *farm-based experience* for teachers and students while connecting schools to professionals in the agriculture industry. Teachers built relationships with the Extension specialists and scientists during the TPD experience. An Extension specialist explained the field trials of different vegetable varieties that she was conducting at the station to teachers. In addition to the showcase event, a teacher took his agriculture class to the research plots and learned about horticultural research and the field trials. While the group was there, the Extension specialist offered free produce, from which research data were already collected. Students harvested and donated tomatoes to a local food pantry. They also picked and sold pumpkins to raise money for their travel to a national leadership development conference (i.e., National FFA Convention). Another agriculture teacher took students to the research station’s annual field day. The group met community professionals, scientists, and producers, and learned about the field trials conducted on the farm.

Teachers discussed how the partnership provided the opportunity for *expanding resources* to help them as a teacher. This included supplies and funds from the grant they received through the university to design, build, and experiment with a hydroponics system. Teachers now had access to local resources as discussed in the previous sections. A teacher stated that they could “tap into [the scientist]’s brain and have

her come in and talk about some greenhouse techniques and growing techniques. And then we can compare solar versus hydropower.” Teachers also identified the research station as an accessible location to network locally. Another teacher felt comfortable asking the experts. He said, “We had that in our back pocket if something came up and our kids had questions that we knew we had that expert that could help us out. I think having those things is really, really important.” A teacher pointed out that while the main campus is too far for a field trip, the research station is much closer. She said, “[The research station] is closer than I thought,...if we could actually see one of the research projects,” such as water tolerant plant for sustainability. The teacher continued, “I’d love to talk about agriculture and how we are making things more sustainable” by doing research on “water tolerance of plants, so that the kids could actually see it in the field, see comparisons, [see] why this is important.”

The project also provided the opportunity for *connecting resources* to enhance students’ learning. Teachers were reminded of existing connections with local communities. A teacher said, “[For] the community members, I know that’s something that we need to get the list of [colleague]’s contacts, because [colleague] knows everybody...To get more people involved.” Similarly, another teacher planned to reach out to other farmers. She said, “There are farms out here that we could explore as far as getting more information that we touched on [in class].” Teachers were also reminded to share in-school opportunities with students who were interested in related topics. The opportunities included “soil-judging team” through their Envirothon program at school, as well as elective programs like animal science and Advanced Placement environmental science. A teacher said, “If [students] are interested in this, we do have the add[on] program...That came up when we were out on the track with the one guy, talking about the field.”

Teachers *engaged other people* in the school and the community with the project. Staff and other teachers observed the hydroponics project from afar, which created social pressure and a sense of accountability. Initially, a teacher shared that “people were scratching their heads” when their hydroponics system flooded the greenhouse. Later on, once the team successfully grew the vegetables, they felt accomplished and gained respect and engagement. A teacher shared, “I think they have more faith in us now...They actually come up and ask about what we’re doing and what’s going on.” After increasing supporters, the project was publicized through social media. A teacher shared, “It’s on [a] blog or whatever—got some pictures...And they did a little tweet from the school’s thing about us, putting it out there.” The project was used as a catalyst to gain administrative support. Another team got permission from the administration to work collaboratively. A teacher shared, “We’re like, ‘See. When you let us do these things, this is what can come out of it.’ That was really helpful for us to have an excuse to get to talk to other [teachers].”

### Discussion and Implications

The tripartite mission of the U.S. land-grant system has served multiple generations, and the relevance of these missions has been questioned if it meets the needs of current stakeholders (King et al., 2022). The LOCAL STEM Model is an example of how a land-grant institution’s infrastructure can be leveraged to meet the needs of teaching and learning for local high school teachers and students. To achieve this, substantial efforts need to be made in structural changes to impact public engagement (Bao et al., 2022). A land-based approach to K-12 education is an opportunity for land-grant colleges and universities to adapt, leverage existing capacities, and enhance learning for future students who can solve 21<sup>st</sup> century challenges as STEM professionals in AFNR disciplines (Wang & Knobloch, 2023). The localized education partnership, which integrated the tripartite mission, helped teachers and students see how knowledge is discovered through applied research that is shared through Extension specialists in the learning environment that was intentionally created by the outreach and teacher educators. Additionally, scientists were involved in learning how to communicate and educate audiences to increase land-grant engagement (Bao et al., 2022; Monk et al., 2014). A pathway was created to connect partners from the land-grant university to engage with local high schools and help enhance their teaching of STEM through AFNR context. The partnership

supported Sternberg's (2014) statement that Extension reaches community needs through engagement and outreach.

The localized education partnership used the LOCAL STEM Model (Figure 1) as a structure to organize, coordinate, and connect high school teachers and students with a local university research station, experts, and industry partners to provide them with real-world land-based experiences (Lyons et al., 2018; Toheri et al., 2020; Wang et al., 2020). The model can serve as a transferable example for collaborative local partners regarding AFNR context to contextualize STEM teaching for land-based learning, making it relevant and engaging to students as well as increasing their STEM application literacy and career interests (McKim et al., 2023; Wang & Knobloch, 2023). As we reflected on the findings, we grouped implications into four categories to help inform practice and guide program developers to implement effective programs: (1) teacher development; (2) student engagement; (3) the model implementation; and (4) future partnerships.

We share three implications regarding teacher development. First, the one-week immersive place-based experience (Langran & DeWitt, 2020) at the research station gave teachers real-world practical resources and examples that helped them brainstorm relevant connections for their students and develop relationships to openly discuss educational plans across their content areas (Bryan et al., 2016; English, 2016; NRC, 2014; McKim et al., 2019; Scherer et al., 2019). This supported McDowell's (2003) statement that land-grant engagement can create synergy when stakeholders find knowledge useful. Second, teacher teams worked better when provided with flexibility to adapt the hydroponics system to fit the school structure and local curricula. Teachers came up with their own strategies to integrate the contextualized STEM lessons into their existing courses, making meaningful learning experiences for their students to learn academic content that aligned with the state learning standards (Wang et al., 2020; Wang & Knobloch, 2023). Finally, the LOCAL STEM Model expanded resources for the high school teachers that was crucial to the localized partnership. The resources included knowledge, supplies funded by the grant, relationships with scientists and education specialists, and a local outdoor classroom at the research station.

We present two implications for engaging high school students. First, the experience at the research station contributed to students' learning and introduced them to contemporary STEM-related careers in AFNR disciplines. Students extended their learning when they interacted with Extension specialists and local industry partners who used STEM to conduct research and provide products and services in the local food system. Aeroponic vegetables and farm-raised shrimp were two examples of how local businesses were raising food in a closed-loop system year-round, similar to students raising plants using hydroponics systems when applying STEM. The challenge of growing food in a controlled environment motivated high school students to think about local connections in their community and future career possibilities (Thies, 2023). Students do not necessarily have concrete ideas of a specific career until they see the work in action. Second, the class projects offered many opportunities to engage students to feel ownership, apply knowledge and skills from different disciplines, and develop various career readiness skills including leadership and systems thinking, which aligned with McKim et al.'s (2019) proposed outcomes of land-based learning. The instruction should be clear to have students taking the lead on the project and teachers serve as facilitators.

We present three implications regarding the model implementation. First, collaborative spaces should be structured for participating schools to share ideas among teachers and students both within the same school (i.e., PLC and a project conducted by multiple classes) and between different schools (i.e., TPD and the showcase event). Second, virtual collaborative support was convenient for the team from the land-grant university and teachers to communicate, share resources, and get feedback throughout the project. Finally, the showcase event can be improved by: (1) making activities, including showcase presentations, competitive to attract students' attention; (2) training partners who lead the learning stations to provide hands-on activities more than giving a lecture; and (3) offering at least two levels of learning

stations: longer and more in-depth sessions for a group that is more interested in agriculture and short and concise ones for those less interested.

We share two implications regarding future partnerships. First, in terms of location, a half an hour driving distance or closer from schools was convenient for teachers to participate in professional development opportunities, connect with resources and partners, and bring students on site for place-based experience. Second, organizations that are willing to provide educational opportunities tend to be uninformed of the interested audience or have limited capacities to offer their resources. The pathway to connect these entities and form partnerships must be organized intentionally and patiently. Nonetheless, these localized education partnerships are worthwhile much like Lyons and colleagues (2018) stated that new partnerships can provide higher quality learning experiences and develop human capital.

In summary, the infrastructure of a land-grant university can be used in an education partnership as a theory of change to help high school teachers localize and contextualize integrated STEM learning experiences for their students. A localized land-grant university educational partnership model can facilitate professional development for teachers who can engage students to solve complex real-world problems and introduce them to STEM-related careers in AFNR disciplines.

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