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Partnerships in STEAM: How Collaborating with STEAM Experts Impacts K-12 Teachers' Abilities to Implement STEAM Lessons in the Classroom

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Abstract: K-12 teacher professional development in STEAM (Science, Technology, Engineering, Arts, and Mathematics) is often utilized to enhance teachers' abilities to use STEAM pedagogical methods in the classroom. One such program is GoSTEAM, a five-year initiative centered on K-12 teacher professional development in STEAM. Teachers participating in GoSTEAM collaborate on the implementation of STEAM lessons and activities with an Innovator-in-Residence, who is an individual with experience in a STEAM field, often from a local community organization or university. This study analyzes focus group findings from teachers and school administrators to assess how the partnership with the Innovator-in-Residence impacts teachers' professional development in STEAM. The findings suggest teachers and administrators perceived there to be several impacts on teachers' professional development as a result of the partnership, such as the development of STEAM skills and making connections between STEAM, district standards, and real-world concepts. As such, the results of this study indicate that a teacher's professional development in STEAM can be impacted by an ongoing partnership and collaboration with community partners and those experienced in STEAM fields.

Keywords: STEAM; community partnerships; K-12 teacher professional development; STEAM professional development

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1. Introduction

STEAM education is an approach to learning that utilizes Science, Technology, Engineering, Arts, and Mathematics as access points for guiding student inquiry, dialogue, and critical thinking [1]. Several studies have highlighted the effectiveness of this pedagogy, finding that STEAM teaching can impact student understanding of real-world concepts and improve learning outcomes [2,3]. To effectively train K-12 teachers in STEAM, professional development can be an impactful tool to support STEAM pedagogical development, especially when conducted with community partners [2–6].

First implemented in 2019, GoSTEAM is a K-12 teacher professional learning program focused on STEAM instruction. The program was developed and implemented by the Center for Education Integrating Science, Mathematics, and Computing (CEISMC) at the Georgia Institute of Technology (Georgia Tech). GoSTEAM is a five-year initiative, partnering with three local public-school districts to integrate STEAM learning with an emphasis in technology, computer science, and engineering subjects. During the first four years of implementation, 65 teachers from 12 schools participated in the program, representing a variety of taught subjects and levels of teaching experience.

GoSTEAM has several components. First, as a part of the program, teachers attend an annual summer institute focused on STEAM professional development. At the summer institute and throughout the school year, teachers collaborate with a STEAM Innovation Team to cultivate their skills in STEAM instruction. The STEAM Innovation Team consists of the teachers at each school, a GoSTEAM instructional coach ("Coach"), and an Innovator-in-Residence ("Innovator"). Coaches are university staff members with extensive knowledge of K-12 instruction, all of whom were previous classroom teachers. Innovators are community members with expertise in STEAM fields, including local artists and university students, who bring knowledge and connections with local partner organizations.

At the conclusion of each summer institute, teachers finalize an outline of the STEAM project(s) they intend to implement during the school year, known as an Action Plan. Each Action Plan is designed to include either an engineering, computer science, or technology component. Coaches and Innovators are an integral part of the Action Plan development process, as they provide teachers with additional contexts or knowledge to consider when creating their STEAM lessons. Furthermore, the STEAM Innovation Team continues to work together during the school year, with Coaches and Innovators supporting teachers throughout the implementation of the Action Plan.

Through Innovator and GoSTEAM staff networks, teachers are presented with opportunities to visit and learn from local community organizations, such as art galleries, theater production companies, and music producers. Teachers can leverage their connections with community partners to organize class field trips to the partner's location, host classroom visits, and partake in resource sharing, with logistical assistance from the GoSTEAM staff. Action Plans may also reference visits to community partners or organizations discovered through the summer institute and partnership with the program.

While each member of the STEAM Innovation Team is an important contributor in the implementation process, this paper investigates a unique component of GoSTEAM, which is the collaboration between the teachers and the Innovators. As a part of their role in the program, Innovators are hosted in the classroom, directly assisting teachers with the enactment of their Action Plans and the implementation of STEAM lessons. In this paper, our goal is to develop a deeper insight into and articulate a framework for long-term partnerships that promote STEAM education, focusing on the collaboration between teachers and Innovators in the GoSTEAM program.

1.1. Literature Review

1.1.1. K-12 School Collaboration with Community Partners

K-12 schools have often partnered with community organizations, such as universities, museums, and businesses, to provide resources and activities for students and teachers [7,8]. While partnerships differ depending on school and community context, studies have established best practices for ensuring a successful collaborative experience for both the school as well as the community partner [7–9]. Using data gathered from community partners participating in school–community partnerships, Lees and Kenney [9] identified three themes which were integral to the success of the collaboration. The findings included consistent involvement between partners, maintaining respect for their partner's knowledge and professional skills, and being flexible throughout the partnership. Similarly, in Gross and colleagues [8], community partners described a need for school administrators who showed dedication to the partnership, as well as a school environment that was invested in the community partnership. Other necessary requirements for success included teacher commitment to student knowledge generation and collaboration between the community partners themselves [8].

In general, school–community partnerships can generate resources that schools would not otherwise have access to, expose teachers to new pedagogical methods, and provide real-world connections to enhance student learning [7,8,10,11]. Teacher professional development can also facilitate partnerships between community organizations and schools [3,6]. By incorporating community partners into professional development spaces, teachers have

the potential to learn about new forms of instruction, collaboration, and knowledge, regardless of the field of study [12]. Morrissey and Kenny [13] describe an example of utilizing community partners in professional development settings, finding that art teachers who participated in a partnership with local artists expanded their pedagogical methods and felt more confident in their ability to teach their lessons. Suggestions for designing successful professional development with community partners include focusing on various pedagogies, collaboration both inside and outside the classroom space, and long-standing commitments from both teachers and community partners that extend beyond a one-off interaction [14,15].

1.1.2. Collaboration with Community Partners for K-12 STEAM Teacher Professional Development

Professional development programs designed to guide teachers through K-12 STEAM instruction may positively impact teacher confidence in and perceptions of STEAM [16,17]. To be most effective, STEAM professional development programs are typically designed to include collaborative experiences, focused on different pedagogical methods, such as project-based learning or evidence-based learning [17,18]. Houghton and colleagues [18] describe the need for professional development settings to provide teachers with ongoing support, the relevance of STEAM in their classroom, and the ability to work collaboratively in multidisciplinary settings. To further enhance STEAM professional development, studies have suggested the use of community partnerships to provide teachers with new ideas for STEAM lessons and to otherwise expand knowledge on STEAM implementation [6]. Specifically, research suggests that community partnerships could expose teachers to additional contexts and connect to real-world concepts that are useful for lesson planning [6,19].

While the literature describing the use of STEAM experts and community partners in STEAM professional development settings for K-12 teachers is limited, there are some studies that provide examples of this collaboration. Bush and colleagues [20] reference the use of the PrimeD framework to implement a STEAM professional development program. In this case, teachers collaborated with STEAM implementation coaches, who are described as content experts, to cultivate their understanding of STEAM concepts [20,21]. This collaboration did not exist solely within the context of the professional development program, but also throughout the school year, as coaches guided teachers through the implementation of STEAM lessons in the classroom [20,21].

By participating in STEAM professional development with experts and community partners, teachers are better equipped to design lessons that connect to real-world concepts and integrate STEAM content [2,3]. Experts and partners can also directly contribute to classroom settings by visiting schools to assist teachers with classroom enactment [3–6]. In an out-of-classroom setting, Grant and Patterson [22] described how local partners developed STEAM lessons for teachers and students, hosted at a partner site. While the partners initially led the activities, teachers often continued the STEAM lessons in their classroom, finding there was considerable student engagement and interest in the STEAM activities [22].

Some studies highlight pertinent challenges or considerations for collaboration. For example, it is necessary for community partners to understand the needs of the school, as each K-12 environment is unique [5]. Though working with community partners can draw connections to real-world concepts, referencing learning standards ensures the developed STEAM activities maintain relevance to the school curriculum [2,22]. Regardless, working with community partners can elevate teachers' understanding of STEAM instruction, acting as a useful resource [2,3,5].

1.1.3. GoSTEAM

GoSTEAM was designed to incorporate collaborative work, pedagogical content, and ongoing school-year support. Boice and colleagues [23] describe the pilot year of implementation, including evaluation findings from the summer institute. The authors

found that the ability to collaborate with their peers, Coaches, and Innovators during the summer institute, as well as receiving ongoing resource and pedagogical support from their Innovator and Coaches, were crucial for many teachers [23]. Teachers especially valued the role of Innovators in sharing novel ideas, arts concepts, and innovative technologies when helping teachers design and implement STEAM lessons throughout the school year [23]. The second year of the program was greatly impacted by the onset of the COVID-19 pandemic, and GoSTEAM adapted in response to changing circumstances and teacher feedback. Rao and colleagues [24] reference the impact of moving the summer institute to a virtual setting due to the COVID-19 pandemic. Teachers appreciated having a more flexible schedule and learning from a wide variety of STEAM professionals and community partners in a virtual format. However, they wanted more opportunities to collaborate with their STEAM Innovation Team, anticipating that their Innovator would be especially important during the school year to support collaboration and supplement their STEAM content knowledge [24]. In response to teacher feedback, and as a result of changing COVID-19 policies, the summer institute transitioned to a hybrid format in Year 3, including an increasing number of in-person sessions, site visits to local community partners, and working sessions with Innovators and Coaches. The program's adaptability was essential in maintaining support for teachers, as well as connections with community partners who were also navigating their own changing COVID-19 policies.

1.1.4. Historical Context of the Innovator Model

Prior to GoSTEAM, CEISMC had facilitated over twenty years of K-12 partnerships which resembled the GoSTEAM Innovator Model. The current model has roots in another university program: The Georgia Tech Student and Teacher Enhancement Partnership (STEP) (NSF Project Number DGE-0086420) [25]. In STEP, 12 graduate students were placed each year in local high schools, where they assisted teachers with classroom instruction and the implementation of educational technologies. The graduate students tutored and mentored K-12 students through additional enrichment activities, such as Science Olympiad or math clubs [25]. CEISMC then received funding for a program called Science Learning: Integrating Design, Engineering and Robotics (SLIDER) (NSF Award Number 0918618). This program was a project-based learning curriculum for middle school physical science, which also incorporated engineering practices, crosscutting concepts, and LEGO robotics, and it was piloted in several middle schools within the state [26]. As part of the project, Fellows, who were university engineering graduate students, worked alongside teachers as they implemented the new curriculum, and the Fellows also served as mentors and tutors to students [26]. More recently, CEISMC partnered with a local, public PK-8 Education Expeditionary STEM School to strengthen the school's instructional program through integrating STEM initiatives with the school curriculum. Part of these efforts included assigning four Innovators to teachers at the school in order to support their STEM efforts. Unlike the Fellows, these Innovators were working professionals, not university students, who were interested in the positions because of a desire to bring design thinking and their unique skillsets into classrooms. Many of the successes and challenges of the Innovator program helped to shape the GoSTEAM Innovator Model into its current form.

1.2. Innovator Model

In GoSTEAM, Innovators are members of the local community who bring expertise in STEAM backgrounds to assist teachers in developing and implementing STEAM lessons in their classroom. Initially, the program was designed so that one Innovator was assigned to each participating school, where they were expected to spend up to 20 h per week on site. Each Innovator was intentionally paired with a school based on their class or work schedule, their STEAM expertise, and the school's intended Action Plan. For example, an engineering undergraduate student would be placed at a school with an interest in implementing an engineering-focused Action Plan. In terms of compensation, Innovators were paid an hourly rate for their time spent at their assigned school.

Innovators were recruited via email, word of mouth, and marketing at makerspace fairs or other community events. Recruitment from the surrounding communities, including from partnering organizations and local universities, resulted in Innovators with varied educational backgrounds, STEAM discipline content knowledge, and career tenure (Table 1). In total, 20 Innovators participated in the first four years of GoSTEAM, and most (60%) were undergraduate or graduate students, while the remainder were working professionals.

Table 1. Description of GoSTEAM Innovators.

Year	No. of Innovators (% New to GoSTEAM)	Innovator Backgrounds
1 (2019–2020)	10 (100% new) *	visual arts, performing arts, music technology, entrepreneurship, makerspaces, math, engineering, robotics, neuroscience, technology
2 (2020–2021)	8 (38% new)	visual arts, performing arts, music technology, engineering, robotics, computer science, neuroscience, technology
3 (2021–2022)	10 (50% new) *	visual arts, humanities, performing arts, music technology, computer engineering, engineering, robotics, neuroscience, chemistry, biology
4 (2022–2023)	8 (50% new)	visual arts, humanities, performing arts, music technology, computer science, engineering, robotics

* Note. One Innovator left the program before the end of the school year due to other commitments.

Innovators brought a wealth of expertise from various backgrounds, including visual and performing arts, engineering, computer science, and music technology. These professional experiences also provided a network of STEAM organizations and professionals, which offered authentic STEAM learning experiences for students. Innovators helped arrange fieldtrips, school visits, and communication with experts throughout the community. They were also able to connect teachers and students with numerous local organizations, including art studios, museums, gardens, manufacturing facilities, and nature centers. Innovators were particularly attentive to this aspect of their role in Year 4 in an effort to promote STEAM sustainability and build relationships between schools and local partners headed into Year 5 of the five-year initiative.

As most Innovators did not have previous experience as K-12 classroom teachers, GoSTEAM provided Innovators with support and training to help acclimate them to K-12 instruction. Specifically, Year 1 Innovators were required to participate in several summer institute sessions, totaling 20 h across four weeks. These sessions were identified and assigned by program staff, and part of their 20 h included a 10 h project-based inquiry learning course (PBIL) to prepare them for their in-classroom efforts. In conjunction with their summer institute requirements, Innovators were also asked to work with a week-long, K-12 summer program in order to practice their K-12 instructional skills. These programs were hosted at CEISMC and had a STEAM focus.

In Years 2–4, there were some other support mechanisms which were implemented by GoSTEAM. In particular, GoSTEAM held virtual, bi-weekly group meetings for Innovators to discuss challenges, obtain feedback on upcoming lessons, and receive support with administrative tasks, like ordering supplies or tracking their work hours. Group Innovator meetings supported Innovators' professional development, allowing them to learn from other Innovators and exposing them to new ideas and technologies. These regular group meetings, as well as one-on-one meetings with Coaches and GoSTEAM support staff, became essential support mechanisms for Innovators. As another level of support, the program created the role of "Lead Innovators", who were experienced Innovators that served as a peer mentor for other Innovators working within their school district. During Year 3, Lead Innovators were hired as salaried, full-time employees at the Center. As full-time staff members, Lead Innovators were able to support both schools and other Innovators with their skills and expertise in STEAM teaching and learning. Throughout the course of the program, Innovators expressed increased confidence in navigating relationships with

school employees and the K-12 environment, commonly referencing the support provided by GoSTEAM.

Because the pilot year of GoSTEAM took place during the 2019–2020 school year, when the world experienced the COVID-19 pandemic, programmatic shifts were required during Years 2 and 3. These changes were necessary in order to accommodate the safety restrictions employed by both school districts and the program to involve virtual or socially distanced learning spaces. In Year 2, it was also more challenging to recruit Innovators due to fewer in-person interactions, though each school was paired with an Innovator by the beginning of the school year. Some restrictions continued into Year 3, as some school districts maintained a hybrid learning model. By Year 4, schools fully returned to in-person instruction. While these transitions posed challenges, the Innovator program was able to respond by allowing for more flexibility for Innovators' in-person and remote work schedules.

In Years 2–4, in part because of the COVID-19 pandemic, Innovators had fewer requirements for the summer institute, such that they were only required to participate in the 10 h PBIL course. Furthermore, hiring Lead Innovators as full-time staff members also reduced the need for Innovators to attend the summer institute. Lead Innovators required less training, and, instead, they were able to use their previous experience and expertise to guide and mentor Innovators over the course of the year. Regardless, Innovators were given the opportunity to participate in other virtual summer institute sessions or K-12 summer programs, if interested. While there were fewer summer requirements during Years 2–4, Innovators became more involved in presenting sessions or workshops during the summer institute, due in part to feedback about the benefits of establishing relationships with teachers prior to the start of the school year. Innovators also met with teachers at their assigned school before the beginning of the academic year to design their Action Plan.

2. Materials and Methods

The purpose of this paper is to describe how the ongoing partnership between the GoSTEAM Innovators and teachers impacted teachers' ability to enact STEAM lessons within their classroom. Using qualitative methodology to build understanding on lived experiences, we hope to provide a descriptive account that demonstrates the ways in which Innovators partner with teachers to develop meaning in their role within the program [27]. Applying this methodology, we will address the following question:

- How does the partnership between Innovators and teachers contribute to teacher professional development in STEAM?

2.1. Data Collection

At the conclusion of each school year, all teachers participating in GoSTEAM throughout the school year were invited to partake in a one-hour long focus group or interview. Teachers from each school were invited to participate in a focus group together; however, an interview was conducted in instances where only one teacher at the school was participating in GoSTEAM or if there were time conflicts between teachers. These focus groups and interviews took place virtually, using video conferencing software. A semi-structured protocol was utilized for teacher focus groups and interviews to assess teachers' implementation of their Action Plan (overall experience and challenges faced), collaboration (with other teachers, Coach, and/or Innovator), professional development (usefulness and future needs), and program impact (both impact on teachers personally as well as perceived student impacts). This paper will specifically focus on the qualitative data collected in focus groups and interviews in relation to teachers' experiences with their Innovator(s).

Additionally, at the end of Year 4, 30 min focus groups and interviews were conducted with school administrators at participating GoSTEAM schools. Researchers identified between one and three administrators at each school to invite for a focus group or an interview. Administrators were invited if they either worked directly with GoSTEAM or if they helped implement STEAM instruction within the school. This data collection also

took place virtually, using video conferencing software. Focus groups were organized by the school. If there was only one school administrator available, an interview was conducted. The semi-structured protocol for the focus groups and interviews was designed to understand the support required for the sustainability of STEAM learning after the conclusion of GoSTEAM. Items included administrator involvement in GoSTEAM activities, motivation to participate in GoSTEAM, challenges experienced, and STEAM sustainability efforts, though only data collected in relation to the school administrators' experiences with their Innovator(s) are included in this study.

A team of four researchers conducted the teacher and administrator focus groups and interviews. Often, focus groups and interviews were conducted by only one interviewer. However, in some cases, another researcher was present to assist with notetaking or to familiarize a new research team member with the data collection process.

2.2. Ethics Approval

All instruments and data collection plans were submitted and approved by both the University Institutional Review Board, as well as the Institutional Review Boards for each of the three school districts. All participants provided voluntary, informed consent. Additionally, all researchers completed the Collaborative Institutional Training Initiative (CITI) training before participating in any data collection activities.

2.3. Participants

In order to understand the role of Innovators in teacher professional development in STEAM, both teacher and administrator perspectives were sought.

2.3.1. Teachers

During the first four years of the program, 65 teachers participated in GoSTEAM. Focus group and interview data are available for 45 teachers (69% of those recruited), some of whom participated in multiple years of the program and, thus, multiple end-of-year focus groups or interviews. Of the teachers who participated in data collection, 33% taught in elementary schools, 20% in middle schools, 20% in K-8 schools, and 27% in high schools. About two-thirds of participants (62%) were well established in their career as an educator, having taught for at least five years. On average, teachers joined GoSTEAM with almost a decade of teaching experience (M = 9.72, SD = 6.75) and about 4 years of experience teaching at their school (M = 4.26, SD = 4.17). There were also a wide range of subjects taught, though most teachers (40%) identified teaching STEM-related subjects, including science, computer science, and engineering. Twenty-nine percent of teachers taught arts-based subjects, such as music and fine arts; and almost a third of the teachers (31%) taught another subject, such as K-5 general education, social studies, or English. A description of the teacher focus group and interview dataset, categorized by year, can be found in Table 2.

Table 2. Description of teacher focus group and interview dataset.

Year	No. of Teachers Who Participated in End-of-Year Data Collection (% new to GoSTEAM)	School Level (% Taught)	Subject (% Taught)
1 (2019–2020)	17 (100%)	Elementary School (47%), K-8 School (12%), Middle School (18%), High School (12%)	STEM (41%), Art (41%), Other (18%)
2 (2020–2021)	22 (56%)	Elementary School (27%), K-8 School (23%), Middle School (23%), High School (23%)	STEM (32%), Art (41%), Other (27%)
3 (2021–2022)	21 (57%)	Elementary School (29%), K-8 School (24%), Middle School (24%), High School (24%)	STEM (43%), Art (14%), Other (43%)
4 (2022–2023)	16 (25%)	Elementary School (44%), K-8 School (13%), Middle School (6%), High School (38%)	STEM (50%), Art (19%), Other (31%)

2.3.2. School Administrators

Ten school administrators (67% of those recruited) at six GoSTEAM schools participated in focus groups, including school principals, vice principals, and STEM/STEAM instructional coaches. Of those who participated, 70% had served as an administrator at the school for over a year. Before arriving at their school, some administrators identified holding previous positions at the district level or as a classroom teacher. One STEM/STEAM instructional coach participated in teacher focus groups for Years 1–4, as they joined the program as a classroom teacher. This participant shared their perspectives on the program from the teacher perspective, helping to implement STEAM lessons in the classroom, and as an administrator, overseeing the program within their school. As such, their data are included in both sections.

2.4. Analysis

Transcripts from both teacher and administrator focus groups and interviews were coded following an inductive coding process using NVivo Software (https://lumivero.com/products/nvivo/, accessed on 18 April 2024). For the teacher focus groups and interviews, transcripts were coded by four researchers from the GoSTEAM team. Two of these researchers also coded the transcripts from the administrator focus groups and interviews.

A thematic content analysis approach was used to provide descriptions of the collected qualitative data from both teacher and administrator transcripts [28]. A multiple-cycle descriptive coding strategy was applied to develop a series of initial codes, and then subsequent rounds of coding were completed to refine existing codes [29]. Specifically, the first cycle of coding utilized an inductive strategy to identify the meaning of the data excerpts. One transcript was used by researchers to code individually, and after their initial coding, the researchers met to discuss and reach consensus about how data would be coded for the subsequent rounds. This process helped researchers construct a shared meaning and trustworthiness of the interpretation of the data. The emergent codes were used to create a codebook, which was used for the second round of coding. The second round of coding was followed by subsequent consensus meetings to further refine codes and discuss interpretation of the data. The codebook was used for a final of coding and analysis. The coded qualitative data were merged across years, and the themes illuminated based on the patterns in the data are described below.

3. Results and Discussion

To understand how the partnership between teachers and Innovators impacted teachers' professional development in STEAM, this paper centers on data collected from GoSTEAM teachers in end-of-year focus groups and interviews across Years 1–4, as well as administrator focus groups and interviews collected at the end of Year 4. Contextual data that reference teachers' and administrators' overall perceptions of the partnership are first offered. Then, major themes that depict the impact of the partnership on teachers' professional development in STEAM are highlighted and addressed, followed by a description of any challenges mentioned in the focus groups and interviews.

3.1. Overall Perceptions of the Innovator Partnership

Generally, teachers and administrators mentioned that Innovators provided teachers with necessary support in the classroom, sharing that the Innovators' knowledge and professional understanding of STEAM enhanced the implementation of teachers' Action Plans. Most Innovators (aside from Year 2) worked with teachers in person over the course of the school year, in which Innovators provided continuous support of the Action Plan, including co-facilitating STEAM activities. Overall perceptions are further detailed, categorized by perceptions revealed in either teacher or administrator focus groups and interviews.

3.1.1. Teacher Perceptions of Action Plan Implementation Support

Teachers commonly described their experience with the Innovator as an important factor in the implementation of their Action Plan. Often, the Innovator was referred to as an integral part of the classroom, who put in extra time to support teachers throughout the Action Plan implementation process. Teachers described having a "*vision*" of their goals for the year, and through collaboration with the Innovator, were able to execute STEAM lessons successfully. Frequently, Innovators were labeled as "*a partner*", "*essential*", and "*critical*", in the implementation of the Action Plan. Specifically, Year 1 and 3 teachers explained that the Innovator was not just another person to manage in the classroom but was an asset to their instruction. For example, a Year 3 teacher explained, "*it was great having a second person in the classroom to help out*". This is further evidenced by two other Year 3 teachers, who shared the following:

> *[Innovator] was a, the key part, because honestly, I'm not good at TinkerCAD, and [Innovator] was able to give the kids, a lot of direction and, you know, [Innovator] helped [the students]. . .And [Innovator] helped us put the final model together. So, basically [Innovator] was very essential in the process.*

> *I would just say, having an Innovator on campus, that was just great. I mean, it was just, you know, it informed our ability to do the things that we wanted to do.*

Though Innovators came from a variety of STEAM fields, teachers often shared that the Innovators' creativity and passion for STEAM provided support throughout the implementation of the Action Plan. This was still the case even on occasions when the Innovator was unfamiliar with certain Action Plan topics. For instance, a Year 1 teacher, whose Innovator was an entrepreneur, explained how their Innovator would "*take home some of the projects*" in order to best assist with the Action Plan, which centered on coding. In this case, the teacher shared that the Innovator wanted to take on the additional work because they were "*invested in [the Action Plan]*". In Year 4 focus groups and interviews, teachers specifically mentioned working with a Lead Innovator, as some teachers were supported by both an Innovator and a Lead Innovator. These teachers often highlighted the usefulness of working with both an Innovator and a Lead Innovator, illustrated by a Year 4 teacher who explained that an Innovator was at their school "*pretty much every time*" they were implementing the Action Plan. Such findings speak to recommendations drawn from Houghton and colleagues [18], as well as Bush and colleagues [20], in which the authors describe a need for continuous support and collaboration in professional development to better enhance STEAM instruction. In GoSTEAM, the Innovator support provided to teachers extended beyond the summer institute, as it was not only continuously provided throughout the course of the school year but also within a classroom setting.

3.1.2. Administrator Perceptions of Innovator Support

Administrators at four schools shared that the Innovator was one of the greatest benefits of their school's participation in GoSTEAM. This was demonstrated by a school administrator, who has participated in GoSTEAM since its inception, sharing, "*I just can't speak to the impact of [the Innovator] enough*". Overall, administrators found that the Innovators were consistently available to provide support and guidance to teachers through their projects without "*overtaking*" their instruction. Instead, Innovators worked "*alongside [teachers]*" to facilitate STEAM lessons. The ongoing support described by both teachers and administrators has been referred to in the literature as a necessary aspect of partnerships with community organizations and STEAM experts, as it allows teachers to expand their understanding of STEAM instruction [9,14,15,18,20]. Specifically, administrators found the supportive nature of the Innovator impacted teachers' abilities to implement STEAM lessons, with some administrators describing Innovators as "*another teacher here in the building*" or "*another co-facilitator in the classroom*". In Lees and Kennedy [9], the authors recommend a strategy of STEAM experts co-teaching in an education setting to support teachers' implementation of STEAM instruction. The findings presented by administrators

suggest success in this strategy, with administrators perceiving Innovators to be integral in supporting the classroom implementation of STEAM.

3.2. Impacts of the Innovator Partnership

The findings from Years 1–4 teacher focus groups and interviews, as well as Year 4 administrator focus groups and interviews, illuminate several related themes regarding how the partnership between Innovators and teachers impacted teachers' professional development in STEAM. Specifically, teachers and administrators perceived Innovators to be impactful in developing teachers' skills in STEAM, in areas such as coding and 3D printing, as well as drawing connections between STEAM, district standards, and real-world concepts. Other themes present, though not consistent across each year, were the Innovators' impact on teachers' ability to ideate STEAM lessons, exposure to STEAM resources, and opportunities for collaboration with non-GoSTEAM teachers and other community partners.

3.2.1. Development of STEAM Pedagogical Skills

Across all focus groups conducted, teachers and administrators described impacts on teachers' development in STEAM pedagogical skills. Often, teachers shared the Innovator "*took away some of that fear of trying. . .new technology-based things*" or guided them through learning new skills related to STEAM. Specifically, a STEM/STEAM coordinator shared, "*. . .The Innovator role has really helped open up our teachers to being willing to try very STEAM-based projects, where I think initially, if it were just them, they would shy away from them*".

Additionally, Innovators ensured teachers were equipped with the knowledge to provide STEAM instruction to their students. In particular, a Year 1 teacher, who was implementing an Action Plan with Thunkable coding language, explained, "*[Innovator] would come in and show me exactly what we would be working on, so I would be able to help my kids, as well, throughout the period*". Moreover, Innovators taught teachers how to use tools or resources they were uncomfortable utilizing, which helped teachers feel "*more confident in being able to take. . .what [they] learned from [the Innovator] and apply it*" to their classroom. For example, a Year 2 teacher explained that when their Innovator was instructing students on how to code in Scratch, which is a block-based programming language, the Innovator also provided the teacher with "*some simulations that [they] could use in the classroom to help the students out*". Two other teachers described similar experiences with their Innovator, finding they were able to assist students with STEAM tools, such as a music technology coding program called EarSketch, even in the absence of their Innovator:

> *. . .[Innovator's] like, 'Do you know how to do that?' And of course, I don't. So, [Innovator's] like, 'Do you want me to show you?' And then [Innovator] would usually give me a mini lesson, so that when [they were] giving the kids a lesson, I would have some clue as to what was going on. And then it would be on the days when [they weren't] here, and I had kids that finished a project early, I'd be like, ". . .Go do your code maker, or whatever." They'd be like, "I don't remember how to do that, can you show me?" And luckily, most of the time, I could, because [Innovator] had also instructed me how to do it.*

> *It taught me patience, you know, and it definitely taught me patience and also perseverance and grit working through it. Because it, especially with your first couple times of working with EarSketch, you can kind of get frustrated when you make one wrong move and then you just keep getting the Syntax error. . .I was actually able to motivate and help my scholars with it.*

School administrators also perceived that the Innovator played a role in the professional development of all teachers at the school, not only those in the program. For example, one administrator described how the Innovator's "*industry knowledge*" helped teachers overcome the technology "*learning curve*" that is sometimes apparent with STEAM projects. Additionally, Innovators helped teachers to think "*outside of the box or to try new things*". One administrator described how this was particularly relevant at their school:

> *. . .The teachers also get excited with what the Innovators can bring to their instruction. A lot of teachers will say, "Oh, I don't know how to do that", or "I don't feel comfortable with that". And I. . .immediately silence. I'm like, "Nope, stop there. We have an innovator, and they're coming to save the day, essentially. Like, they will come in your classroom, and they will support you with this, not do it for you, but they will support you". And that is enough to get any teacher who is hesitant, and who maybe presents as unwilling at the onset of the project. It gets them to kind of come over and say, "You know what? All right, let me give it a try". And those have been some of the best projects, where the teachers have thought, "Nah, we can't", or "I can't as a teacher". And then we present them with the innovator who comes in and supports them through that process, and they come out on the other side and the scholars of course benefit from it 100%, but the teachers grow too.*

Generally, administrators highlighted the usefulness of working with Innovators and were able to identify changes in teacher confidence and experience with STEAM instruction, with two administrators sharing the following:

> *Having some house experts when it comes to STEAM has really been beneficial because even, you know, when the partnership no longer exists, these teachers have created a level of expertise when it comes to STEM and STEAM and how to incorporate it into everyday learning.*

> *For me, for residual impact, where now even if the Innovator is not here, then we may have some teachers who will try to think outside the box or try to try new things as well, and so I think it's that partnership that also kind of buds a newness, a refreshing, so to speak.*

Teachers and administrators both described situations in which teachers displayed more confidence in their abilities to use their skills in STEAM, such as coding, 3D printing, and interdisciplinary instruction, such that even when the Innovator was unable to participate in classroom instruction, teachers were able to answer student questions and address technical issues. Scholars have previously concluded that teacher professional development which fosters community partnerships can further elevate teacher confidence [7,8,10,11,13,16]. For example, in Paradise and colleagues [11], the study indicates that teachers' partnerships with community members expanded their understanding of engineering concepts. While GoSTEAM focuses on STEAM generally, findings from focus groups and interviews with teachers and administrators across Years 1–4 indicated similar sentiments, suggesting that the impact of partnerships can expand across fields.

3.2.2. Connections between STEAM Concepts, District Standards, and the Real-World

Commonly, teachers indicated Innovators helped them see where STEAM connects "*day to day*". Drawing connections between STEAM, district standards, and real-world aspects is often referenced in the previous literature, in which scholars found that the collaboration between community partners and teachers often encouraged teachers to make these associations [2,6–8,10,11,19,22]. In GoSTEAM, teachers frequently described Innovators as a "*co-teacher*" in the classroom, providing a unique perspective to STEAM concepts with "*different ways of looking at a problem*". In fact, some teachers explained they designed their Action Plans to leverage the Innovator's expertise, as teachers found their students were receptive to learning from the Innovator's real-world experiences in STEAM. For example, a Year 3 theater teacher described how the Innovator helped to create STEAM lessons by using their professional skills in costume design:

> *. . .We had to capitalize on [Innovator's] strengths because [their] strengths are in cosplay and making armor and fantasy and things like that. So, we did a production. . .which had a lot to do with fantasy and dungeon dragons and that kind of stuff. So, [Innovator] worked, creating lesson plans and working with students, [they] taught a handful of the students to sew. And so, [students] were able to sew and utilized our new costume shop and build really, really awesome costumes for our show.*

Furthermore, Year 1 and 2 teachers explained that Innovators helped them connect STEAM lessons to the core standards set by the school district through using knowledge and resources from their own professional experience, such as music technology, EarSketch coding, and light graffiti. These teachers described sharing the district standards or the upcoming curriculum with the Innovator, and the Innovator would assist with "*bring[ing] everything together into one project*". In particular, a Year 2 music teacher described how the "*first thing [Innovator] asked was for the standards, and everything was based on the standards*".

The process of connecting the standards to the Action Plan is further demonstrated by a Year 2 teacher's experience working with their Innovator, stating, "*[Innovator] asked. . .the standards. . .that I really wanted to incorporate in the lessons, and [they were] able to throw out those ideas. I would tell [Innovator] an idea that I had, and [they] would help me come up with some resources*". In this instance, the teacher was teaching an advanced high school drawing and painting class, and their Action Plan involved creating digital art. Specifically, the teacher intended to integrate technology with their standards in sketching. To do this, the Innovator directed the teacher to Sketchpad and Magma Studio, which are platforms for creating and designing digital artwork. Students "*create[d] sketches*" on paper and "*upload[ed] those sketches*" to Magma Studio or to Sketchpad. Then, students shared their digital artwork on a Padlet, allowing the students to "*see across the board*" the variety of "*different art styles*" possible through digital art.

The experiences described by teachers illuminate the ability of Innovators to work collaboratively to develop lessons which connect to STEAM concepts, district standards, and the real-world. The previous literature suggests similar findings, such that community partnerships are beneficial in ensuring teachers can make connections across STEAM concepts, standards, and real-world contexts [6,19].

3.2.3. Ideation of STEAM Lessons

In teacher focus groups and interviews from Years 2 and 4, teachers described how the Innovator elevated their ideas related to STEAM lessons, with one teacher explaining, "*[Innovator] helped us ramp up what we were already thinking*". Year 2 and 4 teachers characterized their Innovator as a resource for ensuring their ideas could come to life, further highlighting the role community partners can play in the development of new and innovative STEAM lessons, as captured in Caplan [6]. Specifically, two teachers identified generating new ideas for STEAM content and methods for instruction with the use of their Innovator, as follows:

> *The only thing I would want to do is, I want to get [Innovator] and all [their] little ideas and just keep [them] with me. . .really, really helpful for me this year, opened up my way of thinking. Adding the technology into visual arts was, it was really exciting, and being able to use [Innovator] a lot to be able to talk my ideas and just really take it beyond drawing boards was nice.*

> *Whether it was specific to a GoSTEAM project or just things that we were thinking around STEAM in general. . .like I was like, a thought partner, like, "Hey, what do you think about this? We're thinking this." And you know, [Innovator] input was invaluable.*

3.2.4. Identification of STEAM Resources

As described only in Year 2, Innovators introduced teachers to new STEAM resources or new ways of using STEAM resources, including "*3D printers*", "*Sketchpad*", and "*Canva*". At times, if teachers were unsure about what resources to use for Action Plan implementation, the Innovator would "*literally find materials and find the resources to do*" the Action Plan. The introduction to new resources provided teachers with examples of ways to conceptualize STEAM instruction within their classroom, offering new avenues for implementing their Action Plan. Within the literature, scholars have found that community partnerships can connect teachers to new resources, especially those which they might otherwise not have access to [7,8,10,11]. Meanwhile, in GoSTEAM, this finding was not presented in Years 1, 3, or 4, and teachers in Year 2 referenced their Innovators' ability to connect them to new STEAM resources. These resources assisted teachers with their implementation

of STEAM lessons during an especially challenging year due to the COVID-19 pandemic, indicating another level of support provided by Innovators.

3.2.5. Additional Opportunities for Collaboration

Teachers in Year 3 mentioned that Innovators collaborated with teachers outside of the program on additional STEAM activities taking place at the school. This led to GoSTEAM teachers participating in collaborative lessons with non-GoSTEAM teachers at their school "*whenever possible*", as well as with other community partners specializing in STEAM, such as a local non-profit that specializes in STEAM outreach. In Gross and colleagues [8], the authors explain that one method for ensuring partnerships in K-12 spaces are successful is encouraging other partnerships, too. The findings within the literature are similar to those found in Year 3, as teachers found their Innovator was influential in forging new partnerships. The new opportunities for collaboration expanded the reach of STEAM instruction and provided collaborative opportunities on STEAM projects across the school.

3.3. Challenges Experienced

In teacher focus groups and interviews across all years, participants commonly referenced some challenges related to the partnership with their Innovator. Primarily, because Year 2 took place during the global COVID-19 pandemic, teachers were managing a new, virtual or socially distanced classroom space while also implementing an Action Plan. In Year 1, Innovators were present inside the classroom and throughout the school space, but with COVID-19 measures in place at schools, Innovators in Year 2 were often restricted from visiting the schools in person. Due to the challenging year, teachers described the need for flexibility and communication when working with Innovators. Regardless, some teachers, especially those new to the program, found their Innovator to be a positive resource, helping teachers in navigating the virtual space and also to "*lean on [Innovator] for basically anything*".

A common challenge mentioned by teachers in Year 3 was the larger number of teachers participating in the program, which led to an increasing number of teachers participating at some schools, specifically. This posed a challenge in terms of collaboration between teachers and Innovators, as Innovators at some schools assisted with the implementation of multiple Action Plans. Though most teachers felt there were sufficient and ample interactions, some Innovators needed to split their time between classrooms due to class-scheduling conflicts and other implementation requirements. In most cases, though the interactions were less frequent, teachers still found their Innovator was constantly checking in and was useful for "*brainstorming*" and "*[providing] resources and ideas*" towards Action Plan and STEAM lesson implementation. These challenges speak to the delicate balance that Innovators need to strike in order to adequately support and collaborate with teachers to support STEAM instruction.

3.4. Limitations

A limitation of this study is the differing context of each year of implementation. Specifically, the Innovators and teachers who participated in the partnership sometimes changed year-to-year, as schools and teachers left the program or Innovators accepted positions elsewhere. The year-to-year change in teacher and Innovator participation may have contributed to some themes arising solely within the context of a specific year and not necessarily in other years. Another possible limitation comprises the programmatic changes to the Innovator Model in Year 2, which were required due to COVID-19 pandemic restrictions. Specifically, the programmatic changes may have contributed to some themes only arising in Year 2 and not in other years. However, the findings suggest that, even with the changes and challenges due to the COVID-19 pandemic, the partnership between the Innovators and teachers during Year 2 was consistently perceived to positively impact the development of teachers' skills in STEAM and their ability to draw connections between STEAM, district standards, and real-world concepts. As such, despite Year 2 posing new

challenges for teachers and Innovators, the program was able to restructure the Innovator Model to maintain the stability of the partnership.

3.5. Next Steps for the GoSTEAM Program

During Year 5, the program attempted a skill-to-project model, in which Innovators were assigned not to a school, but to a particular project that matches their unique skill set. This model allows the program to connect teachers with local community members who have relevant expertise but may not be able to commit to a full year of part-time work. Based on feedback about the onboarding process in Years 1–4, Innovators also began Year 5 with a guidebook developed by program staff, which includes information about the Innovator role, expectations, and resources. This guidebook may serve as a helpful resource for other schools and organizations interested in implementing a similar partnership model. GoSTEAM also disseminates opportunities for teachers to visit and learn from local community partners which may be of interest to their Action Plan. These opportunities include trips to local art exhibits, museums, and theater productions. Connecting teachers with community partners (aside from their Innovator) can help sustain the STEAM professional development provided during teachers' time working with their Innovator, even at the end of the program [22].

3.6. Future Considerations

Based on the findings of this study, there are some recommendations to consider for policymakers and practitioners who are interested in developing teachers' professional development in STEAM. One recommendation would be to encourage long-standing partnerships not only with community organizations but also with individual experts within STEAM fields. Our findings suggest that having space to collaborate and work consistently alongside a STEAM expert was beneficial in developing teachers' understanding and implementation of STEAM lessons and concepts. Moreover, policymakers and practitioners could advocate for partnerships in which STEAM professionals co-facilitate in-classroom STEAM instruction, as the findings presented in this study suggest these types of partnerships enhance teachers' implementation of STEAM instruction, as well. Such partnerships require the allocation of resources and time to support educators and STEAM professionals in building these partnerships, which should be further considered.

4. Conclusions

The previous literature regarding partnerships between teachers and community experts in a professional development setting emphasize the importance of fostering long-standing partnerships which emphasize consistent collaboration and support [3–6,18,20]. Partnerships between educators and community partners can encourage connections between the real-world, district standards, and STEAM concepts, suggesting that community partnerships can be beneficial for enhancing teachers' STEAM professional development [2,6,19,22]. The findings of this study provide a unique contribution to the literature, as the GoSTEAM Innovator Model instills a yearlong collaboration between teachers and community partners to implement STEAM lessons in a classroom setting. Due to the long-standing partnership, Innovators were often viewed as an integral part of the classroom, as they spent several hours a week working and collaborating with teachers and students in a classroom setting. In particular, the Innovators often acted as a co-facilitator or co-instructor in the classroom, creating a collaborative environment for implementing STEAM instruction, similar to suggestions made in the literature [18]. The findings of this study indicate that Innovators were a crucial aspect of teachers' ability to enact STEAM lessons within the classroom, providing a wealth of knowledge to expose teachers to new ways of implementing STEAM in their classroom. By participating in the partnership, teachers perceived they were more confident in their ability to participate in STEAM instruction, and they were also able to make connections between STEAM, the real-world, and district standards. These findings support the established literature related

to the unique ability of STEAM professionals to elevate teachers' abilities and confidence with integrated STEAM instruction [2,6–8,10,11,19,22] and, furthermore, speak to how a long-standing partnership with community experts can contribute to teachers' ability to implement STEAM in their classroom.

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