education sciences

MDPI

Article

Integrated STEM and Partnerships: What to Do for More Effective Teams in Informal Settings

Trina J. Kilty [1,*] and Andrea C. Burrows [2]

[1] Department of Computer Science, University of Wyoming, Laramie, WY 82071, USA
[2] School of Teacher Education, University of Wyoming, Laramie, WY 82071, USA; andrea.burrows@uwyo.edu
* Correspondence: tkilty@uwyo.edu

Abstract: The purpose of this study was to explore how undergraduate college students formed partnerships in informal educational teams to design and build an interdisciplinary, ill-defined, integrated science, technology, engineering, and mathematics (STEM) project and translate it to lessons taught to a pre-collegiate student (e.g., K-12 in the US) audience. The authors pursued two research questions: (a) How does an authentic research project provide space for integrating STEM disciplines? (b) How does an authentic research project impact partnerships among team members? Nine undergraduate college students were accepted into the 2020 cohort, forming three teams of three undergraduates each. Teams were roughly composed of one engineering major, one science major, and one education major. Methods of data collection included interviews and field notes. Data were analyzed by assessing the level of partnership achieved based on an already established model. Results indicate that all teams progressed through pre-partnership to at least the partnership (little p) level. Two partnership dimensions achieved the highest (big P) level: one of perception of benefit and one of products and activities. The results have implications that integration of STEM disciplines and forming partnerships could be related, and that building teamwork skills results in products of higher quality. The results are linked to previous research and recommendations for more effective partnerships are provided.

Keywords: integrated STEM; partnerships; interdisciplinary teams; informal education; team building; real-world problems; authentic science; effective collaboration; partnership dimensions

check for updates

Citation: Kilty, T.J.; Burrows, A.C. Integrated STEM and Partnerships: What to Do for More Effective Teams in Informal Settings. *Educ. Sci.* **2022**, *12*, 58. https://doi.org/10.3390/educsci12010058

Academic Editors: Mieke De Cock and Billy Wong

Received: 21 October 2021
Accepted: 11 January 2022
Published: 17 January 2022

1. Introduction

There is a nationwide call throughout the United States and the world for integrating the disciplines of science, technology, engineering, and mathematics (STEM) to prepare students for needed 21st-century skills [1,2]. Researchers have identified necessary core skills including effective communication, collaboration, problem solving, critical thinking, and creativity, along with technical skills and information management [3]. Some researchers claim that these skills are equally essential [4]. To achieve these skills, teachers may integrate the STEM disciplines, and one way is implementing engineering design principles in different contexts that emphasize underlying crosscutting concepts [5]. The authors of this study were inspired to develop and implement an undergraduate college student research project using an authentic setting and bringing together undergraduates from engineering, science, and education majors and disciplines, as those projects have been successful in the past [6]. The authors were interested in exploring how a context favoring integrated STEM might impact undergraduate college students to form a team and work in partnership toward designing and building a quality product.

The grant-funded internship project was implemented for the duration of three calendar years. During the second year, 2020, the authors designed and carried out a study to explore how undergraduate college students formed partnerships through teamwork to design and build an interdisciplinary, ill-defined, integrated STEM project (taking place outside of college coursework) and translate their project to lessons taught to a pre-collegiate student (e.g., K-12) audience. The authors utilized the idea that "encouraging design teams to monitor their activities can be beneficial" [7] p. 623. Many researchers have explored teaming; however, many of these studies are conducted outside of the educational setting [3,8–17]. Seeking understanding in an educational setting, but in a non-traditional learning space, the authors pursued the following research questions: (a) How does an authentic research project provide space for integrating STEM disciplines? (b) How does an authentic research project impact partnerships among team members?

1.1. Theoretical Framework and Background Literature

The authors conceptualized the overall project according to themes of authentic scientific inquiry, problem-based learning, integration of STEM disciplines, hands-on learning, and emphasis on engineering design practices, as components of integrated STEM learning [18]. The authors used problem-based learning [19], described by Merrit and others [20] as solving problems by integration and application of knowledge in actual settings and similar to clinical or medicine education. The authors encouraged utilization of engineering design practices as a model for this qualitative case study. The authors asked undergraduate college students to build and teach in authentic pre-collegiate school settings, and both of these components align with authentic scientific inquiry [21]. The projects were ill-defined problems the participants chose together as a team. The authors placed undergraduates in teams to encourage teamwork, an implied definition of such reported by Newell and Bain [22] to include higher education students, interdisciplinary, focus on the process, using problem-based learning, of developing interpersonal skills and partnerships [22]. The undergraduate teams needed to conduct research to determine if their problem and proposed solution was feasible, how to plan and carry out an experiment to collect data, and how to translate their work to a younger, less-technical audience. The undergraduates taught lessons as outreach with a partnering local school.

The theoretical framework utilized was an interpretivist, hermeneutics lens. The authors purposely attempted to understand participants' experiences, and to interpret the phenomenon of the authentic STEM project and partnership development. The research questions that ask "how" the project integrates with disciplines and impacts partnerships are in line with a hermeneutics framework. In this case study, where the participants were all tasked with the same problem, the participants were interviewed as well as observed, and the participant was the main producer of knowledge. The authors' role was to describe what they heard and saw as detached researchers [23].

1.1.1. Integrated STEM

For the authors of this article, and informed by multiple authors [24], STEM integration is defined as a space where STEM problems are from the real-world, connected by concepts and skillsets, have multiple disciplines represented, provide structure for the integration, and offer a space for participant collaboration. The nine undergraduate college students in this study, comprised three teams of three members each. The three projects required the undergraduates to stretch beyond the comfort zone of their major of study to learn new skills and knowledge from other disciplines. The completion of the project asked students to utilize engineering design practices, which non-engineering majors may have been unfamiliar with but have been implemented as part of national science standards in many pre-collegiate schools [5]. Possibilities for integration of disciplines were involved with formulating a real-world scientific question or an engineering problem that could be addressed by gathering data associated with a high-altitude balloon, designing and building a payload project to accompany a high-altitude balloon, collect and analyze data attached to sensors on a high-altitude balloon answering the question or solving the problem, and finally, to translate the project into lessons for informal outreach to a pre-collegiate audience. To accomplish this, the undergraduates worked with a partnering teacher at a participating pre-collegiate (e.g., K-12) school. This integration and emphasis on interconnectedness involved STEM majors working with education majors, some of whom intended to teach in a non-STEM discipline (e.g., English).

The authors conceptualized the participants working as teams on the project according to integration of STEM disciplines, with emphasis on engineering design practices [18]. The authors tried to place projects in the context of authenticity [21] as well as emphasizing engineering design practices [25,26]. Overall, the undergraduate teams used a modified collaborative and cooperative learning approach, which has been shown to increase meaningful learning in a social environment [27]. A true cooperative learning strategy encourages interdependence among team members, which we encouraged, but lacked structure and teacher direction [28], given that this study took place outside of formal undergraduate coursework. The authors followed the collaborative learning model as defined by van Leeuwen and Janssen [29] more closely than they did the cooperative learning model, by encouraging the undergraduate team members to coordinate effort to successfully complete the project, which aligned well with integrated STEM. Researchers may use collaborative and cooperative learning interchangeably [20,29], while others define the concept broadly to mean any setting in which more than two people come together to learn something [30] to include learning in online settings [31].

The authors used a design like other studies exploring how preservice teachers integrate STEM and followed recommendations to modify for strategic, purposeful partnerships, a focus on how the project applies to real life, encourage reflection on prior experience of teaching and learning, and use online resources to conduct background research [32]. The authors of this study followed other's recommendations to allow the undergraduates time for maximum exploration and choice of project during the initial stages as well as to encourage iteration and monitor perceptions of team dynamics [7].

The undergraduates were expected to design and develop an experiment product, hereafter referred to as a payload, that would collect data necessary to answer their real-world question or solve their problem. This utilized a problem-based learning strategy that asks learners to pursue knowledge germane to solving the problem. Researchers have found that educational activities utilizing problem-based learning have resulted in learning gains [25], creativity [33], lateral thinking [34], and one twenty-year meta-analysis of project-based learning showed medium to large mean effect size (0.71) for student achievement [35]. Problem-based learning has a constructivist context, and one of the six aspects researchers have described is that going through the process results in participants seeing value in interdisciplinary teamwork and accepting the challenges in working with different perspectives [36]. Moreover, other researchers have found that problem-based learning contributes to teamwork, communication, and time management [13]. The conversation is ongoing, but still supported, as some researchers have proposed moving from problem-based learning (and the prior project-based learning) to practice-based education [37].

For this study, the authors provided undergraduates a choice of project, but purposefully formed teams based on intended major of study. The teams were encouraged to make the project community-based, culturally relevant, collaborative, engaging, and representative of all the STEM disciplines. The authors studied the teams' process leading to performance in the sense of creating a payload and teaching lessons to a younger audience. Both mental models and team interactions, insofar as their knowledge gleaned from their major area of study, constitute a teamwork process [15]. Although the projects in 2020 aligned with personal interests of the participants, there was a greater societal impact to all projects. The partnering pre-collegiate teacher helped tailor projects to provide place-based and locally relevant context for lessons at the local school. Moreover, the authors guided the undergraduates to select projects that would apply their coursework to an actual problem, the real world, and what they might do in their future career.

Each team conducted a background study to choose their project query, in terms of a problem to solve or a question to answer by collecting data attached to sensors on a high-altitude balloon and translate their learning to lessons they taught to a younger audience. Although this overall goal was stated upfront by leadership and time on task was clearly outlined, intermediate goals of test launch, writing lesson plans, and planning classroom visits were decided by the undergraduate teams. Thus, teams set their own intermediate goals with the ultimate goals of completion of the project. Some researchers have shown that the most difficult goals lead to the highest effort and performance [12]. Setting goals that direct effort in a relevant way may energize team members and lead to action and persistence [12]. This goal setting theory was the foundation of the authors allowing undergraduate teams free rein to choose project questions, develop a payload, communicate with the partner teacher, and plan and deliver lessons in a K12 classroom. In addition to the performance goals of payload data collection and delivery of classroom lessons, the authors recommended that the undergraduates set goals as well, because research has shown the even the perception of others' mastery goals has a positive effect on a team's overall engagement and motivation [11].

1.1.2. Partnerships

As recommended [18], the authors encouraged "transfer knowledge across disciplines" by purposefully forming diverse teams. The project team spent time considering "the [informal] environment where the activities [would] take place, time allotment, facilitator background and availability, and the [grant's] overarching goals" [38] p. 44, which are important factors to consider when creating a non-traditional learning environment. The authors, following recommendations by researchers, did not designate a leader, allowing students to organically develop a leader—or not, as researchers have shown that there is no measurable difference unless there is a time constraint [17]. Each team included one engineering major, one science major, and one preservice teacher education major. The teams were asked over the course of a calendar year to build a real-world experiment, a device that collected data, or payload, that was attached to sensors on a high-altitude balloon launched at the participating pre-collegiate school. The project provided real-world experience for the preservice teacher by packaging lessons and activities and teaching them as informal outreach to a local classroom.

By deliberately creating this synergy, the authors were orchestrating a high level of integration [39] among undergraduate teams and aligning goals. Researchers have suggested that outcomes are better if team members' goals are aligned [9]. The authors purposefully formed undergraduate teams to foster teamwork and develop partnerships. Researchers showcased how discussions based on evidence-based justification for design decisions among middle school students were a key factor in fully integrating STEM disciplines [40]. Applications to the real-world extend to not only the problem chosen, but also to the teamwork (potentially forming partnerships) necessary in STEM disciplines as well as education. This style of collaborative learning through interaction has been shown to increase intrinsic motivation and satisfaction and will affect attitudes of participants [41]. Overall, evidence exists that communication is key to successful teamwork [8].

Working from this model, the authors designed a study to explore the intersection and interactions between integrated STEM projects and the development of partnerships among a team of undergraduates with different majors of study. STEM discipline cohesion is aided by coordination of tools and materials, forward and backward projection to reference when teaching, and use of consistent underlying concepts when teaching [42]. Conflicts, both micro and macro, were expected. Researchers have shown that micro conflicts are bound to happen, and the resulting interactions reduced uncertainty in successful teams and increased it in unsuccessful ones [16]. Educational researchers have proposed a definition of a team, "members' interdependent acts that convert inputs to outcomes, through cognitive, verbal, and behavioral activities directed toward organizing taskwork to achieve collective goals" [16] p. 357. The process of teamwork describes how a team is doing and the nature of member interaction [14]. These researchers propose the time span for a team be divided into episodes based on activity, thereby defining a period in which goals are set, another of action, and the third of interpersonal relationships [14]. In this sense, the team progresses towards the ultimate goal by moving in and out of episodes in which attention shifts towards one of these episodes. Because the study timeframe was open under the umbrella of a calendar year, the authors framed teamwork into episodes of goal setting, followed by payload work, followed by goal setting, followed by lesson planning. Action mainly happened in the final semester as payloads were launched and lessons taught.

The undergraduate teams based the projects themselves on integrated STEM content, drawing from all disciplines of STEM to an extent, as described in Table 1 and met the collaboration, skills, and structure pieces too. The authors designed the integrated nature of the projects to facilitate participants to learn from each other, gain appreciation of the integrated nature of STEM, and build a potentially partnership-based team.

Table 1. Description of team members and projects.

Team Members (Pseudonyms)	Major Area of Study	Project Description	STEM Integration
May (Female) Meg (Female) Mike (Male)	Science Education Mechanical Engineering Civil Engineering	**Microbes**: Collect microbes at high altitude	S = microbes background knowledge T = payload, high-altitude balloon E = design mechanism to collect data M = coding, programming Arduino (&T)
Gabe (Male) Glen (Male) Gail (Female)	Science Education Computer Engineering Physics	**GPS**: Measure occultation of GPS signal at high altitude	S = occultation and weather prediction T = program raspberry pi E = build payload M = works with T, coding, angles
Carla (Female) Carol (Female) Cal (Male)	English Education Mechanical Engineering Physics	**Cell Signal**: Determine nature of cell phone signals at high altitude	S = nature of cell signals T = payload, high-altitude balloon E = build payload, collect data M = interpret and display data as graph

2. Materials and Methods

The authors conceptualized this study as a qualitative, collective case study [43]. The case study was instrumental to refining understanding of how, in undergraduate teams, partnerships intersect with integrated STEM. The overall National Science Foundation grant-funded project spanned three calendar years, and the purpose was to address the issue of improving undergraduate STEM education. This study focused on the 2020 cohort according to three purposefully selected teams, which made cross analysis multiple case study possible by comparing each team, or case, with each other in the overall context of the collective case study [43,44]. The authors used an interpretivist, theoretical stance in this study to describe the undergraduates' experiences and meaning making during the process of forming partnerships and building teamwork [23]. Sources of data in this process-based study included interviews with each participant and observational field notes (taken by the authors) of the teams during weekly official meetings and during teaching in the pre-collegiate classroom. The field notes and transcribed interviews were coded and analyzed deductively according to the model of partnerships developed by Mullinix [45]. Triangulation of data collection, namely observations, interviews, and the products of the undergraduates' projects (e.g., experimental payload and lesson plans) ensured credibility. Credibility was also enhanced by discussion between the authors, and constant comparison of authors' interpretations of the data and the coding of partnership level [44]. Teams (cases) were analyzed within and comparatively [44] to further understanding of the research questions.

The authors asked the undergraduates to work from an engineering perspective (as described by [46]) as a construct of human-made test of a solution. The criteria were the practical success of the payload as a technical product that was effective and efficient at answering the question or solving the problem. The nuances of how teamwork functioned were perceived, constructed, and communicated by the participants to the authors. Although the authors considered studying the undergraduates' conversations through the function–behavior–structure method [10], research shows that if content-based analysis is not the focus of study, there is no significant difference between the more laborious function–behavior–structure and using more informal methods, such as a turn-taking approach [10]. A simpler approach indicates involvement of team members and may be analyzed by a single coder (first author), which was a constraint of this study. Moreover, meeting and dialogue data among team members were not collected. Thus, the authors relied on interview and perceptions of team members regarding the project narrative. Perceptions of the undergraduates toward their teamwork process constructed the knowledge gleaned by this study. The authors purposefully used this framework to facilitate success by following others' recommendations [7]. The authors functioned in a detached role, while the participants were the main knowledge builders. Although present at weekly meetings and interacting with all team members, the authors strove to bracket themselves from each project, minimally participating in meetings to concentrate on taking observational field notes.

The three projects are described in Table 1 including a description of team members included in this study, their declared major area of study, a brief description of their project, and a description of how STEM disciplines were integrated in the execution of each project. Because the project questions were defined by the undergraduates in terms of scope, full integration of all disciplines of STEM, although encouraged, did not always happen. For example, mathematics was used as a tool more so than a concept. Others have found that college student teams used mathematics as a tool and underutilized mathematics, thereby not fully integrating STEM [32]. The authors followed [32] recommendations, including (a) purposefully selecting teams to encourage partnerships, (b) encouraging teams to utilize online resources, (c) emphasize the application of the project to real life, and (d) encourage undergraduates to reflect on their own experiences when planning lessons to deliver to a younger audience.

The undergraduate teams were purposefully selected by the authors to maximize integration of STEM. The undergraduates applied to be a part of the project and all participants consented to take part in this study. IRB approval was given by the supporting university (blinded for review). Undergraduates were sophomores or juniors at the beginning of the program; people from traditionally underrepresented groups were encouraged to apply, although data pertaining to those characteristics were not collected as part of this study. Nine undergraduates were accepted into the 2020 cohort, forming three teams of three undergraduates each. The GPS and Cell Signal teams were composed of one engineering major, one science major, and one education major. However, the Microbes team was slightly different with two engineering majors and one participant double majoring in science and education. That double-major participant left the project early due to issues related to the COVID-19 pandemic. A replacement was found who held a prior degree in science while pursuing a certificate in secondary education. Although the changes in participants of the Microbes team caused a departure from the authors' plan of similar teams of undergraduates, a collaborative, engaging, skill-based, and real-world problem set was still the foundation of the Microbe team.

Results are based on data collected during interviews with each participant and observational field notes during weekly meetings and teaching in the pre-collegiate classrooms. The authors conducted one-on-one interviews with all team members in a semi-structured manner. Due to the COVID-19 pandemic, the authors conducted some interviews in person, while others were conducted over web conferencing software Zoom. Interviews were recorded and transcribed verbatim. For the analysis of the team partnership levels, the continuum presented by Mullinix [45] was utilized and bolstered by the previous work by Burrows [47]. Basically, there are three stages of the partnership where the least developed is the pre-partnership, followed by the partnership (little p), and the most developed is the Partnership (big P). The dimensions of these three stages are focus of interaction, activities/projects, time/orientation, benefit, trust/respect organizational structure, organizational strategies, influence, and contracts. Each team was holistically assessed according to this continuum.

3. Results

The lesson plans were a product indicating effective and efficient planning of lessons and activities that engaged a pre-collegiate class and provided motivation to learn STEM. The process of developing partnerships and teamwork skills contributed to the quality of the products and is described within each team in the following sections.

3.1. Microbes Team

The Microbes team is described in Table 2. This team differed from the other two teams in two ways. First, it was composed of an education major who holds a prior degree in geology, and who joined the team halfway through 2020 as a replacement for a team member who left the project due to issues related to the COVID-19 pandemic. In addition, the Microbes team was composed of two engineering majors, civil and mechanical, instead of one engineer and one science major.

Table 2. Microbes team summary, successes, challenges.

Team Member and Major	Summary of Learning Learned from or by . . .	Successes	Challenges
Meg: Mechanical Engineer	Others Teamwork Teaching Independent research	Integrated relationship of integrated STEM and teamwork	Impact of loss of team member
Mike: Civil Engineer	Doing Others (remotely) Teaching	Teamwork was separate but coordinated	Impact of loss of team member Teamwork was remote
May: Geology, Secondary Science Education	Others Independent research "The Engineers"	Teamwork was a relationship	Felt separate, "them and me" Joined team late Longed for more involvement

3.1.1. Integrated STEM—Microbes Team

The Microbes team perceived a level of benefit from the project, both by learning from each other and by learning content outside their major area of study. As Mike summarized, "I went from knowing nothing about Arduino besides the fact it was a microcomputer brain to actually being able to code and attach parts to it." Mike gleaned this knowledge by learning from others online in chat rooms and discussion boards, where he modified examples posted by others.

Mike considered his work with the other engineer, Meg, to have been productive and cooperative. He described:

> We were pretty in sequence. [Meg] obviously took charge of more the actual, like, physical design and layout, where I took control over, like, the electronics and the motors and stuff like that. But we still had to work very closely together, and it was very integrated, what we did. Or, like, the stuff was very reliant on each other. We had to test them with both parts.

Meg realized a missed opportunity to expand her locus of influence but also recognized the value of experiencing an engineering design process firsthand. She summarized the project:

> Well, I've realized, and this is something you would never learn in an engineering classroom, that you can have all these ideas, and they could be a really good idea, look super pretty on paper, but they're not actually practical. And I went through so many different designs, and I was like, oh this is awesome! And then I'd show

> it to [Mike] and he'd be like, yeah, but that and that and that . . . and I'd be like, yeah, that's a really good point. Gotta change it. So, I don't know, I think my understanding of the engineering process overall definitely improved. Um, like, I think there was an opportunity for me to gain a better understanding of, like, the electronic components, except I didn't really take [Mike] up on that. But it was a potential.

Meg learned from the education major as well. Meg said that May "widened my range of thought" by presenting a different, science-focused perspective on the project, where "sometimes I kind of felt like a student too." Meg's role in the classroom as guide helped her learn the content:

> It helps me understand the project more when I'm trying to explain it to other people . . . I think it helped me realize, like, the good parts and the bad parts of the payload, like the parts I wasn't really able to explain? Those were the parts that I should reevaluate.

Meg learned confidence from observing May teach in the K-12 classroom, explaining that, "after watching her in the classroom, I feel like I could possibly do that if I had to."

The Microbes team faced a challenge by losing a team member due to impacts of the COVID-19 pandemic. Thus, the team was left with two engineers. An education major, May, joined the team in fall 2020, more than halfway through the project and after the project was chosen, payload built, and a test launch performed. May joined the team mere weeks before the team went into the classroom to teach lessons and activities and encourage pre-collegiate students to participate in the launch. The close timing and late start affected the integration of the scientific and engineering content with education and tailoring the payload-related concepts to a pre-collegiate audience as May scrambled to design lesson plans and activities that pertained to the project and research the concepts to provide a foundational context to the lessons. Although she found meeting helpful and enjoyed getting to know the two engineer team members, May said, "sometimes it did feel like I was separate from the engineers . . . . I had to do a lot of research" in order to understand the Microbes content, "I had to really dig in." Although May gave credit to the engineers' role in the classroom, "they were great when they were explaining, the, you know, engineering portion", she wishes she would have had an "explicit part for them, to be more involved in" the classroom portion. She suggested that "having a more structured plan and structured meetings between me and [Mike] and [Meg] um, would have helped their involvement in the classroom."

3.1.2. Partnerships and Teamwork

May acknowledged the challenge of joining a team midway through the project, saying "coming in earlier probably would have helped a lot, just with my communication with them, and you know, us getting comfortable with each other and figuring out what each other's expectations were." She said, "it would have been nice to know them for longer" which indicates a perception that she did not fully move from getting to know them into true collaborative teamwork. This feeling of incompleteness was sensed by May, who "would have loved to be more involved in, like, the payload development. Because even though I'm not an engineer, you know, I have a STEM background . . . I think it would have been wonderful to be there for the whole year".

Mike described the impact of the unexpected team member change on the teamwork process:

> We kind of put the [lesson plans] on the education major at the last minute. And uh, because they kind of had to show up and then take charge of all that. While me and [Meg] were working on the actual payload from uh, since back in January, so that was a little separated, but that was just kind of because of the events that unfolded this semester, or this year.

Mike acknowledged the consequences of having "to get an education major at the last minute instead of having them from the start, who actually worked with the package and would have seen how far we've progressed." Meg as well felt the impacts of the constraints dictated by the COVID-19 pandemic. She described the impact:

> Just like because of COVID, and it being kind of like scared to be together for the first part of the spring, and in the summer. It was hard to work together, me and [Mike], I think. In normal times, I think we would have done a lot better, having a good solid team foundation.

> Meg felt that as the pandemic progressed, teamwork broke down. She explained:

> I think at the beginning in the spring, when it was [former team member, Mike] and I, I think there was a lot more integration. We would have weekly Zoom meetings or whatever where we would just discuss where we were all at. Maybe give each other ideas of what to look for, what to do. But then, I can't really say what happened, but then there was just this time that we were all kind of separated and kind of just working on our own stuff. We would come to the weekly meetings, or on Zoom, during the summer. But I don't know, there wasn't a whole lot of integration . . . and I don't know if it would have been different if we were more in-person, if COVID wasn't a thing.

The changeup in team members may have impacted how the team integrated the content with the lessons and how integrated STEM content and developing a partnership were impacted by not knowing each other for very long. As May described:

> I feel like the [roles] were pretty separate. Like, they pretty much did the engineering, they figured out all that. Of course, they did all that before I even joined the project so there wasn't really a place for me within that. Um, and I felt like, you know, my teaching aspect was completely separate from what they were doing. Other than, you know, I have to integrate the payload and the balloon launch into the lessons.

However, May still perceived that "they taught me a lot about the payload" and that "they were really helpful to consult in the engineering portion of this".

3.2. GPS Team

The GPS team is described in Table 3. This team is one of the traditional teams. Each member was an undergraduate, sophomore or junior in credits at the beginning of the project. The GPS team was composed of one engineering major, one science major, and one education major, who was pursuing a double major in physics as well as secondary education.

Table 3. GPS team summary, successes, challenges.

Team Member and Major	Summary of Learning Learned from or by . . .	Successes	Challenges
Glen: Computer Engineering	Experts Independent research	Taught teammates	Integration and teamwork "difficult" Disciplines remained separate
Gail: Physics	Experts Doing Teammates	Learned skills outside major, e.g., soldering, building payload, software	COVID restrictions kept team from in-person classroom experience
Gabe: Physics and Secondary Education	Experts Hands-on activities Profs and online community	Jigsaw—did not know all the pieces, but understood enough Developed a team	Team "rarely worked together" but "on the same page" Team roles defined and separate

3.2.1. Integrated STEM

Members of the GPS team described learning outside of one's discipline as a perceived benefit. Gabe, the physics education major, said:

> Well, I didn't have much of an understanding at all before the idea was presented. I had never heard of radio occultation. I had never known too much about GPS either. Um, so definitely my understanding developed as we did more research.

Gabe spent the summer building an antenna for the payload, which was outside his area of expertise and experience, and ultimately discarded in favor of a pre-built antenna. However, he considered it a worthwhile challenge and grasped the design constraints while researching how to build or acquire the item. As he described a little patch antenna that got the job done. But I did all sorts of research this summer learning about that. Um, how those work, and I built a few prototypes, and tried to find one that would get the job done right. There, you have to think about the directionality of it. Um, and the wavelength that you're trying to pick up. And there's a range of wavelengths that we were trying to pick up, and we wanted a satellite that goes to all directions because we weren't controlling the orientation of the balloon. Um, so that was a good challenge to find an antenna that did that.

The education major respected how STEM majors conducted research. Gabe mentioned:

> I was definitely impressed with the way my team did research. I just couldn't think of a single idea ... and they really left the chart with that. And that was impressive to me. Um, how they had an idea, without having a real teacher or curriculum or anything, just like grab on to an idea and then learn a bunch about it.

This respect developed into a frame of mind that the authors liken to jigsaw-style active learning, in which individuals learn a part of the whole, then communicate to combine their knowledge to socially construct the whole. As Gabe explained, "I can say I still don't understand completely like the computation behind it, um, but I think I have a better understanding of what the components are, now." The engineer member of the team took on responsibility for the computation side of the payload project.

Glen, the computer engineering major, described the project as "where I've learned the most, ever. I learned a lot in this project." Glen described his experience, "I was surprised at how difficult it would be, I'll be honest, and how complex." In terms of content, Glen researched how GPS and satellites work. In terms of engineering design process, Glen mentioned learning how to collect data, data communication, and data processing, or analysis. Glen also mentioned learning a new coding language to analyze the data. Finally, Glen mentioned learning how to use tools such as atmospheric sensors and a thermocouple, which he had never encountered prior to this project. He conducted research both on Google Scholar and product sheets, as well as user guides and what he described as "self-learning", or trial-and-error. Glen was confident that the knowledge and skills he learned from this project would be helpful in his future senior capstone design class.

Gail, the physics major, also learned from others, including an informal interview with a leading scientist in the field, and more hands-on activities such as soldering parts of the payload together. She demonstrated awareness of gaining a locus of influence from others. Gail said, "I learned a lot from my teammates. I think they are both very, like, brilliant and driven individuals ... they taught me things all the time ... I'd say we all learned from each other a great deal".

3.2.2. Partnerships and Teamwork

Glen said the project "gives you the opportunity to learn about stuff, so it gives you a lot of experience. Both technical and, like, soft skills too, when you're trying to teach and then, um, working in a group." Glen, the engineer, learned from the education major. He described, "I did learn a lot about teaching from [Gabe], seeing how he kind of did things, it kind of gave me ideas of how to teach things when it was my turn to, like, talk about how radio occultation worked and stuff".

Although the GPS team worked as a partnership, team members often worked independently in discipline-specific roles. As Gabe described the roles, "I think they were pretty separate. Um, we all collaborated on the side of who was going to do what. But we rarely actually worked together." As Gabe explained:

> But I think we were on the same page for most of it. I don't think that's bad, like I think that we all knew what was happening and no one was getting left out. But we just had our separate jobs to do.

On the other hand, Gail perceived strong teamwork and partnership development. She described the project as a "collaborative effort overall" and that "we all collaborated um, and on lesson plans too" but that the team "didn't have assigned roles." She gave credit to teammates for teaching her how to solder, build parts of the payload, and learn about software. "I feel very fortunate to have had teammates like them. Because, yeah, they were always, like, if I didn't understand something, they would explain it to me." This team in fact did deliver lessons together, albeit remote synchronous with the partnering pre-collegiate school due to distancing requirements, and recorded videos of experiments, demonstrations, and mini lectures together that they shared with the partnering school.

3.3. Cell Signal Team

The third group, the Cell Signal team, is described in Table 4. This team was the other traditional team. As with the GPS team, all members were undergraduates in their sophomore or junior year at the beginning of the project and remained with the project to completion. The Cell Signal team was composed of one engineering major, one science major, and one secondary education major, who intended to teach English.

Table 4. Cell Signal team summary, successes, challenges.

Team Member and Major	Summary of Learning Learned from or by . . .	Successes	Challenges
Carol: Mechanical Engineer	Others Teaching Independent research	Teamwork is crucial Took steps to improve	Communication a "struggle"
Cal: Physics	Doing Experts Teaching	Perceived content as interdisciplinary, complex	Would have liked more collaboration Teamwork difficult because "online"
Carla: English Secondary Education	Others Independent research Experts Communicating	Took leadership role in K-12 class, earned respect from teammates. In turn, recognized others' expertise, appreciated explanations	Felt separate, "them and me" "Didn't question" separate discipline dynamic

3.3.1. Integrated STEM

The Cell Signal team learned from others while staying within the confines of major of study. The team members held a high level of trust and respect for each other's expertise and readily admitted learning from each other. Carla said the STEM majors "did a great job making sure we had all of the parts that we needed to get the data" and that "I did learn some things about the payload . . . the circuitry they used, the antennas they used . . . different receptors and receivers" that she translated, with the STEM majors' assistance, to visualizations "that were good for the lesson." Carla appreciated the work the STEM majors put into the classroom visit, saying they:

> Did a good job of explaining, like, how the pieces of our payload operated. And, like, what the technology was. And we talked about circuitry and all of those things. And so, we really did bring in a lot of those technological engineering pieces.

Cal, as a physics major, described a growing respect for "the difficulty of teaching difficult concepts to children." Carol echoed this sentiment, saying she learned "how much you need to know to be able to teach someone else". She mentioned a respect for Carla's skills in "controlling a classroom" and "maintaining their focus" portions of her "teaching style".

Carol, the mechanical engineer, showed respect for Cal's knowledge, crediting him for finding documentation about their experiment "that said that we were actually operating outside of its range, and so that would account for most of the spikes that we saw." Carla, the education major, learned from independent research, "for me, it was learning it. I had to learn the material, and then figure out, okay, how am I going to teach this to an audience?" as well as learning from experts, "Pretty much all I could do was talk to people." Carla also learned from the STEM majors, complimenting then on "a good job of telling me what sort of things we were working on, and what the exact focus and what the exact capabilities of our payload were. So that I could plan around that." Carol agreed, saying:

> [Carla] did a really good job of coming in and understanding and asking the right questions to make sure she understood, and then the activities that she was able to put together I thought were really good as far as, like, helping the kids to learn about it as well.

Carol, the mechanical engineering major, described finding a better understanding of how the engineering process works ... a lot of mistakes made along the way ... that is where I learned the most ... learning about the details of the process ... like how our specific board works ... operating outside of the board's range...just understanding that experiments don't yield ideal results.

Carla, the education major, regretted the missed opportunity to engage the pre-collegiate students in hands-on learning:

> I would have liked to go a little bit more in depth on, like, how our payload worked. I think that would have been interesting for students to actually get to look at our boards and at our antennas and learn about how all of these different pieces come together.

However, Carla valued her role as delivering the content in ways that pre-collegiate students could understand and engage with, to "translate what [Carol and Cal] are saying about these concepts and about our payload and about the project and give it to students in a way that they could understand. I would say that I was the translator." Cal, the physics major, supported that, explaining that in the classroom, "in order to um, to distill it down into a simpler version, I had to have a better understanding of the foundations of those ideas." Cal mentioned, "those concepts are very interdisciplinary, and more complex than we were able to teach them".

3.3.2. Partnerships

The Cell Signal team did not develop into a fully integrated partnership. Carla's perspective was:

> I wish that we would have incorporated with each other or worked with each other more. Um, because it felt sometimes that like [Carol] and [Cal] were their own separate team and then it was me. And I was just trying to grab at all the ideas that they were getting, um, I'm surprised we weren't more of a unit.

Although Carla identified the lack of teamwork as discipline specific, saying, "[Carol and Cal] didn't question things that I did in the classroom I didn't question things they were doing with the payload. Um, and that's just kind of the dynamic that it was, which is fine" she also hinted at a communication issue, "no matter how much we talked, we could never quite get there" and "I think from the outside, it looked like it came together, but from the inside, it didn't feel like it came together."

Cal seemed to support that perception, saying that "we only, I guess, interacted to help [Carla] understand the technical side of the project." Cal regretted that there was "little collaboration" saying, "I would have liked to, um, to collaborate more." Cal was frustrated by spending the summer doing "an entire separate project that didn't work" and had mixed feelings about switching to Carol's choice of project, something he said Carol "kind of did this as an offshoot" and "then we hopped on to her idea." Cal said that he wasn't sure if Carol "didn't trust my abilities, or if she had, like, the foresight or if it was just because we were so disjointed, we were doing our own things" but his initial idea to do a project focused on radio signals morphed into a project studying cell phone signals. Carol, on the other hand, did not perceive this frustration, saying that "I think once we decided on [cell], I think that, um, it went as smoothly as we could have asked for." However, Carol spoke about a "struggle" with communication, which she said eased "once we started seeing each other in person more." Cal supported this perception, mentioning that he had poor "online" skills. Carol suggested that she took on a leadership role in the team, "I made it a goal to kind of, like, just say, like, hey, let's meet at this time and this place, and we definitely started doing that more. And that was helpful, um, for sure it was helpful for me".

3.4. Cross-Case Analysis

The authors analyzed how the three teams functioned holistically and developed partnerships. The partnership model that the authors used was a modified version (Table 5) of the Mullinix model [20], and the authors modified it to pertain to undergraduates working together toward a clearly defined goal. A few categories were eliminated from the original scale because those areas did not pertain to the needs of this study. The modified partnership development continuum is provided in Table 5. The authors describe how the three teams functioned in each dimension and include rationale for modifications to the model. The levels the teams reached in each dimension are indicated by lightly shading the boxes in gray.

Table 5. Modified model after Mullinix (2001).

Dimension	Pre-Partnership	Partnership	Partnership
Focus of Interaction	Getting to know each other	Working to achieve mutually valued objectives (payload and lessons)	Developing and implementing payload and lessons together
Activities/Projects/Programs (Payload and Lessons)	Limited—specifically defined relationships which allow teams to become acquainted with each other	Opportunistic—teams work together because it is convenient and appropriate (a good match)	Integral—teams develop joint payload and lessons that grow directly out of common skills and interests
Time and Orientation	N/A	N/A	N/A
Benefit	Increased Networking—teams develop relationships and skills	Increased capacity—teams able to do more and/or access more resources than they could alone	Increased status—teams able to become more than what they would be alone
Trust and Respect	Building trust and earning respect	Trust and respect exist among some team members	Mutual trust and respect throughout team
Team Structures, strategies, and information access	Completely autonomous and separate	Separate but coordinated	Appropriately integrated and developed together
Locus of Influence	Separate	Shared or differentiated according to expertise and capacity	Integrated with acknowledgement of expertise and capacity
Written Agreements or Contracts	N/A	N/A	N/A

Note: Gray boxes show the levels accomplished by all teams.

The first dimension, **focus of interaction**, was of prime importance to the authors. The authors guided the teams to progress beyond getting to know one another to fully collaborate and integrate their skills to develop and implement the payload. However, the line was fine between working on the payload and working together on the payload. Observations collected during weekly meetings documented team meetings held outside the official weekly meetings, but the authors, who acted in dual roles as researchers and supervisors, did not attend these meetings. Further complicating the issue for the 2020 cohort was the onset of the COVID-19 pandemic and associated requirements of remote communication. Team members coped with the rapid transformation to a situation mandating remote learning, social distancing, mask wearing, and quarantine for all but the first third of the project. Each team, though, made efforts to progress into the partnership stage. This process occurred by informal meetings, social get-togethers, and synchronous Zoom meetings before or after the official weekly meeting. The Microbes team was able to progress through the pre-partnership stage considering the change in team members. The GPS and Cell Signal team unanimously perceived they progressed into the partnership (little p) stage, with some members perceiving teamwork reaching Partnership (big P) stage. The authors' conclusion is that all three teams landed squarely in **partnership**, with occasional leaps into Partnership for this dimension. The members all worked to achieve their goal of successful payload launch and lesson plan, but they did not work seamlessly together all the time.

The second dimension, which were the **products** created including payload and lesson plans, were also of major importance to the authors. Here is where the authors noted a specificity of roles taken on according to one's major area of study. For example, engineers did not typically take part in lesson planning. Nor did the education majors become deeply involved with building the payload. However, there were some overlaps. For the GPS team, that may be due to the education major also double majoring in physics. He spent the summer building an antenna, in this case a direct piece of the payload. Although the antenna was ultimately not used, he shared that he learned "a lot" from the experience. This dimension fit into **Partnership**, in that team members contributed equally to the success of the project.

A perception of **benefit** from the project was felt by all the team members, and all mentioned they had learned from each other. Learning from each other helped transcend disciplines and truly integrate the STEM aspects of the payload as well as the educational aspects of lesson planning and teaching. Each team increased status and were able to become more than what they would be alone. Each member contributed something to the project; no one team member took on every task. Together, the team delivered lessons and activities to a pre-collegiate classroom that would have been impossible for a single person, STEM major or education major, to accomplish alone. Here too the teams clearly achieved a **Partnership**, achieving and becoming more as a team than they would have alone.

The **trust and respect** dimension varied among the teams. The Microbes team suffered from a loss of a team member due to difficulties brought on by the pandemic. That team, understandably, had less history with the replacement team member, although all members indicated a level of respect for one another's expertise, and a regret that the time was insufficient to get to know one another well. The GPS team valued and respected each other and could name specific instances where they were impressed. The Cell Signal team, although hampered by the challenge of changing project topics, harbored a feeling of respect as well. Because the authors heard mentions of "struggles", "frustrations", and "didn't come together from the inside"; however, they hesitate to assign this dimension higher than **partnership** level. Although some team members trusted and respected others, and many disclosed so during the final interview, listening to what was unsaid indicates there may have been some difficulties here and there with team members.

The **locus of influence** was marked among the undergraduates. Every STEM major mentioned respect and admiration for the education major's demeanor and management skills in the classroom. Even STEM majors who did not include education majors while building the payload readily followed the expertise of the education major when it came to lesson plans, classroom management, and so forth. STEM majors concentrated on "simplifying" content during the classroom visits and viewed themselves as something akin to subject matter experts, focusing exclusively on content. They recognized the difficulty in keeping pre-collegiate students focused and engaged and indicated respect for how the education major handled this issue. The STEM majors did not indicate any issues regarding each other's expertise, but nor were they overly appreciative. The authors would place this dimension into a **partnership**, due to the division, often mentioned, between STEM majors and the education major. The "them and me" mentality suggests a partnership, in which the project was shared or differentiated according to expertise (major area of study) or capacity. The authors made efforts to nudge this into Partnership and full integration by asking the entire team design and deliver lessons to the pre-collegiate audience but left it up to the team to determine how the lessons would be organized, which generally fell to the education major to delegate.

The **team structures**, **strategies**, and **access to information** were combined into one dimension. The three teams aligned in these areas. In the Cell Signal team, the education major worked separate from the STEM majors. The education major developed the lesson plans mostly in isolation, although seemed to be willing to ask for help when needed. The Microbes team also had the STEM majors working in isolation as well due to the unexpected departure of the education major and the replacement not coming in until fall. The GPS team worked together most often of the teams. Besides the education major working on a piece of the payload most of the summer, the STEM majors came together to record video to share with the pre-collegiate students and participated in the experiments and demonstrations shared via remote synchronous with the pre-collegiate classroom. One reason why the authors decided to combine these categories is the COVID-19 pandemic. The teams began working in early 2020 under normal circumstances, and then needed to abruptly shift in March. The isolation, remoteness, and quarantining were more unfamiliar and stringent during 2020, and it is unknown what effect this had on teams' working preferences (separately or together). Therefore, the authors give these dimensions less emphasis and place each team into a **partnership** level, separate but coordinated.

Time and orientation, along with **written agreements and contracts**, were not considered during this study because of the nature of those dimensions. All the undergraduates were under the same time constraint, one calendar year, thus nullifying any differences. The 2020 cohort began brainstorming and developing the payload the spring semester, work was optional during summer, and concluded with teaching lessons and collecting the data from the payload fall semester. Although time on task undoubtedly varied among the teams, no documentation exists for the informal and social meetings outside of what was mentioned during the exit interviews. Likewise, all undergraduates signed an agreement for compensation and expectations for time on task were delivered verbally by the supervisors.

4. Discussion

To summarize, teams reached the highest **Partnership** level with:

- Activities/projects/programs (products created, both lesson plans and payload);
- Benefit each team member perceived.

Teams achieved a moderate **partnership** level with:

- Focus of interaction;
- Trust and respect;
- Locus of influence;
- Team structures, strategies, and access to information.

The authors did not consider two dimensions for this study:

- Time and orientation;
- Written agreements and contracts.

The authors found a relationship between the degree of STEM integration and the strength of the partnerships formed. In general, the authors found, qualitatively, that STEM integration and partnerships seemed to increase together. The products of payload and lesson plans were supported by team members working together to become more than what they would have alone. Moreover, all teams progressed into partnership (little p) from pre-partnership, and establishing this foundation allowed teams to accomplish the higher levels in benefit and products. Engineers felt confident about teaching concepts to others after watching future educators' demeanor in a pre-collegiate classroom; educators felt confident delivering complex material to a younger audience when STEM majors were present to address questions and confusion. The level of STEM integration increased with trust and respect among team members. The more team members trusted each other, the more they learned from each other during this project. Some team members viewed the project like a jigsaw exercise, a term used in the education discipline, in which not everyone needed to learn everything about the project, but everyone contributed according to their expertise. Hands-on learning led to integration and appreciation of the locus of influence. For example, a physics major learned to solder from a fellow team member, something she had never done before and contributed to her skill set. The authentic nature of the project as opposed to pursuing a theoretical question encouraged integration of STEM integration and meaningful learning. As Gail explained, "when you think about how GPS radio occultation works, like in theory in your mind, it's definitely different when you're actually seeing, um, readings from when, like, when we took it from that high hill . . . "

The teams overall progressed from pre-partnership into partnership and then Partnership levels, which is encouraging given the constraints imposed by COVID-19 pandemic social distancing. Even the Microbes team, who faced the challenge of a new team member, made strides into partnership levels and establishing trust and respect. Each team seemed firm in their resolve to see the project through and adapted to various constraints. The weekly official meetings with the authors were a mixture of in-person and remote synchronous, dictated by quarantine and isolation requirements. Access to pre-collegiate schools varied as well. The Cell Signal team enjoyed full access with no restrictions at the private elementary/middle school they visited; the Microbes team were granted visitor access but were required to mask and social distance at the high school for at-risk students they worked with; and the GPS team were not granted access to the middle school in another town and had to deliver all lessons remotely using synchronous software and web cameras.

The nature of the challenges presented by the COVID-19 pandemic makes assessment of STEM integration and partnership skills overall an uncertain venture and represents a limitation to this study. Nevertheless, nuances of how each team navigated integration of STEM and teamwork skills would have presented whether the pandemic had happened or not. Those nuances represent facets of each member's personality and brought dynamics to how the team functioned. The pandemic threw a confounding factor into this study but did not derail the team's collective will to produce or the conclusions drawn by the authors.

5. Conclusions

Overall, this study showcases the importance of partnerships and teamwork to integrated STEM and indirectly the importance of authentic and hands-on activities to integrated STEM. The authors found there is a relationship between quality of formed partnerships and the quality of team products. Team members progressed through the pre-partnership stage to reach partnership (little p), and in some cases Partnership (big P) status and achieved their common goals. Undergraduate teams progressed from pre-partnership to partnership in all other areas studied, which indicates that fulfilling the pre-partnership prerequisites was necessary to achieve the higher Partnership levels in the dimensions of benefits and products. Collaborative learning helped teams accomplish higher levels of partnership, underscoring the value in this learning approach other researchers have described [41,47]. Moreover, team members often stated in their interview the importance of communication and how the lack thereof increased their uncertainty about the project [8,16,47].

In multidisciplinary teams, gaining the perception of benefit from each member of the team is essential to producing a product of quality. Team members used problem-based learning to rely on each other's area of expertise (indicated by their chosen major area of study) and learn from each other, which supports researchers' claim of benefit to using a collaborative and problem-based learning approach [7,32,36]. Moreover, teams integrated the disciplines of STEM to build a payload that relied on aspects of each STEM discipline. This integration of discipline knowledge was crucial for a successful problem resolution and indicates that STEM integration can solve some of the issues discussed by researchers [18,40].

What should you do to build partnerships? The authors recommend that those looking to assist in partnership creation pay attention to the following dimensions adapted from [45]:

1. Focus of Interactions—Teams develop and implement activities together to assist in team building, unified objectives, and end targets;
2. Activities/Projects/Programs—Teams develop integral activities/projects/programs that grow directly out of common skills and interests to create cohesion;
3. Time and Orientation—Teams work on open ended and goal-oriented problems and can explain short- and long-term objectives and the overall mission;
4. Benefit—Teams (not just an individual) are able to become more than what they would be alone and should be able to articulate this accomplishment;
5. Trust and Respect—Teams build mutual trust and respect with all members through expectations and norms;
6. Organizational Structure—Teams work together, not as separate individuals, but instead as coordinated and transparent interactions with all members;
7. Organizational Strategies and Information Access—Teams develop activities/projects/programs together and sensitive information is promoted together;
8. Locus of Influence—Teams share the responsibility, based on expertise, to create tasks and actions for the whole team assisting with whole team ownership;
9. Written Agreements—Teams write out areas of interest, expectations, and commitments to each other and review them periodically for continued growth;
10. Conflict Management—Teams watch for conflicts and follow expectations and norms in discussing feelings, actions needed, or soliciting outside intervention.

Future research might focus on partnership integration versus jigsaw regarding STEM integration in authentic, ill-defined projects. Are there tradeoffs? Might one be preferable to the other? Are they different or two sides of the same coin?

Overall, this study assisted participants with providing hands-on, authentic activities, built on the necessity of communication skills and teamwork, which are 21st-century skills [1,2]. The soft skills, like communication, were shown to be important in creating stronger partnerships, along with the other dimensions outlined. This study might provide a means to facilitate undergraduates to practice both hard and soft skills in building partnerships as they engage in both teamwork and creating authentic, meaningful products.

Author Contributions: Conceptualization, T.J.K. and A.C.B.; methodology, T.J.K.; validation, T.J.K. and A.C.B.; formal analysis, T.J.K. and A.C.B.; investigation, T.J.K.; resources, A.C.B.; data curation, T.K.; writing—original draft preparation, T.J.K.; writing—review and editing, A.C.B.; visualization, T.J.K. and A.C.B.; supervision, T.J.K. and A.C.B.; project administration, T.J.K. and A.C.B.; funding acquisition, T.K. and A.C.B. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported in part by a National Science Foundation LIFT grant [#1821566], EPSCoR K-12 EOD [#1655726], and SWARMS grant [#1339853]. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of University of Wyoming (#20191101TK02576 approved 1 November 2019).

Informed Consent Statement: Informed consent was obtained for all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to IRB restrictions and confidentiality of subjects.

Acknowledgments: The authors wish to thank the following members of the LIFT Project and acknowledge their work: Philip Bergmaier, Shawna McBride, Kate Muir-Welsh, and Kevin Kilty.

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

References

1. National Academies of Sciences, Engineering, and Medicine. *Graduate STEM Education for the 21st Century*; The National Academies Press: Washington, DC, USA, 2018. [CrossRef]
2. National Research Council. *A Framework of K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*; The National Academies Press: Washington, DC, USA, 2014.
3. Van Laar, E.; Van Deursen, A.J.; Van Dijk, J.A.; De Haan, J. The relation between 21st-Century skills and digital skills: A systematic literature review. *Comput. Hum. Behav.* **2017**, *72*, 577–588. [CrossRef]
4. Balcar, J. Is it better to invest in hard or soft skills? *Econ. Labour Relat. Rev.* **2016**, *27*, 453–470. [CrossRef]
5. NGSS Lead States. *Next Generation Science Standards: For States, by States*; The National Academies Press: Washington, DC, USA, 2013.
6. Burrows, A.; Lockwood, M.; Borowczak, M.; Janak, E.; Barber, B. Integrated STEM: Focus on informal education and community collaboration through engineering. *Educ. Sci.* **2018**, *8*, 4. [CrossRef]
7. Agogino, A.M.; Shuang, S. Triangulation of indicators of successful student design teams. *Int. J. Eng. Educ.* **2006**, *22*, 617–625.
8. Dong, A. The latent semantic approach to studying design team communication. *Des. Stud.* **2005**, *26*, 445–461. [CrossRef]
9. Giel, L.I.S.; Noordzij, G.; Wijnia, L.; Noordegraaf-Eelens, L.; Denktaş, S. When birds of the same feather fly together: The impact of achievement goal compatibility in collaborative learning. *Educ. Psychol.* **2021**, *41*, 79–98. [CrossRef]
10. Jiang, H.; Gero, J.S. Comparing two approaches to studying communications in team design. In *Design Computing and Cognition '16*; Springer: Cham, Switzerland, 2017; pp. 301–319. [CrossRef]
11. Kristof-Brown, A.L.; Stevens, C.K. Goal congruence in project teams: Does the fit between members' personal mastery and performance goals matter? *J. Appl. Psychol.* **2001**, *86*, 1083–1095. [CrossRef]
12. Locke, E.A.; Latham, G.P. Building a practically useful theory of goal setting and task motivation: A 35-year odyssey. *Am. Psychol.* **2002**, *57*, 705–717. [CrossRef]
13. Louw, L.; Duncan, Q. Teaching industrie 4.0 technologies in a learning factory through problem-based learning: Case study of a semi-automated robotic cell design. *Procedia Manuf.* **2020**, *45*, 265–270. [CrossRef]
14. Marks, M.A.; Mathieu, J.E.; Zaccaro, S.J. A temporally based framework and taxonomy of team processes. *Acad. Manag. Rev.* **2001**, *26*, 356–376. Available online: https://www.jstor.org/stable/259182 (accessed on 16 October 2021). [CrossRef]
15. Mathieu, J.E.; Heffner, T.S.; Goodwin, G.F.; Salas, E.; Cannon-Bowers, J.A. The influence of shared mental models on eam process and performance. *J. Appl. Psychol.* **2000**, *85*, 273–283. [CrossRef] [PubMed]
16. Paletz SB, F.; Chan, J.; Schunn, C.D. Dynamics of micro-conflicts and uncertainty in successful and unsuccessful design teams. *Des. Stud.* **2017**, *50*, 39–69. [CrossRef]
17. Yang, M.C. Consensus and single leader decision-making in teams using structured design methods. *Des. Stud.* **2010**, *31*, 345–363. [CrossRef]
18. Moore, T.J.; Johnston, A.C.; Glancy, A.W. STEM integration: A synthesis of conceptual frameworks and definitions. In *Handbook of Research on STEM Education*; Johnson, C.C., Mohr-Schroeder, M.J., Moore, T.J., English, L.D., Eds.; Routlege: New York, NY, USA, 2020; pp. 3–16.
19. Woods, D.R. PBL: An evaluation of the effectiveness of authentic problem-based learning (aPBL). *J. Chem. Eng. Educ.* **2012**, *46*, 135–144.
20. Merritt, J.; Lee, M.Y.; Rillero, R.; Kinach, B.M. Problem-Based learning in K-8 mathematics and science education: A literature review. *Interdiscip. J Probl. -Based Learn.* **2017**, *11*, 3. [CrossRef]
21. Spuck, T. Putting the "authenticity" in science learning. In *Einstein Fellows: Best Practices in STEM Education*; Spuck, T., Jenkins, L., Dou, R., Eds.; Peter Lang: New York, NY, USA, 2014; pp. 118–156.
22. Newell, C.; Bain, A. *Team-Based Collaboration in Higher Education Learning and Teaching: A Review of the Literature*; Springer: Singapore, 2018; p. 72. [CrossRef]
23. Koro-Ljungberg, M.; Yendol-Hoppey, D.; Smith, J.J.; Hayes, S.B. (E)pistemological awareness, instantiation of methods, and uninformed methodological ambiguity in qualitative research projects. *Educ. Res.* **2009**, *38*, 687–699. [CrossRef]

24. Burrows, A.; Slater, T. A proposed integrated STEM framework for contemporary teacher preparation. *Teach. Educ. Pract.* **2015**, *28*, 318–330.
25. Johns, G.; Mentzer, N. STEM integration through design and inquiry. *Technol. Eng. Teach.* **2016**, *76*, 13–17.
26. Rehmat, A.P.; Hartley, K. Building engineering awareness: Problem-Based learning approach for STEM integration. *Interdiscip. J. Probl.-Based Learn.* **2020**, *14*, n1. [CrossRef]
27. Karaçöp, A. Effects of student teams-achievement divisions cooperative learning with models on students' understanding of electrochemical cells. *Int. Educ. Stud.* **2016**, *9*, 104–120. [CrossRef]
28. Abramczyk, A.; Jurkowski, S. Cooperative learning as an evidence-based teaching strategy: What teachers know, believe, and how they use it. *J. Educ. Teach.* **2020**, *46*, 296–308. [CrossRef]
29. van Leeuwen, A.; Janssen, J. A systematic review of teacher guidance during collaborative learning in primary and secondary education. *Educ. Res. Rev.* **2019**, *27*, 71–89. [CrossRef]
30. Strauß, S.; Rummel, N. Promoting interaction in onine distance education: Designing, implementing, and supporting collaborative learning. *Inf. Learn. Sci.* **2020**, *121*, 251–260. [CrossRef]
31. Robinson, H.A.; Kilgore, W.; Warren, S.J. Care, communication, learner support: Designing meaningful online collaborative learning. *Online Learn.* **2017**, *21*, 29–51. [CrossRef]
32. Ryu, M.; Mentzer, N.; Knoblach, N. Preservice teachers' experiences of STEM integration: Challenges and implications for integrated STEM teacher preparation. *Int. J. Technol. Des. Educ.* **2019**, *29*, 493–512. [CrossRef]
33. Albar, S.B.; Southcott, J.E. Problem and project-based learning through an Investigation lesson: Significant gains in creative thinking behaviour within the Australian Foundation (preparatory) Classroom. *Think. Ski. Creat.* **2021**, *41*, 100853. [CrossRef]
34. Mustofa, R.F.; Hidayah, Y.R. The Effect of Problem-Based Learning on Lateral Thinking Skills. *Int. J. Instr.* **2020**, *13*, 463–474. [CrossRef]
35. Chen, C.H.; Yang, Y.C. Revisiting the effects of project-based learning on students' academic achievement: A meta-analysis investigating moderators. *Educ. Res. Rev.* **2019**, *26*, 71–81. [CrossRef]
36. Ellingsen, P.; Tonholm, T.; Johansen, F.R.; Andersson, G. Learning from problem-based projects in cross-disciplinary student teams. *Educ. Sci.* **2021**, *11*, 259. [CrossRef]
37. Mann, L.; Chang, R.; Chandrasekaran, S.; Coddington, A.; Daniel, S.; Cook, E.; Crossin, E.; Cosson, B.; Turner, J.; Mazzurco, A.; et al. From problem-based learning to practice-based education: A framework for shaping future engineers. *Eur. J. Eng. Educ.* **2021**, *46*, 27–47. [CrossRef]
38. Burghardt, M.D.; Hecht, D. Designing Informal vs. Formal Education Activities—What We've Learned. *Int. J. Des. Learn.* **2020**, *11*, 39–45.
39. Kilty, T.; Burrows, A.C.; Welsh, K.; Kilty, K.; McBride, S.; Bergmaier, P. Transcending disciplines: Engaging college students in interdisciplinary research, integrated STEM, and partnerships. *J. Tech. Sci. Ed.* **2021**, *11*, 146–166. [CrossRef]
40. Siverling, E.A.; Suazo-Flores, E.; Mathis, C.A.; Moore, T.J. Students' use of STEM content in design justifications during engineering design-based STEM integration. *Sch. Sci. Math.* **2019**, *119*, 457–474. [CrossRef]
41. Magen-Nagar, N.; Shonfeld, M. The impact of an online collaborative learning program on students' attitude towards technology. *Interact. Learn. Environ.* **2018**, *26*, 621–637. [CrossRef]
42. Nathan, M.J.; Srisurichan, R.; Walkington, C.; Wofgram, M.; Williams, C.; Alibcli, M.W. Building cohesion across representations: A mechanism for STEM integration. *J. Eng. Educ.* **2013**, *102*, 77–116. [CrossRef]
43. Stake, R.E. *The Art of Case Study Research*; Sage: Thousand Oaks, CA, USA, 1995.
44. Merriam, S.B.; Tisdell, E.J. *Qualitative Research: A Guide to Design and Implementation*, 4th ed.; Jossey-Bass: Hoboken, NJ, USA, 2016.
45. Mullinix, B.B. Nurturing partnership: A Southern African continuum of flexible stages in partnership development. *Curr. Issues Comp. Educ.* **2001**, *3*, 1–12.
46. Couso, D.; Simarro, C. STEM education through the epistemological lens: Unveiling the challenge of STEM transdisciplinarity. In *Handbook* of Research on STEM Education; Johnson, C.C., Mohr-Schroeder, M.J., Moore, T.J., English, L.D., Eds.; Routledge: New York, NY, USA, 2020; pp. 17–28.
47. Burrows, A.C. Secondary Teacher and University Partnerships: Does Being in a Partnership Create Teacher Partners? Doctoral Dissertation, University of Cincinnati, Cincinnati, OH, USA, 2011.