

## Article

# Attending to Teacher Considerations in I-STEM Curriculum Supplementation: The Case of Chip Kids

Shalaunda M. Reeves <sup>1,\*</sup>, Francheska D. Starks <sup>1</sup>, Missy D. Cosby <sup>1</sup> , Brittany Price <sup>1</sup>, Vanessa Mahoney <sup>2</sup> and Joanna Millunchick <sup>3</sup>

<sup>1</sup> College of Education, Health, and Human Sciences, University of Tennessee, 1122 Volunteer Boulevard, Knoxville, TN 37996, USA; fstarks1@utk.edu (F.D.S.); mdcosby@utk.edu (M.D.C.); bprice26@utk.edu (B.P.)

<sup>2</sup> Spark Photonics Foundation, Waltman, MA 02451, USA; vmahoney@sparkphotonics.org

<sup>3</sup> Luddy School of Informatics, Computing and Engineering, Indiana University, Bloomington, IN 47405, USA; jmillunc@iu.edu

\* Correspondence: sreeve10@utk.edu

## Abstract

To address a projected workforce gap in microelectronics, numerous companies and universities are introducing programs that bring authentic, industry-focused practices into K-12 education. Integrated STEM has emerged as an innovative approach to address the urgent push to improve STEM education. Teachers, often trained in a single discipline, are tasked with supplementing their existing curriculum to achieve this interdisciplinary approach. To better understand, we examined the conceptions and considerations of K-12 teachers who were engaged in an industry-led I-STEM professional development and were given supplemental curriculum materials. Teachers were provided with a high-quality, integrated STEM supplemental curriculum, given time to engage with it, and asked how they would use it in their classrooms. This qualitative study sought to understand the factors teachers consider when implementing integrated STEM curriculum supplementation. We found that the primary factors teachers consider during the initial stages of integrated STEM curriculum supplementation are: (1) the curriculum's potential to enhance students' knowledge and students' skill development, (2) the quality of curriculum attributes, and (3) the necessary adaptations for integration into their classroom instruction. Furthermore, teachers rarely mentioned applications across STEM disciplines, which means that meaningful I-STEM PD should be grounded in integrated frameworks that explicitly guide the desired integration and use the curriculum supplement to apply knowledge and practices from other disciplines. Our findings underscore the need to explore how meaningful I-STEM professional development can be designed and delivered using levels of I-STEM integration as a framework.

**Keywords:** integrated STEM; curriculum supplementation; teacher conceptions



Academic Editor: Hyesun You

Received: 10 April 2026

Revised: 15 July 2026

Accepted: 16 July 2026

Published: 23 July 2026

**Copyright:** © 2026 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article distributed under the terms and conditions of the [Creative Commons Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.

## 1. Introduction

Integrated STEM (I-STEM) is an interdisciplinary method of teaching and learning grounded in a constructivist, problem-based learning approach (Nadelson & Seifert, 2017). I-STEM practitioners merge individual topics from the sciences, technology, engineering, and mathematics into integrated curricula that challenge students to apply knowledge from the disciplines to explore technical systems. I-STEM practitioners also focus on how students construct their own understandings through their experiences and reflections on their processes and outcomes. I-STEM educators emphasize that teaching and learning

occur within the context of technical systems or tasks that are often not confined to a single discipline. This could materialize through a project in which students design a wearable device to monitor environmental conditions, applying concepts from physical science (i.e., electricity, circuits, and energy transfer), mathematics (i.e., measurement, data collection, graphing, and pattern analysis), and engineering (i.e., building, testing, and improving functioning prototypes). To implement the I-STEM approach, K-12 teachers often supplement the provided curricula with additional materials in domains where they lack expertise (Rimbach-Jones et al., 2025). These teachers must identify appropriate materials, adapt or remix them for their context, teach the lesson, and reflect on whether and how their efforts met their teaching and learning goals (Schroeder et al., 2025). This labor is both iterative and multi-layered, as each phase requires its own implementation to ensure the goals of the I-STEM approach are realized. Furthermore, this approach runs counter to more traditional organizational structures, such as discipline-specific class periods and academic measures (i.e., standardized and other summative assessments). Addressing these necessary components does not eliminate prevalent traditional structures in American classrooms but instead supports teachers in embracing and implementing an I-STEM approach while working within their specific contexts.

Professional development is a viable approach to providing teachers with relevant content knowledge while also training them to select, modify, develop, and integrate I-STEM supplemental learning activities, thereby building their capacity. Many companies and universities are launching initiatives to integrate supplemental, authentic, domain-specific practices into K-12 classrooms in response to a projected workforce shortage in microelectronics (Strimel et al., 2025). Similarly, the Spark Photonics Foundation (SPF), a nonprofit organization of education and industry experts, developed SparkEd, a virtual professional development program for K-12 teachers interested in implementing I-STEM curricula. Designed to build teacher confidence and awareness of supplemental instructional resources, SparkEd introduced participants to topics such as photonic integrated circuits (PICs), semiconductors, and advanced manufacturing, while promoting project-based learning and career awareness in the semiconductor industry. By using existing resources such as YouTube videos, the SEMI Foundation's ChipPath portal, and Chip Kids, teachers incorporated I-STEM to strengthen student engagement. Through a blend of live sessions, asynchronous learning modules, and expert-led sessions, teachers participated in the workshop via Zoom and Spark's Community of Practice, allowing for flexibility and interaction among peers.

Our case study seeks to understand teachers' conceptions and considerations when provided with I-STEM supplemental materials, introduced to the underlying concepts, and trained on how best to adapt them for their own context. I-STEM has at least two implications for teacher practice. Firstly, it beckons them to consider a focal discipline (i.e., mathematics, chemistry, etc.) and the aims, goals, and habits of mind associated with that discipline. These aims and goals are often mandated by state standards and assessments. Secondly, I-STEM requires a pedagogical shift to sharpen instructional strategies to support inquiry-centered learning rooted in problem- and project-based approaches. This study aims to provide practical insights into how teachers navigate these implications when supplementing I-STEM curriculum materials in their classrooms.

As the majority of the team are former K-12 teachers, we draw on both educational research and our own experiences to inform our position that teachers are active meaning-makers rather than passive implementers of I-STEM programs (Kurup et al., 2021). Thus, any interest in improving the rate and conditions of I-STEM implementation must consider how teachers' decision-making shapes their potential and realized uptake of I-STEM as a pedagogical ideal and practice. As meaning-makers of I-STEM as an approach, teach-

ers proactively interpret and give meaning to I-STEM-related methods within their specific/unique contexts. I-STEM adoption is influenced by how teachers perceive it to be aligned with their instructional goals, feasible within their curricular and structural constraints, and consistent with their STEM knowledge and confidence (Sokha, 2024). We used Chip Kids, a PBS learning program targeted for/as a model of I-STEM instructional implementation, to interrogate teachers' decision-making about I-STEM-related instruction. We sought to understand how teachers contemplate integrating prepared learning materials and activities, in this case, the PBS-produced web series Chip Kids, as an I-STEM-focused curriculum supplement within their existing teaching and learning conditions.

Chip Kids is a PBS-supported I-STEM program designed to support interdisciplinary learning. The host of the educational show introduces and walks viewers through solving a real-life issue or task by integrating STEM disciplines to develop practical solutions. Chip Kids programming supports teachers' classroom implementation of I-STEM by identifying and facilitating opportunities to apply knowledge and skills across multiple disciplines, engaging in real-world problem inquiry and critical thinking. Our research study examined the factors teachers considered when implementing Chip Kids as an I-STEM curriculum supplement. This study asked the following research question: What factors do teachers consider when implementing integrated STEM curriculum supplementation? Our data revealed the conditions under which I-STEM became actionable for our teacher participants, as well as the barriers that disrupted their integration. Teachers' responses illuminated the nuances of how the initial phases of I-STEM planning are mediated at the classroom level.

## 2. Theoretical Framework and Literature Review

### 2.1. Integrated STEM

This study used integrated STEM as described by Stohlmann et al. (2012) as our theoretical perspective. Stohlmann et al. (2012) emphasized the importance of teachers' perspectives in implementing I-STEM. As well as highlighting the need for various types of materials and resources to support the implementation of I-STEM. This focus on the various types of materials supported our inquiry into the types of considerations teachers take into account when deciding to use supplemental material. It was discussed that materials could include a range of items, from readily available classroom materials to more sophisticated technologies (Stohlmann et al., 2012). Because it has been determined that integration can span a continuum (Moore et al., 2020), we wanted to explore the considerations teachers offer when given I-STEM curriculum materials to provide additional insight into the continuum of integration.

### 2.2. Teacher Supplementation

Silver (2022) defines teacher supplementation as "any premeditated, additive change that a teacher makes to their official curriculum materials" (p. 456). Teachers supplement their existing/intended curriculum for a myriad of reasons generally related to the teaching context, student needs, and/or teacher goals. In today's digital age, the options for instructional materials to supplement teaching have increased exponentially, with 91% of teachers using online resources such as Scholastic.com, YouTube, Pinterest, Discovery, and PBS.org to help with lesson planning (Sawyer et al., 2020). With the increasing expectation that students can synthesize their STEM content knowledge to solve complex problems, teachers are having to supplement the current curriculum that has established siloed STEM structures (Nadelson & Seifert, 2017). For example, a math teacher has the disciplinary and pedagogical knowledge to teach simple arithmetic. However, they may be limited in their ability to introduce an ill-structured problem contextualized as an electrical problem and to show how arithmetic concepts connect to science and engineering concepts such as power,

resistance, and current. Each disciplinary domain (i.e., mathematics, science, engineering) is distinct in its knowledge, practices, skills, and habits of mind, and integrating these disciplinary epistemologies poses challenges for single-discipline teachers (Reynante et al., 2020). During implementation, teachers' level of decision-making is heightened, with frequent instances of needing to choose when to privilege their discipline and the extent to which they would make implicit or explicit connections to other disciplines in service of the integrity of STEM integration (Dare et al., 2018). Strimel et al. (2025) further explain that with projected workforce shortages in emerging industries, greater emphasis will be placed on teachers to supplement their curriculum with content that provides new or emerging workforce-driven contexts/content. This emphasizes the need to qualitatively explore teachers' conceptions as they identify opportunities for student learning across multiple STEM disciplines and concepts (Nadelson & Seifert, 2017; Strimel et al., 2025), which may conflict with the ways they were prepared in traditional teacher education programs (Rimbach-Jones et al., 2025). These challenges underscore the need to more deeply consider all aspects of teacher considerations for successful implementation of I-STEM from the initial step, identifying primary and supplementary curricula, and beyond.

### 2.3. Teacher Uptake and Implementation of I-STEM

The promise of I-STEM in enhancing student engagement and promoting critical thinking is well documented (Drake & Burns, 2004; Krathwohl, 2002; Moore et al., 2020). However, the implementation of I-STEM instructional methods relies heavily on how teachers understand and interpret I-STEM, what they believe about the value of I-STEM for students, their abilities to implement I-STEM-focused practices in their classrooms, and their instructional contexts (Kartal et al., 2022; Margot & Kettler, 2019). Mesutoglu and Akgündüz (2025) found that teachers viewed I-STEM as vital for developing students' 21st-century skills. As such, they developed lesson plans that explicitly outlined the development of 21st-century skills across various aspects of their I-STEM lessons.

There are also varying degrees to which a teacher may approach implementing an I-STEM curriculum (Moore et al., 2020). This wide variation is thought to derive from teachers' limited training, experience, and instructional model(s) (Rimbach-Jones et al., 2025). Stohlmann et al. (2012) found that a teacher's confidence in their ability to implement an I-STEM curriculum influenced the extent to which they integrated science, technology, engineering, and math into their lessons. Furthermore, both Mesutoglu and Akgündüz (2025) and Stohlmann et al. (2012) revealed that a teacher's comfort with implementing a student-centered pedagogical approach can influence their comfort with implementing I-STEM. Given the lack of pre-service training in I-STEM pedagogies, this variation in implementation levels may persist.

Professional development has been identified as an opportunity to support teachers in selecting, modifying, and developing I-STEM curricula for their classrooms (Margot & Kettler, 2019; Mesutoglu & Akgündüz, 2025). More specifically, PD programs that focus on STEM in an effort to enable educators to gain experience, confidence, content knowledge, skills, and self-efficacy in delivering interdisciplinary STEM instruction (Van Driel & Berry, 2012; Antoniou & Kyriakides, 2013; Schnittka, 2017; Margot & Kettler, 2019; Dare et al., 2019; Ryu et al., 2019). Research overwhelmingly demonstrates that successful and impactful professional development programs include teachers' acquisition of new pedagogical content knowledge. Features of such PD for within-discipline teachers include collaboration with other teachers, coherence with school programming, a focus on subject-matter knowledge and on how students learn, adequate time and resources for training, and ongoing evaluation of PD outcomes. However, professional learning for I-STEM is heavily dependent on teachers' positive attitude toward an integrated approach.

Although studies have examined teachers' experiences and conceptions (Stohlmann et al., 2012; Mesutoglu & Akgündüz, 2025; Strimel et al., 2025) regarding I-STEM professional development, little is known about their considerations for implementation or instructional integration when presented with I-STEM supplements. Exploring this further will provide insight that can shape not only how we prepare teachers but also how supplemental content is designed. We recognize the evident value of I-STEM as an instructional approach and seek to support the advancement of these methods by better understanding how teacher decision-making shapes it, both as a pedagogical ideal and as a practice.

### 3. Materials and Methods

A single case design (Creswell, 2014) was used to address our research question. The use of this design supported the exploration of a multifaceted issue (the factors that teachers considered) in its real-life context (classroom integration). The participants were educators ( $n = 58$ ) who took part in an online professional development hosted by Spark Photonics Foundation (SPF). Participants in SparkEd are educators located across multiple states, including Arizona, California, Kansas, Maryland, Massachusetts, Michigan, Montana, New Jersey, Ohio, Pennsylvania, and Tennessee, representing both K-12 schools and postsecondary education institutions; therefore, the professional development was held virtually. The goals of Spark Ed were to support educators in gaining foundational and advanced knowledge of photonics and semiconductors. As well as improving their confidence in integrating photonic and semiconductor supplemental materials into their curriculum. Through their participation, teachers gained access to an online community of practice comprising educators and industry professionals.

#### 3.1. Participants and Data Collection

Participant recruitment was via snowball sampling (Cohen et al., 2002). The initial recruitment of participants focused on individuals currently engaged in other related SPF activities. Recruitment expanded to SPF's broader national network, particularly in regions connected to the photonics and semiconductor industries. Additionally, entities with which SPF had a partnership were encouraged to share the opportunity with their networks and invite educators to participate in SparkEd. At registration, educators were given a short survey to learn about their roles, including which grade-level band(s) and subject they taught, as well as their self-reported knowledge of the topics to be covered. Upon completion of the PD modules, educators were given another survey to provide feedback on the sessions and their self-reported knowledge of the same topics from the PD, as well as their perspectives on implementation related to the Chip Kids content. The results from the post-PD surveys indicate that, of the 57 teachers who completed the workshops, 10.5% taught grades K-4, 33.3% taught grades 5-8, 70.1% taught grades 9-12, and 1.8% taught at the college level. Educators reported teaching high school science, engineering & design, mathematics, computer science, STEM/STEAM, career & technical education, special populations & instructional support, and general science/STEM (K-8). Over ninety percent of the participants taught at public schools in the United States, with 54 percent of them being Title-1 schools. In both questions, educators were able to enter more than one answer if they felt it applied. Of the 58 workshop participants, 50 submitted questionnaire responses used in our data analysis. Each teacher was directed to complete the following steps:

1. Visit the Chip Kids Educator Page and review the seven lesson summaries from Season One.
2. Choose one episode and lesson that you think would most interest or resonate with your students.

3. On the shared digital document provided, briefly respond to the following prompt:
  - a. Which episode did you choose and why?
  - b. How could you bring this lesson to your students?
  - c. What modifications or additions would you make to adapt it to your teaching style, classroom needs, or student interests?
  - d. Does this lesson connect to an existing topic, unit, or standard you already teach? If so, how?

Table 1 describes each Chip Kids episode and provides the number of teachers that engaged with each episode.

**Table 1.** Chip Kids Episode Guide and Teacher Viewing.

| Episode # | Episode Title  | Episode Description                                                                                                                                                                                                                                                   | # of Teachers |
|-----------|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| 1         | Etch This!     | In the world of semiconductors, how do we draw the microscopic markings needed for their circuits to work? Mrs. Pope and the Chip Kids perform an experiment with antacids, vinegar, and tape to learn about the process of chemical etching. Let's see how it works! | 8             |
| 2         | Light it Up!   | Did you know you can power a lightbulb with just a battery and aluminum foil? Mrs. Pope illuminates the bright ideas behind electrical current. Let's join the Chip Kids and see how it works!                                                                        | 7             |
| 3         | Space Race     | What do slices of pizza and microchips have in common? In this episode, The Chip Kids race to place as many square chips as they can on a circular wafer and learn about space efficiency. Let's see who wins the space race!                                         | 5             |
| 4         | Microchip 3D   | Microchips are found in electronic devices all around us, from computers to rocket ships, but what do they actually look like? Mrs. Pope zooms in on these tiny devices and their surprising layers. Let's take a closer look with the Chip Kids!                     | 6             |
| 5         | Bending Light  | Have you ever wondered why a magnifying glass distorts your reflection? Mrs. Pope and the Chip Kids discover how to bend light like engineers. Let's see how it's done!                                                                                               | 14            |
| 6         | Diffusion      | What happens when you pour water in the center of a circle of candy? Mrs. Pope connects the colorful result to the principle of diffusion, where particles flow outwards to become evenly spread out. Let's see what happens!                                         | 7             |
| 7         | Keep it Clean! | A speck of dust is huge compared to a semiconductor—so how can we make sure our microchips are clean? Using pennies and various liquids, Mrs. Pope and the Chip Kids discover which substance does the trick. Let's see how they keep it clean!                       | 3             |

### 3.2. Data Analysis

We used iterative thematic inquiry (Morgan & Nica, 2020) to develop themes and patterns that emerged from the teacher questionnaire responses. To begin the analysis, two researchers independently applied a priori coding to the first question of the questionnaire responses from the first four episodes of Chip Kids. This coding was guided by the analytical question: What do teachers take into consideration when deciding on

the uptake of curriculum materials? This form of analysis supported our exploration into teachers' considerations. Though participants may have discussed many facets of the Chip Kids episodes, this study intentionally focused only on their considerations regarding implementing the supplemental material in their curriculum. Having the guiding analytical question (an element of a priori analysis) provided a focused analytical lens through which we explored the responses. Next, the research team convened to discuss the initial emergent codes and their refinement. For instance, codes such as higher-order thinking and disciplinary objectives were both combined into a new, more refined code of knowledge and skill acquisition. Other codes were grouped and refined, resulting in three primary themes: (1) Knowledge and skill development, (2) Curriculum Attributes, and (3) Considerations for Adaptations. To support the validity of the codes, two other members of the research team employed a priori coding for two more sets of responses. They endorsed the preliminary themes and noted multiple instances of how the themes manifested across the additional questionnaire responses. In response, all four researchers (the initial two and the two additional researchers) analyzed the remaining questionnaire responses across all seven episodes for season 1 of Chip Kids. All four researchers met weekly to discuss the codes and emergent themes. The analytic process was cyclical and characterized by iterative refinement, as we were in constant conversation with the data, with one another, and with the literature on teacher curriculum integration. Additional detail and nuance were added to what teachers were considering within those three themes.

## 4. Results

Our results revealed that the factors teachers considered could be grouped into three main categories: (1) students' knowledge and skill development, (2) the quality of curriculum attributes, and (3) the necessary adaptations for integration into their classroom instruction. Knowledge and skill development (KSD) reflects teachers' goals for student learning within either a single or an I-STEM disciplinary domain. It reflects what students would learn, understand, or be able to do when they supplement their curriculum with the Chip Kids video and/or activities associated with a particular episode. The second primary category was curriculum attributes (CA). The CA category was derived from factors focused on the perceived ease of implementing the supplementation, as well as possible student perceptions of the supplementation materials or the overall lesson (e.g., finding the topic/experiment fun, interesting, or exciting). The final category that emerged was adaptation (Ad), which included teacher-centered factors related to how they would alter the Chip Kids materials to fit their current curricular scheme or to assess the feasibility of implementation.

### 4.1. Knowledge and Skill Development

The KSD category (See Table 2) was primarily centered around concept development. Teachers considered using The Chip Kids episodes as an introduction, initial exploration, or hook (Inouye et al., 2020) for a concept or career practice. One teacher shared, "this would be an awesome attention grabber to lead a lesson about manipulating and solving equations. For example, we can explore Ohm's Law, Joule's Law, current, voltage, power, etc. Students have the opportunity to learn and practice equations with real-world applications." Teachers also considered episodes to be supportive of developing deeper explanations or applications of concepts. They stated, "we talk about diffusion and osmosis in biology. So, this lesson is a great way to incorporate semiconductors. I will have students do the candy diffusion experiment, predict outcomes, observe changes, and use it to show how molecules move across membranes, then connect it to diffusion in cells and in semiconductor manufacturing as an interesting comparison." This factor reveals that when

exploring implementing supplemental materials into their curriculum, teachers consider what will students learn because of engaging with this content.

**Table 2.** Educator’s Decision-Making Factors for Implementing I-STEM Supplemental Curriculum.

| <i>Knowledge and Skill Development</i>                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Factor                                                                                    | Quote                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <i>Introduction or initial exploration (like a hook) for a concept or career practice</i> | <p>“This would be an awesome attention grabber to lead a lesson about manipulating and solving equations. For example, we can explore Ohm’s Law, Joule’s Law, current, voltage, power, etc. Students have the opportunity to learn and practice equations with real-world applications.”</p> <p>“We talk about diffusion and osmosis in biology. So this lesson is a great way to incorporate semiconductors. I will have students do the candy diffusion experiment, predict outcomes, observe changes and use it to show how molecules move across membranes, then connect it to diffusion in cells and in semiconductor manufacturing as an interesting comparison.”</p> |
| <i>Supportive of developing deeper explanations or application of concepts.</i>           | <p>“Yes, one of the topics we cover in my physics class is waves and electromagnetic radiation. The NGSSS standard HS- PS45 which states ‘Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy’. Through what we call Systems Thinking we learned in Lesson #3, I can have students “system map” the properties of light.”</p>                                                                                                                                                                                                       |
| <i>Review, revisit, or reinforce concepts</i>                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |

#### 4.2. Curriculum Attributes

The CA category demonstrates teachers’ consideration of the supplemental materials’ clarity, usability, and engagement. Educators considered how their students would perceive their experience by noting, “students like hands-on learning” and “this lesson would be something different for my students”. Teachers expressed considering how easy it would be to implement the materials, noting characteristics like “flow”, “format”, and “organization” as key aspects of their decision-making process. Clarity was discussed from two distinct perspectives. One being, does the content provide clarity to students, especially around abstract concepts? One educator shared that the content providing a “clear visual for how energy can be transferred” positively influenced their choice to implement the Chip Kids content. The other perspective relates to clearly connecting their learning to possible career paths. One educator shared, “I could incorporate it [as a] review of concepts while also educating them about chip manufacturing.” The perceived level of clarity, interest and usability are vital aspects educators consider when making supplementation decisions.

#### 4.3. Adaptations

The factor AD acknowledges the role of the teacher’s classroom context in the decision-making process. Teachers discussed revising the supplemental materials to support accessibility: “building out the worksheets to diagram what is happening and more language support for the questions would be key to being accessible for my students.” They also identified the ability to revise the format of the curriculum to include additional experiences: “I would add a hands-on component where students build a [small] scale prototype or interactive model based on their design.” Educators also identified the needs of their class noting, “To better suit my classroom, I would add structured stations” and “I would need to provide a refresher activity about circuits to make sure that all of my students are coming in with some background knowledge.” Teachers also acknowledged the importance of supplemental materials connecting to their curriculum in an effort to fill perceived content

gaps. One teacher stated, “I didn’t teach much optics to my freshman students this past year, but I would like to include more. This lesson can fit in with my waves and light unit when I talk about refraction and shadows.” How supplemental material fits within their local context is a major factor teachers consider when making implementation decisions.

## 5. Discussion

Attending to the knowledge, skills, and dispositions teachers need to support implementing I-STEM curriculum into their classrooms is vital given the rise of STEM-related workforce initiatives that are developing curriculum supports for K-12 classrooms and the value that the programs could hold for addressing existing goals in K-12 education that want I-STEM instruction. These initiatives typically focus on training teachers about a particular domain or context (i.e., microelectronics) and providing them with supplemental materials or guiding them to create their own supplement. Yet, little to no attention is paid to pedagogical knowledge, skills, and dispositions teachers must master to expand their current curriculum to explicitly or implicitly connect concepts from other disciplines. The results from this study found that teachers’ considerations do not include expanding their current curriculum to introduce or integrate additional disciplinary concepts. This means that despite partaking in a professional development that introduced a multidisciplinary context and supplemental curriculum to support I-STEM integration, teachers approached implementation from a single-discipline perspective. The teachers considered curricular coherence and adaptability, access to materials and time, and perceived impact on student engagement and learning as components within their meaning-making processes. The lack of consideration teachers provided for introducing concepts from disciplines other than their own suggests the need for more intentional experiences that support the pedagogical knowledge, skills, and dispositions needed for integrated STEM implementation.

Teacher conceptions as meaning-making guided our analysis of feedback submitted on Chip Kids, highlighting how teachers’ interpretations shape the instructional integration of I-STEM initiatives. We found that the resulting factors align with previous research citing context as a highly influential consideration (Silver, 2022), disciplinary knowledge and skill development (Brown et al., 2011), and student engagement (Silver, 2022) as primary considerations for teachers when engaging with curriculum materials and supplements. Margot and Kettler (2019) identified similar findings within existing research exploring teacher conceptions. Furthermore, the Chip Kids curriculum was designed to support students’ interest and engagement in I-STEM. It was collaboratively co-designed by STEM experts, teachers, and students with the goal of providing free-to-use, low-fidelity, high-quality supplemental content that teachers can easily integrate into their curriculum. Chip Kids lesson plans included problem framing, objectives, standards, cross-cutting concepts, video content, and handouts. Yet, teachers in this study primarily spoke about using the content as a hook or to engage students’ interest, which Silver (2022) identified as the primary reason teachers sought out supplementary materials. The teachers rarely mentioned using the Chip Kids curriculum to apply knowledge and practices from STEM disciplines beyond their own. Nadelson and Seifert (2017) discussed the “substantial challenges” that come with implementing an I-STEM curriculum. One challenge is that teachers lack the pedagogical knowledge to recognize and facilitate opportunities to learn and apply concepts beyond their specific domain. We recognize that oftentimes, this type of PD is explored in relation to how teachers make meaning of the experience. However, we asked open-ended questions about our topic, I-STEM, in ways that allowed them to respond as needed. We didn’t want to limit the ways that the teachers could respond and wanted to understand what came to the forefront for them. We acknowledge that they may have thought across disciplines, but their responses indicate that the priority was not the

type of integration described by [Rimbach-Jones et al. \(2025\)](#). There is much value in the ways the teachers considered possibilities for supplementation, and our research reveals that PD designers and teacher leaders/educators must take a more direct approach when designing these types of opportunities if they want teachers to attend to integrated STEM in specific ways that support career-connected learning.

With a continued focus on I-STEM for multiple reasons, including developing a STEM workforce ([Strimel et al., 2025](#)), it is imperative that more attention be given to pedagogical aids and support. For instance, [Dare et al. \(2018\)](#) explained that, to effectively support teachers in implementing I-STEM, curriculum materials must go beyond outlining content and include pedagogical guidance on how to teach it. “Teaching integrated STEM is an educational innovation that involves ill-structured problems and novel curricular and instructional approaches” ([Nadelson & Seifert, 2017](#), p. 223). Because most teachers receive little preparation in I-STEM pedagogical approaches during their pre-service education ([Rimbach-Jones et al., 2025](#)), initiatives that fail to support the development of teachers’ I-STEM pedagogical knowledge and skills are unlikely to produce meaningful change. According to [Moore et al. \(2020\)](#), I-STEM implementation can occur at different levels of integration, characterized by the degree to which content, context, tools, and applications are interconnected within the learning experience. However, researchers and practitioners have not reached consensus on how to define a specific level or degree of integration. This highlights the need for consensus, like the Technology Integration Matrix ([Florida Center for Instructional Technology, 2019](#)). The matrix is an implementation guide that supports teachers in meaningfully integrating technology into their classrooms across five progressive levels. Each level of integration is also mapped to five student-centered learning characteristics ([Florida Center for Instructional Technology, 2019](#)). Such a matrix could be used to support teachers in designing, evaluating, and integrating multiple domains in an interconnected, student-centered way. Furthermore, future studies are needed to explore how meaningful I-STEM professional development(s) can be designed and delivered using levels of I-STEM integration as a framework. Such a framework could scaffold professional learning for teachers while increasing their awareness of the level of integration required by a particular I-STEM learning experience for both themselves and their students. One way that we propose to do this is through grounding the design of I-STEM professional development in the [Rimbach-Jones et al. \(2025\)](#) I-STEM conceptual framework. This framework acknowledges that there are specific knowledge, skills, and dispositions that teachers must take on when implementing an I-STEM curriculum and how those factors directly connect to learning experiences and student outcomes.

## 6. Limitations

The results of this study are limited by several factors. One factor is the use of a priori analysis. A priori analysis uses predetermined codes, which can limit the scope of the analysis. Additionally, we acknowledge that a detailed codebook, rigorous procedural practices, and an audit trail do not provide statistical evidence of validity comparable to that of an inter-rater reliability coefficient. Future analysis should build upon this approach, utilizing more rigorous analytical approaches. Another limiting factor is that this study did not interview teachers to further explore their conceptions. Relying solely on open-ended survey responses prevents deeper exploration of the teachers’ conceptions. Additional studies are needed to provide a deeper exploration of teachers’ considerations using other data collection methods, such as focus groups, interviews, or journaling. Finally, the I-STEM supplement, Chip Kids, influenced participants’ perspectives, and different curriculum supplements may elicit different conceptions. Future studies should seek to explore teachers’ conceptions using other industry-specific I-STEM supplemental curricula.

## 7. Conclusions

I-STEM is viewed as a viable approach to preparing students to tackle varied, ill-defined, wicked problems (Kurup et al., 2021). Teachers are tasked with applying I-STEM in their classrooms despite siloed infrastructures that do not adequately support this effort. Many turn to supplemental curriculum materials to provide context and engagement for their students. Our study suggests that teachers may need additional pedagogical aids to support the interconnected elements required for I-STEM as well as the various levels of integration. Given that I-STEM pedagogy is typically not taught in teacher preparation programs, developing intentional professional development focused on I-STEM pedagogical knowledge, skills, and dispositions may be warranted.

**Author Contributions:** Conceptualization, S.M.R., F.D.S. and M.D.C.; methodology, M.D.C.; validation, S.M.R. and M.D.C.; formal analysis, S.M.R., F.D.S., M.D.C. and B.P.; investigation, S.M.R.; resources, V.M. and J.M.; writing—original draft preparation, S.M.R., F.D.S., M.D.C., V.M. and B.P.; writing—review and editing, S.M.R. and J.M.; visualization, B.P. and V.M.; supervision, S.M.R. project administration, S.M.R. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** Determined by IRB at University of Tennessee at Knoxville, IRB or HRPP review and approval are not required for this study.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** The data that support the findings of this study may be made available by request to the corresponding author of this article.

**Conflicts of Interest:** Vanessa Mahoney is employed by Spark Photonics Foundation. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## References

- Antoniou, P., & Kyriakides, L. (2013). A dynamic integrated approach to teacher professional development: Impact and sustainability of the effects on improving teacher behaviour and student outcomes. *Teaching and Teacher Education*, 29, 1–12. [CrossRef]
- Brown, R., Brown, J., Reardon, K., & Merrill, C. (2011). Understanding STEM: Current perceptions. *Technology and Engineering Teacher*, 70(6), 5.
- Cohen, L., Manion, L., & Morrison, K. (2002). *Research methods in education*. Routledge.
- Creswell, J. W. (2014). *Research design: Qualitative, quantitative and mixed methods approaches* (4th ed.). Sage.
- Dare, E. A., Ellis, J. A., & Roehrig, G. H. (2018). Understanding science teachers' implementations of integrated STEM curricular units through a phenomenological multiple case study. *International Journal of STEM Education*, 5(1), 4. [CrossRef] [PubMed]
- Dare, E. A., Ring-Whalen, E. A., & Roehrig, G. H. (2019). Creating a continuum of STEM models: Exploring how K-12 science teachers conceptualize STEM education. *International Journal of Science Education*, 41(12), 1701–1720. [CrossRef]
- Drake, S. M., & Burns, R. C. (2004). *Meeting standards through integrated curriculum*. Association for Supervision and Curriculum Development.
- Florida Center for Instructional Technology. (2019). *Technology integration matrix*. Available online: <https://fcit.usf.edu/matrix/matrix/> (accessed on 26 February 2026).
- Inouye, M., Houseal, A., & Gunshenan, C. (2020). Beyond the hook. *The Science Teacher*, 87(9), 59–63. [CrossRef]
- Kartal, B., Kartal, T., & Taşdemir, A. (2022). *How and why teachers implement STEM? A journey to teacher beliefs and teaching practices* (pp. 41–74). Internalization of STEM Education.
- Krathwohl, D. R. (2002). A revision of bloom's taxonomy: An overview. *Theory into Practice*, 41, 212–218. [CrossRef]
- Kurup, P. M., Yang, Y., Li, X., & Dong, Y. (2021). Interdisciplinary and integrated STEM. *Encyclopedia*, 1(4), 1192–1199. [CrossRef]
- Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: A systematic literature review. *International Journal of STEM Education*, 6(1), 2. [CrossRef]
- Mesutoglu, C., & Akgündüz, D. (2025). Integrated STEM conceptualizations among teachers following a professional development program. *School Science and Mathematics*. [CrossRef]
- Moore, T. J., Johnston, A. C., & Glancy, A. W. (2020). STEM integration: A synthesis of conceptual frameworks and definitions. In *Handbook of research on STEM education* (pp. 3–16). Routledge.

- Morgan, D. L., & Nica, A. (2020). Iterative thematic inquiry: A new method for analyzing qualitative data. *International Journal of Qualitative Methods*, 19, 1–11. [\[CrossRef\]](#)
- Nadelson, L. S., & Seifert, A. L. (2017). Integrated STEM defined: Contexts, challenges, and the future. *The Journal of Educational Research*, 110(3), 221–223. [\[CrossRef\]](#)
- Reynante, B. M., Selbach-Allen, M. E., & Pimentel, D. R. (2020). Exploring the promises and perils of integrated STEM through disciplinary practices and epistemologies. *Science & Education*, 29(4), 785–803. [\[CrossRef\]](#)
- Rimbach-Jones, D., Harper, F. K., & Brown, C. L. (2025). Building primary teachers' capacity for integrated STEM education: A case study of programmatic features and structures. *Education Sciences*, 15(12), 1657. [\[CrossRef\]](#)
- Ryu, M., Mentzer, N., & Knobloch, N. (2019). Preservice teachers' experiences of STEM integration: Challenges and implications for integrated STEM teacher preparation. *International Journal of Technology & Design Education*, 29(3), 493.
- Sawyer, A. G., Dick, L. K., & Sutherland, P. (2020). Online mathematics teacherpreneurs developers on teachers pay teachers: Who are they and why are they popular? *Education Sciences*, 10(9), 248. [\[CrossRef\]](#)
- Schnittka, C. (2017). *STEM road map: A framework for integrated STEM education* (C. C. Johnson, E. E. Peters-Burton, & T. J. Moore, Eds., p. 362). Routledge. ISBN 13: 978-1-13-880422-7. [\[CrossRef\]](#)
- Schroeder, S., Shelton, C. C., & Curcio, R. (2025). Curriculum in the digital age: Intensifying the work of teachers, the remix. *Journal of Curriculum and Pedagogy*, 22(3), 494–521.
- Silver, D. (2022). A theoretical framework for studying teachers' curriculum supplementation. *Review of Educational Research*, 92(3), 455–489.
- Sokha, K. (2024). Examine the impact of contextual, personal, and behavioral factors on high school teachers' engagement in teaching science using an integrated STEM approach. *International Journal of Science and Mathematics Education*, 22(8), 1857–1883. [\[CrossRef\]](#)
- Stohlmann, M., Moore, T. J., & Roehrig, G. H. (2012). Considerations for teaching integrated STEM education. *Journal of Pre-College Engineering Education Research (J-PEER)*, 2(1), 4. [\[CrossRef\]](#)
- Strimel, G., Lucas, D., Lee, Y., Constantine, V., Moore, T., Hynes, M., & Guzey, S. (2025). Semiconductors & microelectronics in middle school technology & engineering: Integrating emerging STEM workforce contexts into the classroom. *Journal of Technology and Education*, 37(1), 32–67. [\[CrossRef\]](#)
- Van Driel, J. H., & Berry, A. (2012). Teacher professional development focusing on pedagogical content knowledge. *Educational Researcher*, 41(1), 26–28. [\[CrossRef\]](#)

**Disclaimer/Publisher's Note:** The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.