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# Teacher Adaptations in the Implementation of a Co-Designed Curriculum

Merijke Coenraad

## Abstract

*While innovations co-designed with teachers show positive outcomes, implementation of co-designed innovations and adaptations made by teacher co-designers during implementation are less examined. This paper explores how teacher co-designers adapt lesson materials when teaching and the factors leading to adaptations. Teachers made adaptations to increase support for students due to characteristics of the innovation, users, and environment. These contextualized and in-the-moment adaptations were in addition to design decisions made during co-designing. The findings point to potential differences in how teachers perceive student needs in design sessions compared with when teaching. This work supports future co-design with teachers by increasing understanding of the adaptations made to a co-designed curriculum and the reasons for these adaptations so that design conversations can support goal-aligned, student-supportive adaptations.*

## Introduction

Teachers are increasingly being included in the curriculum design process through co-design, a technique of innovation development where experienced designers partner with users to develop a product together. Through co-design, researchers and curriculum designers hope to better align with teachers' contexts and incorporate their knowledge and experiences in the classroom (Penuel et al., 2007; Scaife et al., 1997). Co-designed innovations have proven successful from the perspectives of both teachers and students (e.g., Carroll et al., 2000; Coenraad et al., 2021; Lui & Slotta, 2014; Penuel et al., 2007).

While the design process has been studied extensively, less is known about how teachers implement curricula they participated in co-designing. This paper focuses on the equally important implementation process. When implementing a curriculum, it is routine for teachers to make adaptations to curriculum and lessons to meet the perceived needs of their students within the context of their classroom environment. This study aims to expand knowledge about this implementation process and the adaptations made when implementing a co-designed curriculum. Knowledge about how a teacher implements and adapts a curriculum can aid the field in creating more robust curricular materials and supporting teachers to make adaptations that support their students. It can also assist teachers and researchers working together in co-design processes to ensure that adaptations lead to positive outcomes aligned with the goals of both the teachers and researchers.

In this paper, I analyze the implementation of a curriculum co-designed by a researcher-designer and two teachers who were design partners and implemented the curriculum. This work examines how the teacher partners adapted materials developed through co-design when implementing them in the classroom and what factors led to this adaptation. I seek to identify if and how critical components of the co-designed curriculum were productively adapted when implemented by a teacher who co-developed the materials a short time before implementing them. I answer two research questions:

1. When implementing co-designed lessons, how do teachers who co-designed the lessons adapt them for the classroom environment?
2. What factors influence teachers' adaptation of co-designed lessons when implementing them in the classroom environment?

Based on my analyses, I found that even when a curriculum intervention is co-designed with the implementing teachers at a time when they are aware of many factors affecting the classroom, these co-designed innovations still require adaptations to meet students' needs. These findings are significant to researcher-designers working with teachers to co-design curricula for their classrooms, speaking to the likelihood that co-designed curricula are adapted when they are implemented and the importance of collaboratively identifying the components of the lessons that should not be adapted, if possible, and the rationales behind component inclusion. While the specific factors affecting the classroom and the components of the curriculum will differ in other design partnerships, these overall findings and the subsequent discussion can support teams of varied sizes co-designing between researcher-designers and implementing teachers.

# Theory and Prior Work

## Co-Designing Innovations with Teachers

Teachers' involvement in the development of an innovation through co-design replaces the typical top-down design process in which researchers and developers play the main roles in the design of new innovations. Instead, the co-design process places importance on teachers' classroom practices and contexts and their everyday experiences (Penuel et al., 2007) and requires teachers' continuous involvement as designers (Roschelle et al., 2006). Teacher input into educational innovations through co-design provides expertise on learning goals, teaching practices, and what curriculum and procedures currently exist in schools (Scaife et al., 1997). Additionally, considering education through a design framework of education innovations as designs for learning, Halverson et al. (2010) suggest that "by integrating users (and their experiences) into the design process early on, real-world practices can inform an iterative design process, leading to greater faithfulness in enacting the intentions of the artifact" (p. 177).

Literature on co-designing educational innovations with teachers includes studies of and reports on the participatory design process (e.g., Hundal et al., 2014; Matuk et al., 2016), the innovation (e.g., Barab et al., 2001; Cooper & Brna, 2000), or both (e.g., Frossard et al., 2012; Kyza & Georgiou, 2014; Zuiker, 2014). But, when reporting on the implementation of co-designed innovations in the classroom, research typically focuses on student and teacher outcomes (Tan & Guo, 2009; Wong et al., 2015; Zhang et al., 2010).

## Implementation Research on Curricula

Implementation research seeks to “understand if and how educational efforts are accomplishing their goals…[through] systematic inquiry regarding innovations enacted in controlled settings or in ordinary practice, the factors that influence innovation enactment, and the relationship between innovation, influential factors, and outcomes” (Century & Cassata, 2016, pp. 169–170). To do this, implementation research includes studying the implementation of an innovation, factors influencing that implementation, and the outcomes of the innovation (Century & Cassata, 2016). Generally, this analysis occurs across two dimensions: structural and process (Harn et al., 2013). Together, these elements highlight not only whether an innovation is adopted, but also what happens during the adoption and enactment and the factors influencing that enactment (Century & Cassata, 2016).

Adaptation studies, implementation research focused on how teachers adapt curricula or innovations, take as a given that teachers will transform innovations when they adopt them and that this transformation is purposeful rather than accidental (De Vries et al., 2017; Pintó, 2005). Researchers focus on how to support the process of adaptation during the design, planning, and enactment of the curriculum and ensure the most important components of the intervention are not altered as adaptations occur (DeBarger et al., 2013; Harn et al., 2013). Researchers focus on making accommodations based on local needs, contexts, and circumstances while maintaining the core ideas of the innovation (LeMahieu, 2011). These adjustments are known as “productive adaptations,” or “evidence-based curriculum adaptation[s] that are responsive to the demands of a particular classroom context but still consistent with the core design principles and intentions of a curricular intervention” (DeBarger et al., 2013, p. 298).

Implementation research within projects developed through co-design is understudied, particularly within the field of education, with only a few studies having examined teacher adaptations of co-designed innovations. These studies found that even when teachers are part of the initial design of innovations, they adjust when enacting them in their classrooms to fit the learning needs of their students, and professional development can support them to do so productively (DeBarger et al., 2013; Ye et al., 2014).

In this paper, I build upon the prior work by taking an adaptation perspective of innovation implementation to examine how a co-designed curriculum was adapted by the teacher design partner during the implementation process. By examining *how* a partnering teacher implemented a co-designed innovation rather than examining the design process or outcomes, this work provides further insight into the utility of co-design and the implementation following a co-design partnership.

## The Innovation Implementation and Factor Frameworks

This work is guided by two interconnected frameworks: the innovation implementation framework and the factor framework. As a component-based framework, the innovation implementation framework focuses on identifying the critical components within the innovation, or those parts of an innovation that the innovation's developers deem to be essential to attain the intended outcomes (Century et al., 2012; Century & Cassata, 2014), and measuring the use of those components during implementation (Century & Cassata, 2014). The critical components are broken into two categories: structural components and interactional components (Century et al., 2012; Century & Cassata, 2014). Structural components are "the organization, design, and support elements that are the building blocks of the innovation" (Century & Cassata, 2014, p. 88) and divide into two subcategories: procedural and educative. Interactional components are "the behaviors, interactions, and practices of innovation 'users' during enactment" (Century & Cassata, 2014, p. 88) and are organized by user groups (e.g., teacher and learner engagement components in education).

While the innovation implementation framework focuses on the *what* and *how* of innovation implementation, the factor framework provides a conceptual structure to examine *why* an implementation occurs as it does (Century & Cassata, 2014). It is constructed of five research-based categories of factors: characteristics of the innovation, characteristics of individual users, characteristics of the organization, elements of the environment external to the organization, and enacted networks (Century et al., 2012; Century & Cassata, 2014).

In my analysis, I apply both the innovation implementation and factor frameworks to data collected during the classroom implementation of a co-designed curriculum. The innovation implementation framework sheds light on the critical components of the curriculum and frames the analysis of adaptations made during implementation. Subsequently, the factor framework provides insights into possible factors affecting the implementation and the resulting adaptations.

# Methods

## Context and Participants

This work utilizes the Talking Techquity curriculum (Techquity is a portmanteau of technology and equity). Talking Techquity is a co-designed introductory computer science curriculum focused on developing students' computer science skills while simultaneously introducing social justice and equity impacts of computing. The curriculum was developed in the months leading up to its implementation with the goals of being relevant to students' lives and aligning to the needs of the teachers and their classrooms. The curriculum is based on ideation and critiques from youth designers and was developed into a curriculum through co-design with the two teachers implementing the curriculum, Mr. Johnson and Mr. Sanchez (all names in this paper ar pseudonyms), and myself, a researcher. Curriculum materials include unit plans, student worksheets, and coding projects.

Mr. Johnson was the primary teacher on the project who implemented the curriculum in his classroom. He identified as a Black or African American man between the ages of 35 and 44. He was in his 19th year of teaching and taught English and the enrichment course in which the curriculum was implemented. Mr. Sanchez was the school librarian at the same school. He identified as a Hispanic or Latino man between the ages of 45 and 54. Mr.

Sanchez was in his fifth year of teaching. Mr. Sanchez joined the class whenever possible to support Mr. Johnson and the students. I was the final member of the design team. At the time of the research, I was a PhD candidate and former middle school teacher who identified as a mixed-race woman between the ages of 25 and 34.

The curriculum was implemented at an urban middle school in the mid-Atlantic region of the United States. Mr. Johnson taught the first two (of three) units of the curriculum and the final project. During the 2019-2020 school year, when the curriculum was designed and implemented, the school served just over 350 students. Of those students, approximately 86 percent were Black, 13 percent were Hispanic/Latino, and one percent were white. Eight percent of students in the school were English language learners, 20 percent were in special education, and 100 percent of students were identified by the district as economically disadvantaged. The curriculum was designed for use in an enrichment course in which all sixth-grade students participated. The sixth-grade students were divided amongst five class periods. The course met on a block schedule twice per week for 80 minutes per session. Due to the COVID-19 pandemic, students joined the class online using the video conferencing software Microsoft Teams. The district ensured that all students had access to both a device and the internet.

## Data Collection

The design team met weekly beginning five weeks before the curriculum was implemented. The initial design meetings focused on brainstorming and developing the curriculum while later meetings focused on supporting the teachers as they implemented the Talking Techquity lessons. Based on the preferences of the teachers, curricular units were designed immediately before they were needed (e.g., Unit 2 and the final project were developed as students were learning the previous units). Design meetings took place over Zoom video conferencing and were audio- and video-recorded. In addition, I took field notes immediately after each design meeting. The design team discussed and brainstormed curriculum materials which I developed before Mr. Johnson and Mr. Sanchez critiqued and edited them for iteration until we agreed on a final version. In addition to the design meetings, the teachers participated in three interviews throughout implementation, one after each unit and the final project. Interviews lasted between 30 and 60 minutes and were audio- and video-recorded. During implementation, I observed at least one class period in which each lesson was taught. Since Mr. Johnson utilized the curriculum in all five classes he taught, observations varied by unit (i.e., Unit 1 during period 1, Unit 2 during period 5, etc.) to see different classes and observe the implementation of the materials in different contexts (e.g., time of day, students). While observing classes, I kept field notes about what Mr. Johnson did and the flow of the class.

## Data Analysis

I iteratively analyzed the collected data to develop a comprehensive list of critical components, verify this list through triangulation with conversations between the entire design team, and analyze the enactment of the critical components within the classroom as well as the factors affecting those components during design and implementation. As recommended by Century and Cassata (2016), I utilized a variety of approaches to identify the critical components of the curriculum. This included gathering information from curriculum developers, observing the implementation within the classroom, and reviewing curriculum artifacts.

To develop the list of critical components (Table 1), I first reviewed the list of components developed by the framework authors (Century et al., 2010) and extracted all those relevant to the design of the Talking Techquity lessons (15 of 40 components identified by Century et al., 2010). Of the identified components, all are represented in the final taxonomy of critical components (Table 1). In two instances, I expanded single factors from the framework into multiple components (e.g., I expanded "Student choice and relevance" into components 5, 6, and 15 in Table 1 based on the subsequently described steps). In two other instances, I combined components (e.g., I combined the facilitation of manipulatives, materials, and tools with the facilitation of using Scratch in component 13). Then, I framed these factors specifically for the Talking Techquity curriculum and verified their significance. To do so and to bring in the voices of all designers during the design discussions, I deductively coded all the design meeting transcripts and field notes using the broad categories of structural-procedural, structural-educative, interactional-pedagogical, and interactional-learner engagement (Century et al., 2012; Century & Cassata, 2014). I compared this coding to the list of components I developed from the framework to determine whether all initial codes were present in the design discussions, if there were missing components, and to identify which components were critical and given high value in the conversations (rather than just those present in the curriculum). At that point, I also adjusted the language from the general components presented by Century et al (2010) into language specific to the Talking Techquity curriculum. Using this process, I identified 16 critical components (Table 1). As Gale et al. (2020) found previously, some of the interactional components included a parallel teacher and student activity. As such, three of the interactional components are paired based on their parallel structure: discussion-based learning, Techquity content, and the use of Scratch for computer science learning.

I used the 16 components to code the unit plans to identify where and how the components were written into curricular materials and the expected enactment of the critical components. For example, the opening section of Unit 1, Lesson 1 reads, "In order to introduce the idea of bias, generally, and algorithmic bias, specifically, lead a class discussion about bias and the ways that it can be harmful" and includes guided questions and sample student answers. This section is coded as component 9, *Teacher facilitation of discussion*.

Then, I similarly coded the teacher interviews and observation field notes using the 16 critical components to identify where and how these components were enacted during the teaching of the Talking Techquity lessons. For example, during the first interview, Mr. Johnson said, "I think it went pretty, pretty well; I think the instructions and everything were pretty much on point." I coded this observation as component 8, *unit plans and curriculum materials*.

Finally, I completed a side-by-side analysis of the coded lesson plans and the classroom observations to identify instances of adaptation and categorize them according to the critical component to which they aligned.

**Table 1 – Critical components in the Talking Techquity curriculum**

| Structural | | Interactional | |
|---|---|---|---|
| **Procedural** | **Educative** | **Pedagogical** | **Learner Engagement** |
| 1. Include all lesson segments and lessons in order<br>2. Scaffold with use-modify-create<br>3. Introduce both computing and Techquity concepts<br>4. Support student autonomy and knowledge of requirements<br>5. Create opportunities for student choice<br>6. Incorporate topics of relevance | 7. Content background information<br>8. Unit plans and curriculum materials | **Discussion-based Learning** | |
| | | 9. Teacher facilitation of discussion | 10. Students contribute to discussion |
| | | **Techquity Content** | |
| | | 11. Teacher introduces and guides students through engagement with Techquity topics | 12. Students engage with Techquity topics |
| | | **Use of Scratch for computer science learning** | |
| | | 13. Teacher facilitates use of Scratch to learn computer science concepts guided by curriculum worksheets | 14. Students view, manipulate, and create code in Scratch, guided by curriculum worksheets to learn computer science concepts |
| | | | 15. Students make decisions about their work |
| | | | 16. Students share their work |

The identification of factors followed a similar process. First, I identified factors based on those highlighted by the framework authors (19 of 61 factors identified in Century & Cassata, 2014). Then, I extracted factors from the design meeting field notes and transcripts, interviews, and observation field notes. I only extracted factors related to adaptations made to the curriculum, not those related to original design intentions. I compared these factors to the list identified based on the framework to confirm, add, or remove factors that were not present or emphasized in the data and develop a final list of factors (10 factors added and five removed for a total of 24 final factors; Table 2). Finally, I coded the previously extracted factors from the design meetings and observations using the final set of factors. For example, I coded Mr. Johnson's observation that "Unit two was a level up when it comes to Scratch and when it comes to the skill and understanding the skill and Scratch" as *complexity*.

**Table 2 – Factors influencing adaptions by teachers**

<table>
<tr><th colspan="2">Factors</th></tr>
<tr><th colspan="2">Characteristics of Innovation</th></tr>
<tr><td colspan="2">• Adaptability<br>• Complexity<br>• Duration<br>• Modality<br>• Novelty<br>• Specificity</td></tr>
<tr><th colspan="2">Characteristics of Individual Users</th></tr>
<tr><th>Teacher</th><th>Student</th></tr>
<tr><td>• Attitude toward innovation<br>• Self-efficacy<br>• Understanding of innovation</td><td>• Attitude toward and knowledge of things related to the innovation<br>• Ease of use<br>• Engagement level<br>• Patience and persistence<br>• Presence<br>• Time management and organizational skills</td></tr>
<tr><th colspan="2">Characteristics of the Organization</th></tr>
<tr><td colspan="2">• Environment<br>• Organizational goals<br>• Shared beliefs and values<br>• Time</td></tr>
<tr><th colspan="2">Elements of the Environment External to the Organization</th></tr>
<tr><td colspan="2">• COVID-19 pandemic<br>• Political environment<br>• Students' home lives</td></tr>
<tr><th colspan="2">Enacted Networks</th></tr>
<tr><td colspan="2">• Co-design partnership between teachers and university researchers<br>• School District / University of Maryland Research Practice Partnership</td></tr>
</table>

# Results

In addition to the design decisions he made to tailor the curriculum to his class during the design process, Mr. Johnson made contextualized and in-the-moment adaptations to the Talking Techquity curriculum when he implemented it. Specifically, Mr. Johnson adjusted how he presented the content and project requirements. He made these changes to provide more scaffolding and ensure students had the opportunity to be successful. These adaptations were made based on all five types of factors from the Factors Framework (Century & Cassata, 2014). While the curriculum was aligned to Mr. Johnson's beliefs about what his students would need during the design sessions, factors emerged that could not be predicted in the design environment. Mr. Johnson believed these factors warranted adaptation either in the moment during the lesson or based on the successes and difficulties students faced in prior lessons.

## Research Question 1: When implementing co-designed lessons, how does a teacher who co-designed the lessons adapt them for the classroom environment?

Overall, Mr. Johnson made adaptations broadly that affected nearly all critical components within the curriculum. Of the 16 critical components within Talking Techquity (Table 1), 11 were adapted at varying levels during implementation. Mr. Johnson made adaptations in each of the lessons he implemented. These adaptations ranged from providing students with additional time to work on projects and adjusting how students presented their work to removing entire lessons from the units. Example adaptations for each critical component that was modified are presented in Table 3.

**Table 3 – Critical components adapted during classroom implementation**

| Type | Critical Component | Example Adaptation |
|---|---|---|
| Structural-Procedural | Include all lesson segments and lessons in order | Removing the open-ended project from Unit 2 and having students instead continue individualizing their scaffolded project. |
| Structural-Procedural | Scaffold with use-modify-create | Completing the worksheet that guides the exploratory portion of the lesson as a full class rather than having students complete it individually. |
| Structural-Procedural | Introduce both computing and Techquity concepts | Removing the reading assignment in Lesson 1. |
| Structural-Procedural | Incorporate topics of relevance | Replace a universal example of a service that uses recommendations (YouTube) with a school-specific example (iReady). |
| Interactional-Pedagogical; Interactional-Learner Engagement | Discussion-based Learning | Changing the order of questions, adding additional questions, and replacing discussion questions with vocabulary or ideas through definitions. |
| Interactional-Pedagogical; Interactional-Learner Engagement | Techquity Content | Removing follow-up explanations of Threats to Techquity associated with data collection in an interactive class activity. |
| Interactional-Pedagogical; Interactional-Learner Engagement | Use of Scratch for computer science learning | Removing discussion-based review of how to animate in the coding environment and replacing it with a demonstration of specific coding skills or concepts. |
| Interactional-Learner Engagement | Students share their work | Expanding student opportunities to share to include not only sharing their projects, but also demonstrating how they performed certain tasks (such as having two characters talk to one another). |

While Mr. Johnson was on the design team for the curriculum and co-created the lesson plans he was following, he felt the need to adapt Talking Techquity in his classroom, as is necessary with many curricula that teachers use (particularly when implemented by a teacher for the first time). Co-designing the curriculum did not eliminate the need for specific adaptations to meet student needs in the moment or based on changing classroom and educational contexts.

## Research Question 2: What factors influence a teacher's adaptation of co-designed lessons when implementing them in the classroom environment?

In total, 24 factors affected the implementation of Talking Techquity and led to Mr. Johnson making adaptations to the curriculum (Table 2; Table 4). These 24 factors exist across all five categories defined by the factor framework (Century & Cassata, 2014). As such, factors relate to characteristics of the innovation (Talking Techquity: six factors), users (teachers and students: nine factors), the organization (the school: four factors), the external environment (United States and global events: three factors), and networks (within and outside the school: two factors). Table 4 presents each of the 24 factors with an example of how it affected the implementation.

**Table 4 – Factors leading to adaptations of Talking Techquity**

| Factor | Example of Factor |
|---|---|
| **Characteristics of Innovation** | |
| Adaptability | Ability to change the curriculum as technologies change over time |
| Complexity | Difficulty and amount of content covered |
| Duration | Teaching the curriculum for the first time |
| Modality | Teaching the curriculum through distance learning without paper worksheets |
| Novelty | Limited prior knowledge of computer literacy and computer science |
| Specificity | Guiding students through requirements by providing step-by-step instructions for students |
| **Characteristics of Individual Users: Teacher** | |
| Attitude toward innovation | The curriculum needed to teach students and be impactful, but it didn't need to be entertaining when engaging students |
| Self-efficacy | Teachers' comfort levels discussing Techquity topics and computer science |
| Understanding of innovation | Being familiar with the curriculum and preparing steps to implement it ahead of time |

| | |
|---|---|
| **Characteristics of Individual Users: Student** | |
| Attitude toward and knowledge of things related to the innovation | Knowledge of how technology is affecting society or the importance of computer programming |
| Ease of use | Student ability to use the coding platform, particularly with limited teacher support due to online learning |
| Engagement level | Students being attentive in class and taking part in class discussion and classroom activities |
| Patience and persistence | Students taking time to complete work and overcome difficulties |
| Presence | Students missing classes, particularly because the class was taught in 80-minute blocks two days per week |
| Time management and organizational skills | Supporting students to manage time on large projects and make sure they meet all requirements using checklists |
| **Characteristics of the Organization** | |
| Environment | Students have access to computers because of the need to go online |
| Organizational goals | Aligning with the school's goals to increase equity for students and provide opportunities to discuss inequity within society |
| Shared beliefs and values | Being open and transparent with students about sociopolitical contexts |
| Time | Changing schedules due to priorities at the end of the quarter |
| **Elements of the Environment External to the Organization** | |
| COVID-19 pandemic | Magnification of challenges students face due to the ongoing pandemic |
| Political environment | The Black Lives Matter movement and protests over racism within society during 2020 |
| Students' home lives | Students babysitting sibling during the school day or not being able to turn on their microphones due to noise in their house during the day |
| **Enacted Networks** | |
| Co-design partnership between teachers and university researchers | Mr. Johnson and Mr. Sanchez getting to work more closely and collaborating with the author. |
| School District / University of Maryland Research Practice Partnership | An ongoing partnership between the University of Maryland and the school district to support computer science education |

It is important to note that while these factors are listed and explored here individually and within their larger categories, the interconnection between factors and categories cannot be ignored. Although causal connections cannot be made, there is likely interplay between factors, such as between students' presence in class and the external factors of the COVID-19 pandemic and their home lives. The factors are not, in fact, discrete influences, but rather manifestations of the larger sociohistorical and political environment in which the implementation occurred. In the following section, some of this interplay, as well as the connections between factors and adaptations, are explored in an illustrative example from the classroom implementation of Talking Techquity.

## Adaptation Example: Introductory Discussion

Examining how Mr. Johnson implemented the introductory discussion for the first unit of the Talking Techquity curriculum highlights how critical components and factors played out in the classroom. Mr. Johnson engaged his students in the interactionally critical component of discussion-based learning. Using the unit plan as a guide, Mr. Johnson employed questioning to elicit information from students and build knowledge together through a sequence of questioning, eliciting student answers, and clarifying. This discussion incorporated both computing and Techquity concepts and provided opportunities both for students to engage with Techquity topics and for Mr. Johnson to introduce Techquity topics to students. When teaching, Mr. Johnson made some modifications to this discussion. He adapted the lesson by adding a short introduction to the day's content by highlighting the objective of the day and having a student read the objective early in the class. Then, he provided an opportunity for students to give an example of bias, providing opportunities to incorporate topics of relevance. In the conversation, Mr. Johnson not only provided the opportunity for students to incorporate topics of relevance, but he also did so himself. For example, he engaged a specific student by asking about her siblings. Despite these opportunities to make the learning relevant, Mr. Johnson removed some examples of relevant technologies by only mentioning the example of algorithms in YouTube suggestions. He did not connect to other platforms with which students might be familiar (as suggested in the lesson plan).

While incorporating both computing and Techquity concepts into the conversation, Mr. Johnson elected to use definitions different than those in the lesson plans. Although the lesson plans provided definitions of "bias" and "algorithm," Mr. Johnson selected definitions he found online. Finally, Mr. Johnson removed the reading about algorithmic bias from the lesson. This affected the incorporation of both computing and Techquity concepts as well as students engaging with Techquity topics.

These adaptations were likely a result of several factors. The first is the novelty of the topics. Students at the school did not have extensive prior experience with computer literacy or computer science. While they had engaged in some introductory computing in Mr. Johnson's class prior to beginning the Talking Techquity curriculum, terms like "algorithm" were likely new to the students in the class. Additionally, the discussion was affected by students' engagement level. Despite Mr. Johnson leaving wait time and trying to engage individual students, most questions went unanswered until Mr. Sanchez stepped in or Mr. Johnson selected one student to answer. Some questions went completely unanswered. In the moment, Mr. Johnson attempted to increase engagement via different engagement strategies with students, such as allowing answers through various modalities (i.e., out loud or via chat) and alternating between calling on specific students and asking for volunteers. Despite this, in an interview after the unit, Mr. Johnson shared, We're distance learning so one of the biggest challenges that [we] have…faced, and we knew that was coming, was just student engagement…You want students to be engaged and it's hard to tell how engaged they are. Then again, sometimes it's not, so that to me…was the challenge, just to keep them engaged enough…to keep them engaged long enough to grit through the challenges of Scratch when it comes to coding, to grit through that, so that they can…smile at their…end result.

This engagement level is likely intertwined with the following factors: the environment, online learning due to the COVID-19 pandemic, and the fact that students were learning from home and, therefore, were affected to a greater degree by their home lives. Although not in this lesson, in other observations, Mr. Johnson responded to students unable to turn on microphones because of noise in their house or malfunctioning technology. Technical difficulties, as well as the time it took students to navigate their assignments and computers on their own, affected the time available for the lesson and for students to complete activities. The adaptations were also affected by Mr. Johnson's own self-efficacy with regard to Techquity content. His confidence in being able to both have a conversation about equity in general and Techquity more specifically supported his use of discussion-based learning. This confidence is likely due, in part, to the alignment between the curriculum and the school's organizational goals to discuss equity with students.

## Discussion

Grounded in the interconnected innovation implementation and factor frameworks (Century et al., 2012; Century & Cassata, 2014), this work examines the implementation of a co-designed curriculum, utilizing the frameworks to better understand the adaptations made by the implementing teacher-designers and the factors that led to those adaptations. Despite being a designer of the original curriculum, Mr. Johnson elected to make in-the-moment or mid-unit adaptations based on the context of the classroom that could not be predicted within the design environment. Co-design with teachers is motivated by the ability to incorporate the expertise and experiences of teachers and to better align innovations to their context and needs (Penuel et al., 2007; Scaife et al., 1997). However, based on this research, it seems possible that during the design phase of creating a curriculum, teacher beliefs about students' needs differ from their beliefs about students' needs while implementing the curriculum (when they can perceive said needs in the moment). In this instance, many of the adaptations made and the factors that led to them are directly or potentially indirectly impacted by the COVID-19 pandemic, but there is reason to believe similar trends in adaptation of co-designed materials would be seen without the drastic contextual shift that the global pandemic caused. As past research has also found, using co-design does not mean that teachers do not need to make adaptations to co-designed curricula upon implementation, particularly when the innovation is scaled (DeBarger et al., 2013; Ye et al., 2014). Further, the factors that impacted the adaptations made during implementation were based in those identified within the foundational factor framework literature (Century & Cassata, 2014) with over half of them being the same. This correspondence points to the factors in this study being similar to those impacting implementations conducted outside of the COVID-19 pandemic. Finally, the co-design for this study occurred while the teachers were already teaching the classes in which they implemented the curriculum, and the teachers had been teaching online for over half a school year when they were designing. As such, they could and did predict some of the needs related to teaching during the COVID-19 pandemic while co-designing the Talking Techquity curriculum. While this study was certainly impacted by the COVID-19 pandemic and different or potentially less prominent shifts might be seen in an implementation outside of the pandemic context, the alignment with past work points to the need for an expectation that co-design curricula will be adapted. The current work demonstrates that the perceived need for adaptations seen in prior literature remains even when the design team is small and focuses on developing an innovation for a single context in which the teachers already work.

These findings surface several tensions that warrant further exploration and research. First, how to ensure that adaptations are aligned to both teacher and researcher goals. Since this and past research have shown that adaptations are perceived to be necessary even when teachers are part of the design team, the focus within co-design teams needs to include methods for ensuring these adaptations are in alignment with the goals of the curriculum. According to DeBarger et al. (2013), when productively adapting a curriculum, teachers need to: (1) be responsive to multiple stakeholders; (2) make adaptations that reflexively relate to responsive discourse practices; and (3) maintain or enhance task complexity and engagement. Co-design inherently works toward some of these criteria. The adaptations made by Mr. Johnson aligned to the first two requirements of productive adaptation according to DeBarger et al. (2013), but they did not necessarily align with the third (maintaining the complexity of the tasks).

Not only did some of the adaptations decrease the complexity of the task due to needs as identified by Mr. Johnson, but the adaptations did not always align with the researcher's goals for the project. Throughout the design sessions, we discussed goals for the work and elements to include within the curriculum. A balance of these elements was agreed upon and included within the final unit plans. But Pintó (2005) found that, when implementing an innovation and making adaptations, teachers "often demote the goals of innovation designers" (p. 8). In the present work, when teachers were part of the design team, the goals of the non-teacher designer, who did not implement the curriculum, appear to have become less salient in the moments when Mr. Johnson needed to make implementation decisions. Mr. Johnson made modifications to the curriculum to increase scaffolding for students and help them to be and feel successful with the topics covered, but these modifications decreased opportunities for students to engage with impacts of computing topics, a researcher goal. The contextualized and in-the-moment adaptations created a tradeoff between the original design goals, particularly those of the researcher, and Mr. Johnson's perception of student needs when actually implementing the curriculum.

When examining the adaptations made to Talking Techquity, there was a second tension between a pro-adaptation perspective of innovation implementation (Century & Cassata, 2016) and the changes created by the adaptations. A pro-adaptation view sees the adaptations teachers make as contributing positively toward the outcomes of the implementation because the adaptations can align to strategies the teacher knows to be effective with the students they are teaching and can add contextual relevancy to the curriculum. Throughout this work, I adopted this pro-adaptation view, viewing adaptation by the teacher as necessary to personalize lesson content to student needs. Yet, at times, the adaptations made by Mr. Johnson to create a more equitable learning environment appeared to have also countered some of the goals he helped set for the curriculum. For example, whereas in the design process Mr. Johnson advocated for inclusion of students' interests, student autonomy, and choice (as seen in the critical components), some curriculum modifications resulted in fewer opportunities for students to personalize their projects, have agency over their work, and use creativity within the curriculum in order to preference other needs or respond to in the moment factors. Due to the factors affecting the implementation, Mr. Johnson needed to make contextualized adaptations that were impossible to predict during the design phase of the process, causing a change in the methods he felt were necessary to best support his students. Therefore, it is possible that Mr. Johnson's attempts to make the curriculum more equitable actually led to less personalization. Yet, Mr. Johnson made adaptations because he felt that students would not be able to meet the original project objectives and did not want them to be given a task that would be difficult for them to accomplish, given their progress on earlier stages of the scaffolded approach. While Mr. Johnson perceived his students to need less complexity in the tasks they were completing and wanted to provide students with opportunities to feel successful, whether these adaptations were positive or not depends on the set of goals used to measure success and requires consideration of how goals changed based on factors affecting them. A blanket pro-adaptations stance might not be a beneficial means for considering adaptations to curricula. More scaffolding and support might be needed to ensure teachers can select positive adaptations and that they have ways to measure the success of adaptations as they are being made. Simultaneously, researchers need to understand the evolving goals teachers have and how this might affect the definition of success within the curriculum or specific lessons.

## Implications

To alleviate these tensions, both the researchers and teachers on design teams need to receive professional learning opportunities from the other participating designers. For researchers, this professional learning should center around learning more about the contextual constraints and norms in which the teacher operates. Receiving this professional learning from the teachers and other sources will allow researchers to support teachers as they are designing and implementing the curriculum; will help legitimize and validate the experiences of the teachers for the researchers; and will modify researcher goals to align with the constraints. For teachers, this professional learning should center on the philosophy of the curriculum or innovation, what the researcher's goals are, and the past research in which the goals are grounded. While this professional learning could take a variety of forms, it should include explicit conversations about the following: the context for which the co-design team is designing and how that context relates to present and future implementations; the critical components and curriculum goals that should not be changed; and how to align modifications to teacher and researcher curricular goals even when decisions need to be made in the moment.

Based on this work, it is recommended that teams have ongoing and explicit conversations about contexts and design goals. Within this work, our design conversations did not include explicit identification of aspects of the curriculum that should not be adapted. Co-design projects need to add conversations that purposefully identify critical components and discuss adaptations to support teachers in adapting a curriculum in a way that improves it and ensures the adaptations reflect the goals of teachers and researchers regarding the innovation. While the co-design process makes the critical components of a curriculum more explicit than a curriculum simply assigned to a teacher, these explicit conversations about the critical components need to take place during the design sessions to ensure researchers and teachers align in their identification of critical components. As Pintó (2005) highlights, within these conversations, it is important to focus not only on the critical components, but also on the rationale for them and their value.

Finally, the conversations should focus not just on meeting the initial goals of the curriculum, but also on ensuring that adaptations support student learning. Given prior research and the findings of this current research showing teachers adapt co-designed innovations whether they are designed for a small- or large-scale implementation, co-design conversations could be essential in making sure that when teachers adapt, they do so in ways that enhance the innovation. Simultaneously, the conversations should ensure that researchers understand how design goals might change based on the specific moment in which they are being made and what is happening in the classroom. This could include design goals evolving over time as the curriculum is implemented and necessitating iterations upon the co-designed curriculum based on needs identified within the implementation phase of the work.

### Limitations and Future Work

At this time, the research related to the Talking Techquity curriculum has concluded. But the limitations of the current work highlight potential avenues for new or renewed work both with the curriculum and with similar co-design opportunities regarding technological and algorithmic bias. This would be especially timely given the growing prevalence of artificial intelligence (AI) in schools and society.

This study was purposefully completed on a small scale. While this allows for the deep examination of one implementation, further research is needed to determine whether similar trends occur in other co-design teams and settings. Given that the teachers themselves think implementing the curriculum in person will be different than online, future work could examine the implementation of the Talking Techquity lessons in a face-to-face teaching setting and the adaptations made when using it in this manner. From the factor findings, it is apparent that the learning environment had a significant impact on the implementation and led to adaptations. Future work could examine whether the adaptations remain the same as the learning environment changes. Additionally, further research should examine whether there is a relationship between the adaptations and factors and the content area or technology used within the adaptations. Within this work, the implementation used an equity-focused computer science curriculum within a required enrichment class. Since the critical components of each innovation will be different, it is likely some of the adaptations will be as well.

Although students were invited to participate in the research, no parents or students completed and returned consent or assent forms to be part of this study. Only having teacher research participants limited the ability to make claims about the outcomes of this innovation implementation and prevented the inclusion of student voices regarding the implementation of the curriculum. As such, this research is focused on data collected from and with the participating teachers. Future studies should consider student outcomes when implementing the Talking Techquity curriculum and how teacher adaptations affect those student outcomes.

## Conclusion

Even when teachers are core members of the team developing an innovation through co-design, they make adaptations when implementing that innovation due to ever-evolving factors that influence their students, classrooms, and teaching. Knowing how a teacher adapts a curriculum can prevent changes to the curriculum based on their misconceptions or lack of knowledge by illuminating professional learning necessary during design sessions or professional development. The findings presented in this paper further implementation research knowledge of the adaptations teachers make when enacting an educational innovation by further considering the context of a co-designed innovation. It supports future co-design efforts with teachers by providing an understanding of the contextualized and in-the-moment adaptations necessary with a co-designed curriculum, the reasons why teachers make those adaptations, and the methods for ensuring curricular integrity while designing for teacher adaptation. Co-design of innovations is a key method for including the voices of teachers in the development of innovations they will be using, but further support is needed to ensure that as teachers make necessary adaptations to fit their contexts, they do so in ways that enhance the innovation in alignment with both teacher and researcher goals.


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All names used in this paper are pseudonyms

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## About the Author

Merijke Coenraad (mcoenraad@digitalpromise.org) is Program Director, Research-Practice Partnerships at Digital Promise. Her work focuses on the intersections of educational technology and equity, including the creation of materials, platforms, and experiences in partnership with communities, teachers, and youth through participatory design methods. Merijke has a Ph.D. in Teaching and Learning, Policy and Leadership from the University of Maryland, an M.Ed. in Curriculum and Instruction from Boston College, and a B.S. in Elementary Education and Spanish and Hispanic Studies from Creighton University. She is a former middle school teacher.