CoDesign
International Journal of CoCreation in Design and the Arts

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ncdn20

A model of programmatic co-design with teachers: five factors for success

Maren Harris, Alexandra Brasili, Karen Peterman, Ian Collins, Amy Hafford, Abby Plummer, Leslie Salter & Marci Train

To cite this article: Maren Harris, Alexandra Brasili, Karen Peterman, Ian Collins, Amy Hafford, Abby Plummer, Leslie Salter & Marci Train (04 Dec 2023): A model of programmatic co-design with teachers: five factors for success, CoDesign, DOI: 10.1080/15710882.2023.2280582

To link to this article: https://doi.org/10.1080/15710882.2023.2280582

Published online: 04 Dec 2023.

CODESIGN
https://doi.org/10.1080/15710882.2023.2280582

Taylor & Francis
Taylor & Francis Group

A model of programmatic co-design with teachers: five factors for success

Maren Harris[a], Alexandra Brasili[b], Karen Peterman[c], Ian Collins[b], Amy Hafford[d], Abby Plummer[e], Leslie Salter[f] and Marci Train[g]

[a]Research and Evaluation, Catalyst Consulting Group, Livingston, NJ, USA; [b]STEM, Maine Mathematics and Science Alliance, USA; [c]STEM Research and Evaluation, Catalyst Consulting Group, USA; [d]Elementary Education, Regional School Unit 20 Searsport Maine, USA; [e]Elementary Education, Edna Drinkwater Elementary School, Northport, NY, USA; [f]Science, Pascagoula-Gautier School District, Pascagoula, MS, USA; [g]Elementary Education, Long Island School Casco Bay Maine, USA

ABSTRACT

This paper summarises the co-design model utilised throughout 2020–2022 by WeatherBlur, a community-based citizen science project. Project leaders and teachers working in classrooms across multiple states collaborated to develop iterative instructional practices for classroom implementation and professional development to support teachers' use of the program. Participants received necessary support and training to facilitate their ongoing success as the project evolved and grew. External evaluators tracked the planning group's co-design process, collecting data on the research-practitioner partnership and the ways their input impacted the project's development over time. During the final year of the project, the planning group reflected upon their work and identified five criteria that emerged as successful elements of this co-design process. 1. Creating a culture of trust, 2. Time and patience, 3. Foundational knowledge and deconstruction for understanding, 4. Mutually beneficial collaboration, and 5. Commitment to engagement and flexibility. We present a full explanation of these five criteria, including how the WeatherBlur team developed and nurtured the associated behaviours and strategies. This set of takeaways is applicable to many contexts, and this paper provides insight for future co-design models seeking to replicate a development process that utilises collective resources and input from a range of collaborators.

ARTICLE HISTORY
Received 14 February 2023
Accepted 2 November 2023

KEYWORDS
Co-design; collaboration; research-practitioner partnership; computational thinking; WeatherBlur; MMSA

1. Introduction

This paper summarises a co-design model utilised to support a classroom- and community-based citizen science project. The model was defined broadly by drawing on Sanders and Stappers (2008), and guided by elements of design-based implementation research (DBIR). Co-design was achieved by project leaders and developers aspiring to engage teachers as experts in the development process. Though none had specific training in the design process, all were experts within their respective fields who merged their shared expertise in an iterative process.

CONTACT Maren Harris marencharris@gmail.com

In effective co-design, the lines between researcher, developer, and user are becoming increasingly blurry (Sanders and Stappers 2008). The philosophy includes an understanding that oftentimes users are the true experts because of their experience (Sleeswijk Visser et al. 2005). The users' experience matters and is an essential component of informing the design process and informing a product's ongoing development (Sanders and Stappers 2008). However, co-design appreciates the need for the 'on-the ground' experience to be balanced by other voices in the group, and incorporates the perspectives and guidance provided by the project's researchers, PIs, or management. The co-design approach intentionally values the expertise of the researchers or managers as leaders of the project. By honouring the importance of all voices, power struggles can often ensue within a co-design group, as some may view their perspective as more valuable to the end goal. Roschelle, Penuel, and Shechtman (2006) present ways to mitigate this tension. However, their findings support a perspective that the users or practitioners function as advisors who provide significant input and feedback that affect the project's development and outcomes, while the principal roles of developing, managing, and reporting for the project tend to fall within the responsibilities of the researchers.

Co-design processes and approaches complement design-based research (DBR) and DBIR, which are approaches with the intent of developing new theories, artefacts, and practices that potentially affect learning and teaching in naturalistic settings (Anderson and Shattuck 2012; Barab and Squire 2004; Brown 1992; Cobb et al. 2003; Design-Based Research Collective 2003; Penuel et al. 2015). Both research approaches take an iterative approach to education research and challenge the researcher to adapt quickly, responding to the needs and reflections of the practitioners, and adapting the research design to meet those needs while remaining true to the research questions (Anderson and Shattuck 2012).

We explore these principles further in the next section, and within the context of WeatherBlur, a community-based citizen science project that has a 14-year history of fostering science collaboration between educational researchers, teachers, and community experts. We then share results of a collaborative process that was led by an external evaluation team over a two-year period to code project artefacts and interview data to document instances of co-design and then reflect on five factors that contributed to the team's success.

1.1. The project

WeatherBlur is a program developed and run by the Maine Math and Science Alliance (MMSA). Using an online platform, it brings together students, teachers, and community experts as equals in the process of designing and creating investigations relevant to their lives and communities. Participants work together to pose research questions, share knowledge, collaboratively design scientific investigations, collect data, report findings, and create action projects.

The project has a record of generating successful outcomes for student participants and has resulted in several positive outcomes for students ages 8–14, including statistically significant improvement in both graph interpretation skills (Kermish-Allen, Peterman, and Bevc 2019; Peterman et al. 2015), and ability to understand and explain

the scientific process (Kermish-Allen, Peterman, and Bevc 2019). Students have played important roles in online discourse, brokering conversations between other platform users, and initiating online conversation (Peterman, Bevc, and Kermish-Allen 2019) and have taken concrete actions in their communities as a result of their scientific investigations (Brasili and Kermish-Allen 2020; Plummer and Van Dis 2019).

From its inception, WeatherBlur valued input from users, and relied on the expertise of practitioners to guide the development of the project. While co-design can be defined in many ways (Pedersen 2016), one consistent theme across methodological explanations is the commitment by all members of the team to participate, design, and collaborate with others who have varying perspectives and who are not typically included in the design process (Kensing and Greenbaum 2012; Sanders and Stappers 2008). As such, co-design is often described as 'for, by, and with' those who are impacted by the work (Kensing and Greenbaum 2012; Pedersen 2016). The WeatherBlur project facilitated its co-design process through advisory groups consisting of platform users who helped guide the development and iteration of the project.

This paper discusses a WeatherBlur Teacher Advisory Group (TAG) that began meeting regularly in 2020 to assist with the development of professional learning resources and materials for utilising computational thinking in the WeatherBlur project. Computational thinking (CT) is a term popularised by Jeannette Wing in 2006 and defined as the 'thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information processing agent (human or machine, or more generally, by a combination of both).' The development of professional training and supportive materials for CT was a new addition to the project, resulting from feedback and needs expressed by WeatherBlur educators, most of whom had no prior knowledge of CT and found it to be quite challenging. Educators in the WeatherBlur program had expressed a need for additional support for the data analysis portion of their investigations. They had become adept at the process of developing and carrying out scientific investigations but identified a key weakness in their skillset concerning working with and analysing the data collected by the WeatherBlur community, including their students. Integration of computational thinking and computational data analysis was a way to support the development of that skillset and integrate those concepts into other more comfortable stages of the program.

The TAG consisted of five MMSA staff and 10 self-nominated teacher leaders with experience in the program ranging from one to 10 years. Members leveraged their historical and cultural expertise to support the evolution of the project. The team met online each month to reflect on what was working and areas that needed improvement, with a constant focus on how to prepare and support teachers' lesson development. TAG members also served as mentors to help new teachers navigate the process of creating and completing new investigations. Through these efforts, the TAG collaborated to co-design instructional practices, program structure, CT modules and training, professional development, and mentor support.

The TAG was built upon an understanding that true co-design incorporates the perspectives of a variety of people who have direct interest in a specific topic or issue and join forces to achieve a collaborative design (Burkett 2012). In forming the TAG, MMSA believed in the co-design principle that diverse perspectives come together to inform, create, and refine a system, product, or impact with a shared desire to develop

a result that meets the needs of all. Their vision was for the TAG to deliberately focus on the co-design process, and not just the end goal. Using their WeatherBlur expertise, the TAG had two primary objectives. First, to facilitate new teachers' transition into the program, and second, to provide feedback related to program content. This paper was designed to focus on the processes for achieving those two goals, and the five factors that TAG members found most important to their own success with co-design.

2. Materials and methods

Data are presented first to verify instances of co-design. An external evaluation team reviewed artefacts from across a two-year period, and collected qualitative data from members of the TAG group to identify instances in which teacher input were used by the WeatherBlur team to modify the program and achieve the TAG's goals.

Artefacts included transcripts and Zoom recordings from eight monthly TAG meetings during the 2020–2021 school year, a Zoom meeting hosted in spring 2021 to solicit feedback and suggestions from TAG members about their experiences with WeatherBlur, and coding of video and audio recordings from a 2021 summer institute (SI) that provided training for both new and veteran teachers. Artefacts were coded over 18 months as they became available, and with a specific focus on the feedback and recommendations provided by TAG members. Evaluators conducted consensus coding for the videos, while interviews and other written data sets were coded and analysed in Excel and NVivo. Evaluators shared a series of reports with the WeatherBlur team across this period to guide their reflection on the TAG input that both had and had not yet resulted in changes to the program.

TAG members and the WeatherBlur team also shared their perspectives on program refinements that resulted from the co-design process. Individual interviews were conducted with six TAG teachers in late spring 2021 to solicit their feedback about the WeatherBlur project and the TAG co-design process during the 2020–2021 school year. In September 2021, evaluators led a co-interpretation session with the WeatherBlur team to reflect on whether and how they had utilised TAG feedback to revise the program.

Then, in early 2022, our author team of WeatherBlur researchers, evaluators, and TAG members came together for three hour-long meetings to develop a shared understanding of the final key takeaways from the project, with a focus on the successes of the co-design process and the TAG's influence on project end goals to date. Table 1 presents the evaluation timeline of the TAG's co-design process.

3. Results

This section shares findings from the artefact review, interviews, and co-interpretation session to demonstrate that the TAG was successful at co-designing the WeatherBlur program. Then, data from the reflection sessions are used to document the five factors that TAG members believe supported their success with the co-design process. Quotes from the TAG Interview report and the co-interpretation sessions are utilised throughout this section to articulate TAG teachers' experience with the co-design process.

Table 1.

WeatherBlur Co-Design Timeline

3.1. Evidence that co-design occurred

During the 2022 debrief sessions, one TAG member explained, 'Oftentimes, groups like the TAG team form in name, but in the end, the powers that be do what they want to do, how they want to do it'. Through the artefact review, interviews, and co-interpretation session, the evaluation team collected evidence that co-design had taken place, proving that 'the powers that be'—in this case, MMSA—had fully incorporated the TAG's input throughout the program's evolution.

The 2020–2021 artefacts and interviews yielded 15 primary categories of suggestions provided by TAG members, and a total of 35 sub-suggestions were created within these categories. For example, the primary category of 'Onboarding new teachers' included the following three sub-suggestions: 1. Teachers need hands-on experiences to do the work themselves before teaching it; 2. Training should include opportunities to hear from and share/brainstorm with other WeatherBlur teachers both past and present; and 3. Teachers may feel this is 'one more thing', so it is imperative to explain how WeatherBlur fits into what they already do.

MMSA reviewed the 35 sub-suggestions with evaluators. Through this group review and discussion, MMSA identified that nine had been resolved, and articulated the ways in which they were already addressing or planned to address 15 more. In short, during the timeframe between the spring 2021 TAG interviews and the fall 2021 co-interpretation session, the team had committed to 69% of the recommendations provided by the TAG feedback. Next, MMSA identified which remaining items were logical and feasible to focus on, thereby informing the project's future development by prioritizing which

Table 2. Programmatic impact of TAG input.

TAG Feedback	Subsequent Programmatic Changes	End Goal Addressed
Teachers need flexible timelines for project implementation.	Extended acceptable timeframes for each project phase.	1
Teachers' confusion about Computational Thinking concepts and language.	MMSA developed CT training professional development sessions.	2
Suggestions for website improvement.	Changes to website content and layout.	2
Recommendations for new teachers to collaborate with veteran teachers.	Group sharing sessions during new teacher training to facilitate collaboration.	1
Discussions of how to best utilize scientist support for project investigations.	Scientist presentations and collaborative planning sessions coordinated by MMSA during SI and school year.	2
Feedback about student challenges in specific elements of the program.	Professional development targeting these elements.	2
Feelings that teachers need to practice program activities before teaching them.	Simulated WeatherBlur activities during professional development sessions.	1
Feedback that new teachers can feel overwhelmed by the program.	New SI sessions specifically devoted to onboarding new teachers.	1

elements would continue to be critical to address, monitor, and evaluate throughout the final two years of the project.

Table 2 provides examples of how the TAG provided input into the project's development and which programmatic changes addressed each of the TAG's primary goals (1. Facilitating new teachers' transition into the program and 2. Providing feedback related to program content).

3.2. Five factors in co-design success

The reflective discussions in 2022 articulated five primary factors that enabled the TAG to work collaboratively and productively in a co-design process. They are described below, with specific examples of the process used to achieve each.

3.2.1. Creating a culture of trust

MMSA leadership's educational and teaching backgrounds enabled them to understand many of the criteria necessary for successful collaboration with TAG teachers. Two MMSA staff members were former WeatherBlur teachers who related to TAG teachers' experiences. MMSA staff acknowledged the need to work around tight school schedules, mandated learning standards, unexpected changes and challenges, and limited time and resources. To build connections, MMSA made repeated, deliberate connections with TAG teachers through check-ins, emails, and informal conversations outside of TAG meetings. MMSA maintained frequent contact with TAG teachers, offering support and asking teachers to reach out with questions at any time.

Early in the TAG, MMSA incorporated activities that allowed all TAG members to get to know each other. These icebreakers and sharing discussions built rapport and established members' roles within the project. For example, in one icebreaker, all members contributed their favourite bands to a WeatherBlur Spotify playlist. Meetings also always involved all members participating in 'CT Byte', short activities that TAG teachers could then use with their students to model CT concepts. TAG teachers explained how these

activities made them feel comfortable and valued as members of the team. In their feedback interview, one TAG teacher explained,

> We got to know the staff . . . They participated in the activities as we were learning. We met them one-on-one; we saw them on the Web. We got to know these people. So you're a lot more comfortable asking a question of somebody that you know.

The first two months of meetings were a time of building relationships and developing trust. These meetings were designed to provide initial framing for the teachers, develop group norms, and build relationships through icebreaker activities. At first, teachers listened more than they spoke. With each additional meeting, TAG members began to know and understand each other, and discussions began to flow more naturally as teachers became comfortable contributing and the meeting agendas shifted to include more time for feedback and input. Teachers noted when tasks were not clear, or when the project was too demanding of their time. Importantly, they also noticed that their ideas resulted in action by MMSA. For example, one TAG member shared,

> I was able to tell you guys that stuff, and you weren't gonna freak out or be upset about what's going on. You were going to listen. I think that's when it clicked for me.

While the TAG sometimes met as a whole group of 15, participants felt that the use of small groups (two to three teachers and one MMSA staff) was especially effective, as it allowed for relationship-building, trust, and open communication across all members. Each TAG meeting included some full group conversations and the opportunity for breakout rooms for smaller group discussion. Smaller groups also enabled all voices to be heard, and more frequently. Because TAG teachers felt more comfortable in a smaller group setting, they began to admit their own discomfort with the scientific processes they were being asked to utilise, and expressed their fears related to a range of issues.

3.2.2. Time and patience

A critical component to the group's success was TAG teachers' willingness to be patient with each other and the program staff until enough time elapsed to solidify a common understanding of new practices and ideas. Since MMSA staff and TAG teachers all had the same goal of improving teachers' program experience, they were willing to revisit ideas multiple times, have lengthy conversations, and dedicate necessary time to resolve issues and push the project forward. This format enabled teachers to wrestle with new concepts collaboratively and repeatedly across many sessions as they came to develop comfort and confidence with new knowledge. For example, CT content was revisited during at least five meetings, and revisions to the online platform were an ongoing topic of conversation.

Understanding the need for patience as members developed comfort with both the project and meeting norms at different rates, meetings allocated extended time and repeated exposure for participants to practice new skills and embrace new ideas. For example, 'CT Bytes' sessions contributed to developing skills and confidence in CT concepts. Repeated exposure to these concepts through a hands-on activity, followed by discussions of how it demonstrates a particular aspect of CT, provided space for teachers to become comfortable with these ideas. Meetings followed the same format,

with an initial meeting framing, icebreaker, or hands-on activity; small group discussions; and full group debrief and reflections.

3.2.3. Foundational knowledge and deconstruction for understanding

Many WeatherBlur refinements related to both end goals were based on TAG members embracing and sharing their struggles in the classroom. MMSA staff then worked with the TAG to create new training in CT, model example student activities, discuss resources about professional learning design, and provide support for content challenges.

Two particular challenges were the emphasis on the use of the scientific method at the elementary school level, and understanding the project's CT principles. TAG teachers were vocal about their struggles and advocated for opportunities to engage with these concepts prior to implementation. As one explained,

> It was our feedback saying, '[new teachers] need more practice with this. We feel confident with that, but they're just coming new on this and they need it'. It was really listened to by the [MMSA] team: 'Hey, maybe we need a training on this.

Then, acknowledging the need to break down new content and practices into smaller, simpler chunks, MMSA devoted time to scaffolded introduction of program-related content and pedagogy using articulated thought processes and collaboration techniques. When reflecting on how their comments affected support for the program's content, TAG teachers acknowledged MMSA's commitment to addressing classroom-based needs. One teacher articulated that,

> There is a comfort in that . . . realizing that if we say we need help we get it. There's follow through. I think there's something to that.

TAG teachers also appreciated the ways that MMSA staff were honest with them regarding the difficult nature of some of the new concepts.

> From the very beginning the WeatherBlur crew had been really open about the fact that computational thinking is confusing. A lot of people don't necessarily know what it means and [MMSA] were very forthright with saying, 'This might take time and this is why we're gonna go through all the steps'. And so [they] built that environment, that it's okay if not everybody understands . . . It just fostered an environment for us that it was okay if we were one of the people that felt like we weren't sure about this.

Checking for understanding, asking for members' questions, and providing necessary clarifications were all standard practices within TAG meetings. As TAG teachers came to rely on that support, they were more likely to try new things in their classrooms that could be shared back to the TAG and then scaled up for all WeatherBlur teachers.

3.2.4. Mutually beneficial collaboration

By focusing on the project as a whole, the TAG appreciated the importance of fostering collaborations that would result in positive outcomes for all members of the working group. As a result, MMSA staff learned from the honest reflections on the program by experienced teachers who hoped to make it as accessible and useful to teachers as possible. Program staff also received help with curriculum development from TAG

teachers who could immediately implement those changes in their classrooms and provide real-time feedback.

Engaging in this iterative cycle of sharing, brainstorming, implementing, and debriefing within the TAG continually enhanced the program, while simultaneously benefitting the TAG teachers by offering feedback that could make the program fit their classroom needs as much as possible. Furthermore, the teachers were learning skills and content that developed their overall understanding of the scientific method, CT, and other science-based practices that were applicable beyond WeatherBlur.

An important distinction about the collaborative impact of this co-design process was that the focus on people working together caused members to feel valued in the work. The collaboration and the resulting positive feelings stood out as two key successful elements of the project's co-design structure. The inputs and outputs were not always equally reciprocal for everyone, but all members experienced moments of give and take, which resulted in all members feeling important. In this way, mutual benefit was defined as finding similar amounts of value from the experience rather than by identical participation. One TAG member explained,

> You should have that collaboration of, 'Oh, but I also have these resources here and you also have this, and have you ever thought of that? And maybe you could do this', And then you end up in a whole different direction, which is where the greatness comes in.

The TAG co-design model took a deliberately horizontal approach, in which team members worked side by side. Breakout small group discussions involved both teachers and MMSA staff members as thought partners. While the agendas were structured by MMSA, there was always time and flexibility built in for any TAG member to address issues they felt were important. TAG teachers were also invited to lead sections of the monthly meetings to share power across the group. A key component of the project's success was leveraging the knowledge and skills of all contributors throughout the collaborative process. Group members valued the input from a range of perspectives, which allowed for a broader understanding of the project's implementation, impact, and potential. Through embracing multiple lenses, they were able to have a broader view of the project overall, which resulted in improvements for everyone's individual experience with the project.

3.2.5. Commitment to engagement and flexibility

The success of the TAG depended upon all members' willingness to adapt and change, both logistically and behaviourally, to remain focused on its end goals. TAG meetings did not follow a strict protocol. Rather, TAG conversations focused on the timely needs of the group and project. As issues arose, the group abandoned or modified older practices, then collaborated and acquired feedback using new and varied tools such as Jamboard, Padlet, and Slido.

Before each TAG meeting, MMSA developed a plan and structure, however these plans were not rigid, and accommodated TAG members' input. TAG members understood that while MMSA had an idea of where a meeting or project was going, teachers' different interpretations and experiences often meant discussions would change direction. Even within a meeting, TAG teachers could say, 'That's not what we need right now', and the meeting's focus would pivot. In this way, the TAG demonstrated that it was

important to have a direction for the group pre-planned by MMSA, but it was also acceptable to veer off course, especially when that honoured the real and timely needs of the program. This required flexibility on the part of MMSA to realise that as the teachers were implementing the project and reflecting upon the experiences in their classrooms, project staff needed to be open to new ideas and willing to follow alternative paths. Breakout small group discussions involved both teachers and MMSA staff.

Data from the interview report indicated that TAG teachers felt more comfortable openly sharing their ideas because they knew that the program plan would change to accommodate their needs. In their interviews, TAG teachers discussed the group's flexibility:

> [MMSA leader] had our roadmap that we were supposed to be following. However, we decided to take several different side streets and go up the hill and go investigate whatever, wherever we went. She was open to that because it led to a better product in the end.

> We can engage in ways that we interpreted, and follow whatever path we went down as a group, and that was okay. And that I think opens the door for a lot more collaboration and a lot more willingness to jump in . . . I think that flexibility and trusting in the process goes a long way in creating that culture and also opening to more innovation.

Flexibility around logistics and meeting times was also a necessity. Because the TAG involved teachers, this meant there was unpredictability around schedules and time. Members embraced different meeting styles, times, and formats, understanding that there would not be a'one-size fits all' approach. Some meetings were entirely synchronous, mixing small group and whole group discussions, while other meetings broke off early for asynchronous work. The group had a collective understanding that members of the group would follow through on their responsibilities both during and outside of meeting times. One TAG teacher explained:

> I think the frequency of meetings and people just showing up for those meetings goes a long way in establishing a rapport and a culture where people feel willing to share because they know that the people involved with [it] are dependable and in it as well. And so there's some sort of accountability and commitment sharing there that I think allows people to engage in a more authentic way.

Because the TAG meetings included communication from all members, everyone's opinion was valued, regardless of their status. This non-hierarchical approach meant that members' time together centred on connection that felt meaningful and supportive. As a result, members were willing to coordinate their schedules and task completion based upon what worked best for the group, and members understood and agreed that their TAG tasks would be completed on time.

3.3. Challenges

While the TAG approach and the project itself were successful overall, we must also acknowledge that there were challenges along the way. First, as stated earlier, the work required significant time and dedication on the part of the TAG teachers, who had to learn new CT content and modify their teaching schedules to accommodate this additional program. In turn, MMSA staff devoted significant time and resources to

supporting teachers. While being readily available for support was a primary factor in the successful implementation of the program, it required MMSA staff to answer frequent emails, phone calls, and make classroom visits. This devotion to WeatherBlur was difficult to balance alongside the organisation's other endeavours and priorities. Second, technology presented additional challenges for both teachers and MMSA, as the project revolved around the use of a web-based platform. Users had to learn how to interface with the website, and required ongoing training as the site changed and evolved to meet the needs of the growing project.

Challenges also existed with the co-design process itself. The success of the TAG required a group of teachers who would be vulnerable, speak truthfully about their own challenges, and ask for help. They needed to be assertive enough to both advocate for necessary changes and propose solutions. It took time to establish these relationships among TAG members and MMSA. At first, many were reluctant to talk or to speak honestly. In order to build their confidence and willingness to participate, TAG meetings needed to be carefully structured to accommodate time to hear all perspectives and allow all members to speak. Allocating this time meant carefully managing the content and objectives for each session, which was often a challenge given the large scope of topics slated for discussion.

Finally, while the monthly meeting approach proved to be the most ideal option overall, there were tradeoffs in that format. Meetings afterschool were sometimes difficult for exhausted teachers. Although they wanted to contribute meaningfully, they often did not have the energy to do so. As one TAG teacher explained,

> After school is just so hard for people . . . You know we love one another, but there's also other things that are going on in our classrooms that we're always thinking about . . . as teachers, you know, they have kids, they have practices, they have all these things going on . . . To go on like that, just getting into dinner time for people or what they need to do, and it's just too long.

To avoid the after-school fatigue, MMSA attempted other formats for professional development, including a weekend retreat. Although it generated substantial input and feedback, it was time-consuming and stressful for some teachers who then entered the next school week feeling tired and not well-prepared as they had not had adequate time to construct lesson plans for the week and had not been able to address personal and family needs at home during the weekend. This feedback was valuable to MMSA staff for how to consider professional development approaches not only for WeatherBlur, but also for other projects. Teacher feedback from this project will be an informative factor in when and how to structure training sessions in the future in ways that create the least amount of disruption and stress.

4. Discussion

As the project drew to a close, the evaluation team conducted reflective sessions with the TAG, during which the TAG articulated how the lessons learned from the WeatherBlur co-design process were, in actuality, not unique to the project. While we have presented the five factors of successful co-design in the context of WeatherBlur as an educational research project, these factors are not specific to our project. Rather, they highlight and

expand on existing research about the co-design process, which we believe enables them to be applied across a range of contexts.

The literature describes the principles of co-design as 'inclusive, respectful, participative, iterative, and outcomes focused' (NCOSS 2017). Our first factor, *Creating a culture of trust*, emphasised that positive outcomes can occur when members with varied perspectives and responsibilities develop rapport early in the co-design process. Their familiarity and comfort enabled members to feel respected and valued and, thus, willing to speak honestly about the program's successes and needs for improvement. TAG members participated in a form of constructionist co-design similar to one used by teachers, in that they feel empowered to make meaningful change (Kelter et al. 2021). TAG members were encouraged to share and contribute their individual expertise based on their unique classroom contexts and experiences in a collaborative learning space. When participants feel ownership and agency, they are more likely to stay focused on the task and contribute meaningful, thoughtful discourse (Kyza, Eleni, and Nicolaidou 2017; Penuel et al. 2007; Voogt et al. 2015).

As the TAG worked together in a design process—continually brainstorming, creating, testing, and refining its work as it connected back to the two TAG goals—the second factor, *Time and patience*, demonstrated the principle of a 'commitment to collaborative, iterative design', as defined by Penuel (2019). MMSA's repeated willingness to modify the program based on TAG input supports the belief that co-design is a continually evolving iterative process, based upon the needs, feedback, and analysis of all members of the co-design group (Severance et al. 2016), and takes this belief one step further by incorporating the logistical component of time and the emotional component of patience into the requirements for successful collaborative iteration.

Our work also takes sociocultural learning theory and demonstrates how to apply it to a co-design context. Sociocultural learning theory moves away from learning as an individual enterprise and instead prioritises the co-construction of knowledge through social processes (Tobin 2015). When projects take this approach, they benefit from local social and historical contexts to make their goals and activities relevant to the learner and their community. Our third factor, *Foundational knowledge and deconstruction for understanding*, highlights the way that, within a co-design setting, adult professionals can push one another's perspectives and develop new ways of thinking by listening to the input from colleagues who bring different backgrounds and expertise. This work also supports the second principle of a 'commitment to collaborative, iterative design', as defined by Penuel (2019). Through working together in a design process that is continually brainstorming, creating, testing, and refining its work as it connects back to shared goals, the process is truly collaborative on the part of all team members (Burkett 2012). In developing WeatherBlur together, MMSA staff learned what the project needed, and TAG teachers learned content which enabled them to lead the project more effectively.

The impact of the fourth factor, *Mutually beneficial collaboration* was evident in the TAG group dynamic. By focusing on collaboration rather than negotiation, the team developed a more robust and effective project for MMSA while also creating a better classroom experience for TAG teachers. MMSA leadership ensured that the group maintained a clear focus on the project goals and concurrently supported the TAG in their work to revise and improve the project. The resulting programmatic changes

supported and enhanced MMSA's initial goals, and enabled teachers to have a more successful classroom experience. So, while some studies explain that researchers can often be the ones to lose their footing by conceding power and decision making to other stakeholders within the co-design group (Balka 2006; Markussen 1994; Shapiro 2005), our project had the opposite experience. The combined efforts of researchers and teachers resulted in successes for both groups.

Our final factor, *Commitment to engagement and flexibility*, adds further nuance to the known ambiguity that is inherent in co-design (Penuel et al., 2007). This ambiguity is intentional, as co-design is meant to let the participants determine the goals and develop the outcomes. To fully engage in co-design, members must understand and commit to change. The early stages of the process are not outcome-based or tied to specific solutions. Rather, the co-design team begins with identifying their common values and goals for the project. Next, the team works together to develop and test their ideas. These phases result in an iterative process that continually refines the project (NCOSS 2017). Co-design is similar to DBIR in that both processes rely on continual reflection, testing, and revisions, thereby creating an iterative process (Fishman et al. 2013). However, co-design does not require an association with a research partnership, which means that in a co-design project the end goal is not as well articulated and, sometimes, unclear. This ambiguity is intentional, as co-design is intended to let the participants determine the goals and develop the outcomes (Penuel et al. 2007). In doing the work with an open-ended approach, the entire process itself is also iterative in that it is continually evolving based upon the needs, feedback, and analysis of all members (Severance et al. 2016). TAG members' willingness to embrace uncertainty and adapt to change while staying focused on required tasks demonstrated that co-design's ambiguity can be an asset and lead to progress through successive change.

As our project demonstrated, a collaborative design process requires the inclusion of various perspectives and effective models for facilitating the processes and accountability structures to evaluate whether and how the co-design process is occurring. MMSA understood this principle from the beginning, and utilised external evaluators from the beginning to ensure that the TAG functioned as a group of equals by conducting consistent monitoring and maintaining a cyclical feedback loop that kept all participants informed.

In developing the TAG, MMSA was guided by the philosophy that a successful co-design process does not simply mean giving people a seat at the table and accommodating equal participation. Careful consideration must be made to acknowledge and work through power dynamics, relationships, differing professional practices, and varying objectives among participating individuals who will come from a variety of backgrounds and experiences. This vision was articulated clearly and frequently throughout the project, in a deliberate attempt to emphasise the importance of collaboration through equal participation.

WeatherBlur's horizontal approach intentionally merged top-down and bottom-up input to incorporate both experience and evidence into the design process (Austin, Van Dijk, and Drossaert 2020). The lack of hierarchy may have been instrumental in preventing the power struggles, competition, or aggression that often exists in co-design scenarios. During the course of the TAG, no members quit, meetings were generally conflict-free, and members maintained cooperative,

positive attitudes. While our lack of conflict may have been due to the lucky composition of even-tempered, flexible, and willing participants, we suggest that the norms within the group contributed greatly to the peaceful, productive dynamic. While other studies have shown this empowerment to be imbalanced, with priority in power and decision-making allocated to the researchers (Pedersen 2016), this project maintained a determined focus on equitable power and results that would affect all members of the co-design team in their own application of the product.

The results of the TAG co-design process addressed both of the TAG's initial goals. Teachers' feedback and MMSA's response resulted in changes to how new teachers joined the program, and also led to substantial revisions to both the program's design and classroom-based interventions. Additionally, this manuscript is an unexpected outcome of the TAG's collaboration, as it includes contributions from two MMSA staff members and four TAG teachers. We hope that our focus on the five factors that were integral to our process will provide concrete examples of how other organisations and researchers can work with field-based professionals to co-design meaningful learning experiences.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The work was supported by the National Science Foundation [1933491].

ORCID

Karen Peterman http://orcid.org/0000-0003-4388-9412

References

Anderson, T., and J. Shattuck. 2012. "Design-Based Research: A Decade of Progress in Education Research?" *Educational Researcher* 41 (1): 16–25. https://doi.org/10.3102/0013189X11428813.

Austin, J., J. Van Dijk, and C. Drossaert 2020. "When Theory Meets Users in Co-Design: Four Strategies Towards Synergy Between Bottom-Up and Top-Down Input." In *Synergy-DRS International Conference 2020*, edited by S. Boess, M. Cheung, and R. Cain, August 11–14. https://doi.org/10.21606/drs.2020.152.

Balka, E. 2006. "Inside the Belly of the Beast: The Challenges and Successes of a Reformist Participatory Agenda." In *Proceedings of the Ninth Conference on Participatory Design: Expanding Boundaries in Design- Volume 1(PDC 2006)*, 134–143. New York: Association for Computing Machinery.

Barab, S., and K. Squire. 2004. "Design-Based Research: Putting a Stake in the Ground." *Journal of the Learning Sciences* 13 (1): 1–14. https://doi.org/10.1207/s15327809jls1301_1.

Brasili, A., and R. Kermish-Allen. 2020. "Connecting Learning Through Citizen Science in the Classroom, Community, and Online." *Connected Science Learning* 2 (2). https://www.nsta.org/connected-science-learning/connected-science-learning-april-june-2020/connecting-learning-through .

Brown, A. L. 1992. "Design Experiments: Theoretical and Methodological Challenges in Creating Complex Interventions in Classroom Settings." *Journal of the Learning Sciences* 2 (2): 141–178. https://doi.org/10.1207/s15327809jls0202_2.

Burkett, I. 2012. "An Introduction to Co-Design." Knode. Accessed July 28, 2022. https://www.yacwa.org.au/wp-content/uploads/2016/09/An-Introduction-to-Co-Design-by-IngridBurkett.pdf.

Cobb, P., J. Confrey, A. A. diSessa, R. Lehrer, and L. Schauble. 2003. "Design Experiments in Educational Research." *Educational Researcher* 32 (1): 9–13. https://doi.org/10.3102/0013189X032001009.

Design-Based Research Collective. 2003. "Design-Based Research: An Emerging Paradigm for Educational Inquiry." *Educational Researcher* 32 (1): 5–8.

Fishman, B. J., W. R. Penuel, A.-R. Allen, B. H. Cheng, and N. Sabelli. 2013. "Design-Based Implementation Research: An Emerging Model for Transforming the Relationship of Research and Practice." *Teachers College Record* 115 (14): 136–156. https://doi.org/10.1177/016146811311501415.

Kelter, J., A. Peel, C. Bain, G. Anton, S. Dabholkar, M. S. Horn, and U. Wilensky. 2021. "Constructionist Co-Design: A Dual Approach to Curriculum and Professional Development." *British Journal of Educational Technology* 52 (3): 1043–1059. https://doi.org/10.1111/bjet.13084.

Kensing, F., and J. Greenbaum. 2012. "Heritage: Having a Say." In *Routledge International Handbook of Participatory Design*, edited by J. Simonsen and T. Robertson, 21–36. New York: Routledge.

Kermish-Allen, R., K. Peterman, and C. Bevc. 2019. "The Utility of Citizen Science Projects in K-5 Schools: Measures of Community Engagement and Student Impacts." *Cultural Studies of Science Education* 14 (3): 627–641. https://doi.org/10.1007/s11422-017-9830-4.

Kyza Eleni, A., and I. Nicolaidou. 2017. "Co-Designing Reform-Based Online Inquiry Learning Environments as a Situated Approach to Teachers' Professional Development." *CoDesign* 13 (4): 261–286. https://doi.org/10.1080/15710882.2016.1209528.

Markussen, R. 1994. "Constructing Easiness—Historical Perspectives on Work, Computerization, and Women." *The Sociological Review* 42 (1_suppl): 158–180. https://doi.org/10.1111/j.1467-954X.1994.tb03415.x.

NCOSS. 2017. Accessed July 29, 2022. https://www.ncoss.org.au/wp-content/uploads/2017/06/Codesign-principles.pdf .

Pedersen, J. 2016. "War and Peace in Codesign." *CoDesign* 12 (3): 171–184. https://doi.org/10.1080/15710882.2015.1112813.

Penuel, W. R. 2019. "Co-Design as Infrastructuring with Attention to Power: Building Collective Capacity for Equitable Teaching and Learning Through Design-Based Implementation Research." In *Collaborative Curriculum Design for Sustainable Innovation and Teacher Learning*, edited by J. Pieters, J. Voogt, and N. Pareja Roblin. Cham: Springer. https://doi.org/10.1007/978-3-030-20062-6_21.

Penuel, W. R., A.-R. Allen, C. E. Coburn, and C. Farrell. 2015. "Conceptualizing Research–Practice Partnerships as Joint Work at Boundaries." *Journal of Education for Students Placed at Risk (JESPAR)* 20 (1–2): 182–197. https://doi.org/10.1080/10824669.2014.988334.

Penuel, W. R., B. J. Fishman, R. Yamaguchi, and L. P. Gallagher. 2007. "What Makes Professional Development Effective? Strategies That Foster Curriculum Implementation." *American Educational Research Journal* 44 (4): 921–958. https://doi.org/10.3102/0002831207308221.

Peterman, K., C. Bevc, and R. Kermish-Allen. 2019. "Turning the King Tide: Understanding Dialogue and Principal Drivers in an Online Co-Created Investigation." *Citizen Science: Theory and Practice* 4 (1). https://doi.org/10.5334/cstp.189.

Peterman, K., K. A. Cranston, M. Pryor, and R. Kermish-Allen. 2015. "Measuring Primary Students' Graph Interpretation Skills via a Performance Assessment: A Case Study in Instrument Development." *International Journal of Science Education* 37 (17): 2787–2808. https://doi.org/10.1080/09500693.2015.1105399.

Plummer, A., and J. Van Dis. 2019. "Student-driven Citizen Science." *Science Scope* 43 (3): 65–74. https://doi.org/10.2505/4/ss19_043_03_65.

Roschelle, J., W. Penuel, and N. Shechtman 2006. "Co-Design of Innovations with Teachers: Definition and Dynamics." In *The International Conference of the Learning Sciences: Indiana University 2006. Proceedings of ICLS 2006*, edited by S. A. Barab, K. E. Hay, and D. T. Hickey, Vol. 2, 606–612. Bloomington, Indiana: International Society of the Learning Sciences.

Sanders, E. B.-N., and P. J. Stappers. 2008. "Co-Creation and the New Landscapes of Design." *CoDesign* 4 (1): 5–18. https://doi.org/10.1080/15710880701875068.

Severance, S., W. R. Penuel, T. Sumner, and H. Leary. 2016. "Organizing for Teacher Agency in Curricular Co-Design." *Journal of the Learning Sciences* 25 (4): 531–564. https://doi.org/10.1080/10508406.2016.1207541.

Shapiro, D. 2005. "Participatory Design: The Will to Succeed." In *Proc. Forth Decennial Aarhus Conference, Critical Computing- Between Sense and Sensibility*, edited by, O. W. Bertelsen, N. O. Bouvin, P. G. Krough, and M. Kyng, 29–38. New York: ACM Press.

Sleeswijk Visser, F., P. J. Stappers, R. van der Lugt, and E. B.-N. Sanders. 2005. "Contextmapping: Experiences From Practice." *CoDesign* 1 (2): 119–149. https://doi.org/10.1080/15710880500135987.

Tobin, K. 2015. "The Sociocultural Turn in Science Education and Its Transformative Potential." In *Sociocultural Studies and Implications for Science Education. Cultural Studies of Science Education*, edited by C. Milne, K. Tobin, and D. DeGennaro, Vol. 12, 3–31. Dordrecht: Springer.

Voogt, J., P. Fisser, J. Good, P. Mishra, and A. Yadav. 2015. "Computational Thinking in Compulsory Education: Towards an Agenda for Research and Practice." *Education and Information Technologies* 20 (4): 715–728. https://doi.org/10.1007/s10639-015-9412-6.

Wing, J. 2006. "Computational Thinking." *Communications of the ACM* 49 (3): 33–35. https://doi.org/10.1145/1118178.1118215.