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A Research Brief from STELAR

Co-designing STEM Innovations in the NSF ITEST Program

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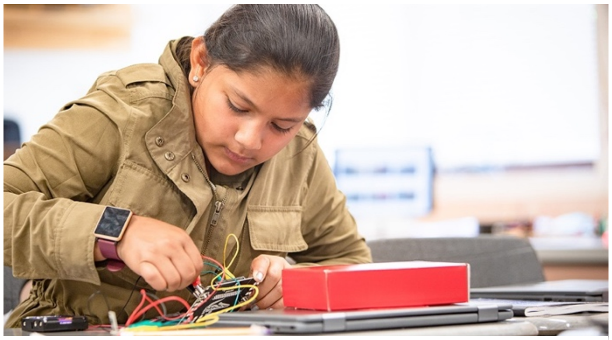
Introduction

Partnerships play an important role in integrating technology into pre-K–12 science, technology, engineering, and mathematics (STEM) education. For more than 20 years, the National Science Foundation's (NSF) **Innovative Technology Experiences for Students and Teachers** (ITEST) program has funded projects that forge partnerships with school districts, colleges and universities, business and industry, and nonprofit organizations. These strategic relationships strengthen the capacity of formal and informal learning institutions to provide technology-rich STEM learning experiences and prepare youth for the rapidly changing, technology-driven workforce. Through their collaborative work, ITEST partners support students' acquisition of foundational STEM knowledge, skills, and dispositions and broaden participation in STEM learning. Increasingly, ITEST projects are adopting **co-design,** a collaborative approach that brings educators, community members, STEM professionals, and youth together with researchers and developers to design and develop educational innovations.

Co-design is a highly facilitated, team-based process that actively involves diverse stakeholders in the design, prototyping, and evaluation of technology-based tools, curricula, and other solutions that address specific challenges or goals (Penuel et al., 2007; Roschelle et al., 2006). Drawing on participatory design principles, co-design aims to democratize innovation, ensuring that those who use and will be affected by technologies play a critical role in their design, and emphasizing understanding of practice and the everyday contexts in which technologies are used (Penuel, 2019; Robertson & Simonsen, 2013; Sanders & Stappers, 2008).



A student wires a programmable sensor technology (micro:bit) at a summer camp experience part of the STEM Career Connections project. Credit: University Corporation for Atmospheric Research (UCAR) and University of Colorado Boulder

The co-design approach, influenced by user-centered and learner-centered design traditions, recognizes and builds on the knowledge and expertise of end-users to create more useful, usable solutions that are responsive to their needs and concerns (Durall et al., 2019; Penuel et al., 2007). Further, through shared experimentation and reflection, co-design creates opportunities for mutual learning among all participants (Bang & Vossoughi, 2016; Durall et al., 2019; Goldman et al., 2019; Robertson & Simonsen, 2013; Sanders & Stappers, 2008).

Co-design's growing prominence was evident at the 2024 NSF ITEST Principal Investigators Meeting, where project leaders and partners highlighted the value of co-design in bridging STEM learning innovations with the communities they are designed to serve and raised questions about how to co-design effectively. In response, the STEM Learning and Research (STELAR) Center has prepared this research brief to synthesize how current and recently funded ITEST projects are using co-design and to share research-informed insights that could inform future work across the ITEST program.

To identify ITEST projects using co-design, the STELAR team searched the [NSF Public Access Repository]() for mentions of "co-design" in abstracts of journal articles and conference papers authored by researchers from active or recently expired ITEST projects. This search yielded 15 articles. The team then created summary tables by extracting key information on study characteristics and outcomes. After reviewing the tables, the team narrowed their selection to articles and papers that described co-design in greater depth. They then compared the studies to identify similarities, differences, and cross-cutting themes related to projects' use of co-design, the role of co-design participants, challenges encountered, and insights gained through research. Page 10 provides more information about the nine ITEST projects referenced in this brief.

How are ITEST projects using co-design in their research and development?

This section describes the ITEST projects included in this brief, including the settings in which co-design was used and who was included in the process.

Project leaders and participants leveraged the co-design process to create curricula, learning activities, instructional practices, and professional development (PD) resources, all aimed at fostering STEM concepts, awareness of and interest in STEM careers among youth. The participants involved in co-design varied widely across projects and included teachers, afterschool educators, community members, technology experts, and youth. Broadly, the co-design projects took place in (1) traditional classroom settings and (2) out-of-school or community settings such as museums, afterschool programs, and a citizen science initiative. Their innovative work integrates technologies such as robotics, artificial intelligence (AI), radio frequency technologies, virtual reality (VR), and augmented reality (AR) into STEM education. Table 1 lists the projects, their co-design focus, and the articles and papers in which they are featured.

Table 1 provides an overview of the ITEST project papers and co-design focus.

Table 1. ITEST Projects: Settings, participants, and focus of co-design

Projects in traditional classroom settings Co-design participants included teachers, teacher leaders, administrators, curriculum and professional development specialists, youth, evaluators, and researchers.	
ITEST Project (citation)	**Co-design focus**
AI Educator Make-a-Thon (DiPaola et al., 2023)	Professional development event for middle school teachers to co-design an AI curriculum
AI for Georgia (AI4GA) (Gelder et al., 2025)	Design and implementation of a nine-week AI elective course for middle school students
Birds and Bots: B-Squared (Lyublinskaya et al., 2024)	Development of robot-coding mathematics curricular activities for elementary school students that integrate culturally relevant mathematics pedagogy
Chicago Geospatial Semester Project (James et al., 2020)	Design and implementation of GIS-infused lessons and content for high school career and technical education (CTE) courses
Computer Science (CS) Frontiers (Grover et al., 2020)	Development of lesson plans for a high school computer science curricular module
WeatherBlur (Harris et al., 2023)	Development of professional learning resources and materials for utilizing computational thinking in a community-based citizen science project
Projects in out-of-school/community settings Co-design participants included afterschool educators, college and career counselors, community members, community college staff, school district administrators, STEM professionals (mentors), technology specialists, youth, evaluators, and researchers.	
ITEST Project (citation)	**Co-design focus**
Making Waves with Radio (Dixon et al., 2022)	Development of resources for educational programming on radio frequency technologies
Native American Middle-School Students Afterschool STEM (NAMSAS) (Chandrasekera et al., 2022)	Modification of STEM learning activities for tribal cultures and afterschool settings using immersive technology and spatial design
STEM Career Connections (STEMCC) (Bhaduri et al., 2022)	Development of STEM learning experiences and STEM career pathways for middle school youth in rural communities (for in-school and out-of-school settings)

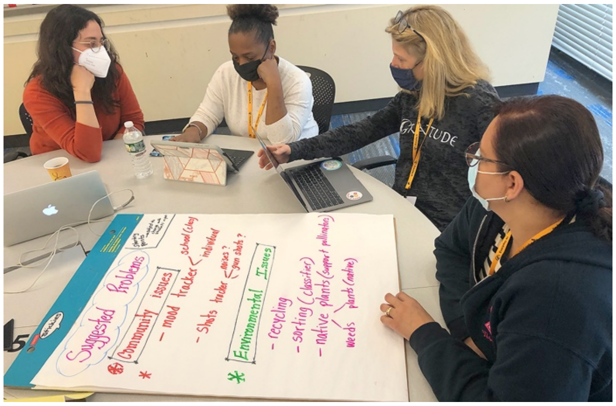
What did ITEST projects learn from their use of co-design?

In this section, we share several themes that emerged from our review and provide examples that offer valuable insights into what ITEST projects have learned through their use of co-design.

1. Lay a strong foundation of community building and collaboration for co-design. Providing time for early-stage community building helped participants develop a sense of belonging and trust in the time leading up to and during the co-design process. Assuming the role of designer was both novel and unfamiliar to participants. Allocating time for co-design participants to develop rapport with researchers, developers, and one another was a key building block for many projects.

Example 1. To lay relational groundwork for co-design, the **WeatherBlur** project emphasized the importance of creating a culture of trust early in the process (Harris et al., 2023). In addition to monthly full-group meetings, the Maine Mathematics and Science Alliance (MMSA) met in small groups with the Teacher Advisory Group (TAG) teachers to provide initial framing, build relationships, clarify roles, and develop group norms. Frequent connections outside of TAG meetings, such as through check-ins, emails, and informal conversations, were also effective in opening lines of communication and helping teachers feel comfortable sharing their ideas.

Example 2. The **AI Educator Make-a-Thon** was the culmination of a yearlong professional learning program, Everyday AI, in which middle school teachers studied AI technologies with AI experts, co-taught lessons from the *Developing AI Literacy* (DAILy) curriculum in a virtual summer camp, and discussed AI and DAILy activities in monthly webinars with AI facilitators (DiPaoloa et al., 2023). These shared experiences, and the teacher community of practice that had been cultivated over the past year, supported their collaborative work at the Make-a-Thon, where teachers and AI practitioner mentors co-designed solutions to the challenges they



A group of educators at the AI Educator Make-a-Thon brainstorm problems for their students to address in a project-based AI literacy lesson. Credit: Kate Moore, MIT

encountered while teaching DAILy.

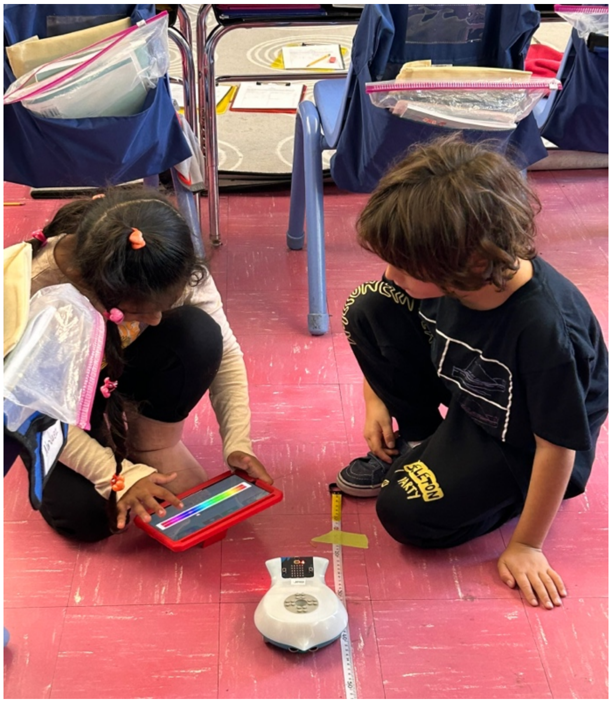
2. Establish shared goals and values early in the project. Establishing common goals and values early in the program helps to anchor both the design and development of technology innovations and the collaborative work with partners. Setting shared goals that are both achievable and relevant during the ideation stage of a project can foster greater trust and commitment among co-design participants.

Example 1. The **Making Waves with Radio** project established a set of values for learning about radio frequency (RF) technologies to guide the design of educational resources for science centers and museums (Dixon et al., 2022). In early-stage workshops with informal science educators, community partners, and youth, researchers utilized participatory design methods, including value sensitive design and strategies from CS4All's research-practice partnerships (RPP), to understand the values they considered important for RF education and their experiences and perspectives on RF technologies. The values that emerged from these workshops formed a *values foundation* to ground the project's subsequent design processes and ensure RF learning experiences would be designed for more equitable participation throughout all phases of the project.

Example 2. The **STEM Career Connections (STEMCC)** project found that achieving a shared set of goals can set the stage for a more collaborative partnership. The project engaged community members and organizations in co-designing local STEM career pathways for rural youth (Bhaduri et al., 2022). Identifying each partner's objectives and shared interests allowed STEMCC to foster connections and pursue goals that were achievable and relevant. In the project's first year, the planning and implementation of a weeklong STEM summer camp helped partners and stakeholders experience the value of providing technology-rich STEM programming for youth in the community, such as using programmable sensor systems (Data and Sensor Hub) to address locally relevant challenges like wildfires.

3. Build in time and support for participants to gain knowledge, skills, and experience with technology-based activities.
Professional development plays a vital role in co-design. Projects provided time and support for educators to (1) develop content knowledge, technical skills, and confidence with the technological tool or innovation and (2) gain experience using the technology or learning activities with students. During co-design sessions, educators could draw on these experiences and their expertise to design activities and modify or adapt curricula to meet their students' needs.

Example 1. Co-design was the center of a yearlong teacher PD program in which elementary teachers and researchers designed culturally relevant robot-coding activities for the supplemental mathematics curriculum **Birds and Bots: B-squared** (Lyublinskaya et al., 2024). An initial summer retreat introduced teachers to robot coding and culturally relevant mathematics pedagogy (CRMP), followed by workshops during the school year in which teachers and researchers explored ways to integrate CRMP and robot coding in the standards-based mathematics curriculum and co-designed lesson activities. Researchers found that with time and support, teachers showed a deeper understanding of their students' cultures and greater agency and ability to utilize robot coding to teach mathematical concepts.



Two students explore measurements on the number line using the Finch robot. Credit: Irina Lyublinskaya, Teachers College, Columbia University

Example 2. In the **Computer Science (CS) Frontiers** project, high school teachers participated in an online synchronous PD and curriculum co-design of the CS Frontiers Distributed Computing (DC) module over three weeks (Grover et al., 2020). In Week 1, teachers received training on DC and the module's Netsblox programming environment. In Week 2, they collaboratively co-taught summer camp students, piloting the initial DC curricular materials. In Week 3, teachers piloted the co-designed curricular refinements and lesson plans for the DC module. Teachers' experiences in teaching students, particularly around a new topic such as DC, played a key role in the PD program's success.

4. Ensure co-design taps into participants' expertise and backgrounds.

Projects built upon participants' knowledge, practices, and experiences by inviting them to share their expertise and integrating their knowledge, values, and local perspectives into the design of innovations.

Example 1. In the **Native American Middle-School Students Afterschool STEM (NAMSAS)** program, researchers highlighted the importance of building relationships with cultural knowledge bearers and integrating cultural activities into STEM programming (Chandrasekera et al., 2022). NAMSAS engaged afterschool educators from three tribal nations to co-design culturally responsive, experiential learning activities relevant to Native American youth. This co-design process identified cultural connections and community-based problems that could serve as rich contexts for engaging youth in spatial design challenges using virtual reality (VR), augmented reality (AR), and 3D printing.

Example 2. Co-design is a cornerstone of the **AI for Georgia (AI4GA)** project, serving as a tool for collaboratively developing an AI curriculum and a mechanism for mutual professional learning (Gardner-McCune, 2023). Through three phases of co-design, middle school teachers learned the basics of AI while AI researchers learned how to actively engage learners with technical content. Together they created AI learning activities that prioritized students' interests and learning needs. The team noted their future work will position AI experts as sources of theoretical AI knowledge, and teachers as "ground shapers" of that knowledge (Gelder et al., 2025).

What strategies did ITEST projects use to address challenges and to build on their successes?

This section highlights co-design strategies that helped ITEST projects address challenges and build on prior successes.

1. **Plan collaborative meetings and workshop activities that work virtually and in person.**

Projects were intentional in ensuring that co-design logistics (timing, format, accessibility) met the needs of all participants. Co-design meetings and workshops were conducted in person and in fully or partially synchronous virtual formats with breakout room discussions and asynchronous engagement opportunities. Projects tailored meeting times to accommodate participants' schedules, particularly educators with limited availability during school and afterschool hours.

The **Making Waves with Radio** project set equitable participation as a core design practice from the start of the project (Dixon et al., 2022). The project team engaged workshop participants in values heatmapping and envisioning exercises using card-based methods, which are interactive participatory design activities aimed at gathering users' experiences and design ideas (Mackay, 2002, 2004). The card activities were effective both with and without technology: in virtual meeting spaces on digital whiteboard platforms such as Mural and Jamboard, and in physical formats such as in-person workshops. The flexibility of the cards supported full participation from groups spread across diverse institutions and locations.

2. **Provide opportunities for participants to share responsibilities and make decisions.**

Co-design is an effective approach for addressing power dynamics inherent in educational research. By recognizing educators, community members, youth, and other participants as experts with deep knowledge of their own contexts, the co-design process can support more impactful innovations and outcomes. It also fosters agency and encourages participants' investment in the work.

Mutually beneficial collaboration was central to the success of **WeatherBlur's** co-design model, which engaged a Teacher Advisory Group (TAG) of teacher leaders and MMSA staff in developing computational thinking instructional practices and PD resources (Harris et al., 2023). The project adopted a horizontal, non-hierarchical approach to co-design, inviting TAG teachers to lead portions of monthly meetings and valuing input from diverse perspectives in efforts to revise and improve the project.

In the **Making Waves with Radio** project, researchers structured values heatmapping activities to equalize power dynamics by holding separate workshops for youth and adults (Dixon et al., 2022). When analyzing the resulting data, they carefully considered "quieter" forms of participation, such as those of junior museum staff, and acknowledged youth participants' hesitancy to suggest values that might conflict with those of others.

3. **Create mechanisms and tools to guide and reflect on the co-design process.**

Projects often face the challenge of ensuring participants' voices are incorporated in all stages of the work. To address this challenge, projects used creative processes, tools, and feedback mechanisms to guide and assess co-design activities. Below we highlight several specific strategies:

- **Templates to scaffold the co-design process**. Projects developed frameworks and lesson planning templates to guide teachers in co-designing learning activities. To support the co-design of geographic information system (GIS)-infused lessons, the **Chicago Geospatial Semester** project created a design framework that combined principles for effective GIS-infused instruction with the Learning for Use model (Edelson, 2001; James et al., 2020). The **AI Educator Make-a-Thon** project provided design journals that encouraged teacher teams to complete goals and summarize their progress during making sessions (DiPaola et al., 2023).
- **Formative evaluation and monitoring tools.** Several projects used surveys, co-reflection sessions, and report cards to hold themselves accountable to the input received from co-design participants as the work evolved. In **Making Waves with Radio**, researchers developed informal report cards to assess whether product ideas aligned with the values identified during early co-design stages (Dixon et al., 2022). In **WeatherBlur**, external evaluators collected evidence of co-design implementation and facilitated a co-interpretation session with the project team to examine how teacher input influenced program development over time (Harris et al., 2023).
- **Newsletters to disseminate project updates.** Researchers leading the **STEMCC** project used regular newsletters, developed in collaboration with partners of the RPP that kept partners and community members informed and recognized the accomplishments of those who had contributed to the project (Bhaduri et al., 2022).

4. **Provide time and space to explore and incorporate feedback.**

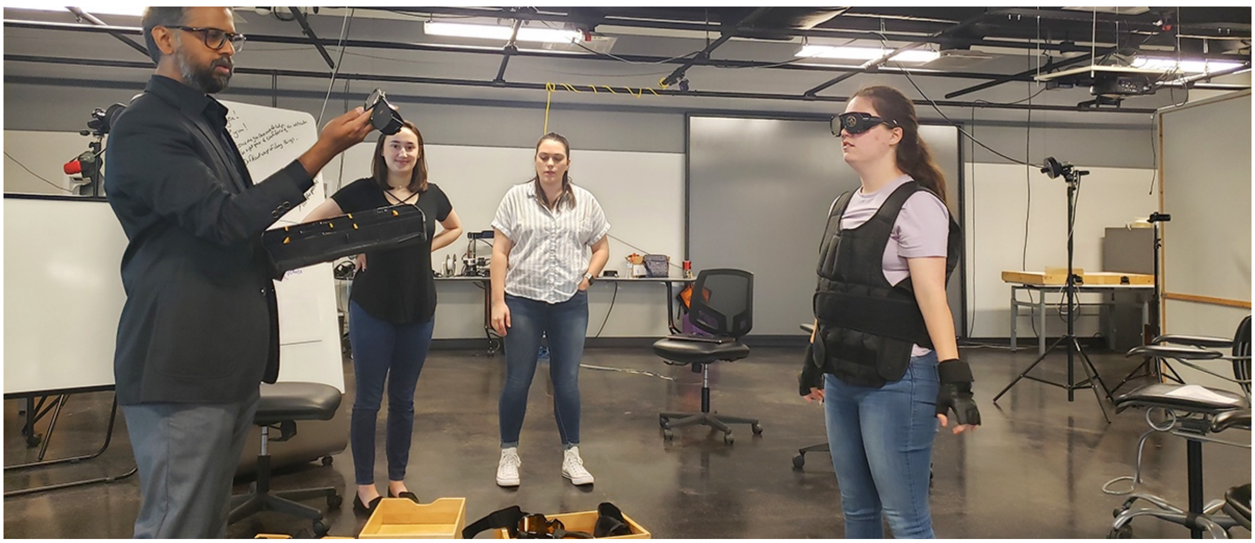
Co-design is iterative and participatory: teams cycle through design, implementation, evaluation, and refinement, with each round shaped by participants' input and experiences. Projects emphasized the importance of structuring co-design sessions to engage every voice and perspective, while also leaving space to explore new ideas and shift direction as insights emerge.

The **WeatherBlur** Teacher Advisory Group (TAG) implemented co-designed lessons in their classrooms and reflected on their experiences during monthly meetings. TAG teachers appreciated that the program accommodated their needs and provided time to address issues they felt were important. The open-ended nature of co-design meant that the end result was not always clear at the outset; comfort with uncertainty and a willingness to adapt were essential. One teacher explained how this flexibility benefitted the project.

"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 a culture and also opening to more innovation." (Harris et al., 2023, p. 10).

Conclusion

This brief highlights the diverse ways ITEST projects are applying co-design methods to develop technology-rich tools and resources for pre-K–12 STEM education. Although the projects operate in different stages and settings, each centers the experiences and perspectives of educators, youth, and community members in designing technology-enhanced programs, ensuring that the resulting innovations are more accessible and better aligned with users' needs and goals. As these projects illustrate, co-design requires a commitment to the group, time to build trust among members, flexibility to iterate and adapt, and thoughtful planning and facilitation. At the same time, they show that co-design serves as a powerful mechanism for collective learning, capacity building, and broadening participation in STEM education.



At the NAMSAS Summer Native American Teacher Workshop, educators engage with the GERT (gerontological) aging simulation suit to experience age-related physical limitations firsthand. Credit: Oklahoma State University

Table 2. ITEST projects: Short and full titles of the 9 ITEST projects highlighted.

ITEST Project (short)	ITEST Project (full), award number (linked to the NSF award abstract), years funded
Projects in traditional classroom settings. Co-design participants included teachers, teacher leaders, administrators, content specialists, youth, and researchers	
AI Educator Make-a-Thon	Everyday AI for Youth: Investigating Middle School Teacher Education, Classroom Implementation, and the Associated Student Learning Outcomes of an Innovative AI Curriculum (DRL–2048746, 2020–2024)
AI for Georgia (AI4GA)	AI4GA – Developing Artificial Intelligence Competencies, Career Awareness, and Interest in Georgia Middle School Teachers and Students (DRL–2048502; 2049029; 2021–2026)
Birds and Bots: B-Squared	Promoting learning and interest in mathematics for urban Black and Latinx children through culturally relevant daily robot coding activities (DRL–2147699, 2022–2026)
Chicago Geospatial Semester Project	Adapting and Implementing a Geospatial High School Course in Career and Technical Education Clusters in Urban Settings (DRL–1759360, 1759370, 1759371; 2018–2024)
Computer Science (CS) Frontiers	Beyond CS Principles: Engaging Female High School Students in New Frontiers of Computing (DRL–1949472, 1949488,1949492; 2020–2025)
WeatherBlur	Sociocultural Approach to Integrating Computational Thinking and Data Analysis into an Online Citizen Science Program Linking Rural Educators in Maine, Mississippi, and Alabama (DRL–1933491, 2020–2024)
Projects in out-of-school/community settings. Co-design participants included afterschool educators, community college staff, community members, museum professionals, STEM mentors, youth, learning scientists, and researchers.	
ITEST Project (short)	**ITEST Project (full), award number (linked to the NSF award abstract)**
Making Waves with Radio	Empowering Informal Educators to Prepare Future Generations in Wireless Radio Communications with Mobile Resources (DRL-2005784, 2053160, 2020–2026)
Native American Middle-School Students Afterschool STEM (NAMSAS)	Engaging Native American Students in STEM Career Development Through a Culturally Responsive After-School Program Using Virtual Environments and 3-D Printing (DRL-2048987, 2021–2026)
STEM Career Connections (STEMCC)	STEM Career Connections: A Model for Preparing Economically Disadvantaged Rural Youth for the Future Workforce (DRL-1948709, 1949299, 1949322; 2020–2024)

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