Research-Education Partnerships: A Co-Design Classroom for College Students with Intellectual and Developmental Disabilities

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Co-design of technology encourages participation and decision-making input of end-users. In the case of technologies for individuals with Intellectual and Developmental Disabilities (IDD), the end-users are historically left out of the design process. Further deepening the disconnect between this group and technology, they are also excluded from formal technology design knowledge sharing, such as college courses. To address this, our study investigates the efficacy of a formal classroom adaptation of co-design activities to encourage learning and participation. Through collaboration between educators and designers, we adopted user-centered co-design activities to facilitate knowledge and application of technological design methods within a class of 13 students with IDD. Findings uncovered factors contributing to co-teaching collaboration planning and reflection between educators and designers, and ways that activities can provide accessible collaborative learning environments for students with IDD by supporting collaboration, cognitive engagement, and meta-cognition. We discuss how these factors can support successful co-teacher collaborations that promote student empowerment. Finally, we contribute collaborative co-teaching strategies for educational co-design activities for individuals with IDD.

CCS Concepts: • **Human-centered computing → Accessibility design and evaluation methods**; *HCI design and evaluation methods.*

Additional Key Words and Phrases: Intellectual Disability, Inclusive Design Education, Co-Design

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1 Introduction

Co-design is a form of participatory design (PD) that aims to increase the voice of marginalized groups by fostering knowledge exchange between designers and design partners who will be end users of technology, ensuring end users have control over design outcomes [21, 41, 80, 85].

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Co-design facilitates knowledge transfer between participants and designers through a series of hands-on design activities that position participants as experts in their own experiences [80]. However, co-design partnerships with people with intellectual and developmental disabilities (IDD) are often neglected by designers and researchers. This is because typically, PD activities demand higher-order thinking and rely on verbal communication, which can be difficult for those with IDD [8, 16]. Consequently, people with IDD are disallowed opportunities to contribute knowledge from their lived experiences, thus decreasing their influence in design outcomes.

The exclusion of people with IDD from participatory design is a recognized problem in HCI [8, 77]. To encourage involvement of people with IDD in participatory design, researchers have proposed participatory design methods that reduce verbal communication and cognitive demands [2, 8, 16, 26, 77]. While these methods decrease barriers to participation, they do not consider the PD aim of mutual learning [10]. Focusing on mutual learning can help researchers avoid propagating HCI's history of extractive research practices where researchers take ideas from within a community without returning value to those communities [18, 54]. Therefore, we consider how to build tools to empower adults with IDD to enact their own designs by equipping them with HCI knowledge and skill sets, enabling them to participate and develop technology according to their own interests.

A classroom-based participatory design methodology shows promise in addressing these challenges by explicitly instructing participants with IDD in the theory and practice of HCI with the intention that they may use these same methods after the course is completed to pursue projects aligned with their own interests. For example, computational empowerment (CE) is an educational participatory design approach that works to build students' skills and capacities in technology development, while encouraging them to consider how this technology brings about better futures [37]. With its emphasis on developing and pursuing one's own goals, this approach aligns with calls in HCI to increase the agency of neurodivergent users through technology design that follows their true priorities, rather than neurotypical priorities, proxy interpretations, or social norms [87, 88, 98]. However, CE has primarily been deployed in K-12 educational settings for neurotypical children, often outside of traditional classroom settings [27, 35, 37, 82, 86]. We consider how to deploy CE in a college classroom for students with IDD.

Implementing participatory design approaches in formal classroom settings is complicated by a need for teachers to expand beyond their typical classroom role as educators and become design facilitators [4, 9, 27, 96]. Similarly, designers in classroom settings can struggle to take on teacher roles to implement learning objectives [4, 23]. Understanding collaboration between teachers and designers is important to effect positive learning outcomes [5]. We investigate how teachers and designers work together to deploy CE approaches through co-design activities in order to achieve both learning outcomes and design implications. To do this, we employed a style of instruction that encourages teamwork and collaboration between educators and researchers. To achieve the best learning and design outcomes from the students, this collaboration focused on delivering a co-design inspired learning approach which emphasizes the importance of knowledge construction through group interactions [38, 100].

We ask the following research questions:

(1) What collaborative practices between educators and designers contribute to user-centered design learning and co-design research outcomes in a co-design classroom setting?
(2) How can co-design activities be adapted for collaborative learning settings to support user-centered design learning and computational empowerment of students with IDD who are enrolled in inclusive post-secondary education programs?

To explore these questions, we partnered with an Inclusive Post-Secondary Education (IPSE) program on a university campus in the United States. We chose a to explore college education settings because HCI methods such as User Centered Design (UCD) are often taught in college-level courses [97], and because university attendance has historically been restricted for individuals with IDD [90]. This restriction has meant that knowledge of the technology design process is not equally accessible to the IDD population. To address the clear lack of inclusion of IDD individuals in technology design both through PD and in the sharing of design knowledge, this study examines how HCI researchers can assume teaching roles in UCD courses created for IPSE programs. By repositioning co-design activities as teaching tools as well as mechanisms of data collection, we aim to both equip and empower students with IDD to participate in and influence technology designs that align with their experiences and visions.

In this paper, we describe how we offered a course on UCD that took a CE approach for students with IDD, aiming to build their skills and capacities as future technology designers. To create learning activities that also supported design outcomes, designers and educators collaboratively adapted typical co-design activities into tools that sought to teach the UCD concepts through completing activities and accompanying lectures. Through deployment of these methods and analysis of student and co-teacher artifacts and interviews, we describe co-teaching practices that led to both positive and challenging classroom outcomes and suggest how our findings can be extended to other formal education settings to foster computational empowerment. In doing so, we contribute collaborative co-teaching strategies for educational co-design activities for individuals with IDD. Ultimately, we aim to inform inclusive design methods, with the added dimension of teaching UCD to neurodivergent individuals for the purpose of increasing their agency and influence in technologies designed for their use.

2 Background

2.1 Empowerment through Participatory Design

Participatory design (PD) emphasizes the importance of shared power between users and designers, in order to ensure that design outcomes are agreeable and useful to end users [19]. This approach is often used in partnership with communities who experience social and economic marginalization, for example racial minorities [32] and children [101]. People with IDD are also marginalized, as they faced legal discrimination in public education and employment well into the 1990s [83]. Although people with IDD experience marginalization, they have often been excluded from direct involvement on PD teams [2, 8, 16]. Researchers who work with adults with IDD have proposed a number of adaptations to maximize choice and autonomy while supporting participation. For example, to support communication, researchers suggest developing relationships directly with participants and offering graded assistance [8]. Others have produced co-design toolkits for adults with IDD which adapt common design tools by using simplified language and incorporating visual aids [24]. Aswad et al. reported that adults with IDD reported a sense of ownership and enjoyment when they worked directly on PD teams that employed adapted tools [2], indicating that including these users in PD results in positive experiences. Researchers have also emphasized the importance of taking strengths-based approaches that offer flexible response options so that participants can use their self-determined assets and competencies to complete design activities [7, 47, 77].

2.1.1 Participatory Design in Classroom Settings. Recently, there has been interest in using a PD approach in classrooms as part of a move toward a computational empowerment (CE) model of technology education. The CE model encourages students to critically reflect on the role of technology in their world and on their role in building technology, through activities that build understanding and competence in skills related to technology development [35, 37, 44, 86]. This model asks students to adopt a 'protagonist' role in design, challenging them to lead design projects that are meaningful to them [36] and become "empowered co-creators" [27]. However, as students adopt new roles in classrooms it is important to understand how PD approaches invite teachers and other classroom authority figures to adopt new roles as well.

In classroom settings that utilize PD methods, teachers often lead design activities while researchers are positioned as consultants who interview, observe, and advise them on design outcomes. Teachers leading classes where students take on PD projects can struggle to balance their role as educators and designer leaders [9, 27, 50, 96]. Studies that position researchers in more active roles where they lead PD design activities in schools show that researchers also have difficulty with role flexibility, reporting difficulty embedding learning goals within design activities [4, 23]. Barendregt et al. published a study of participatory design with students in K-12 special education settings where they examined how to achieve a good balance of agency between teachers, students, and designers in these settings, describing the outcomes of PD activities where designers and teachers worked together to meet their differing goals on learning and design [5]. Negotiating classroom roles and agency can be complicated even between teaching professionals who have only learning goals in mind, where literature on co-teaching describes several roles that co-teachers can take. While PD studies consider how designers can communicate with teachers to plan and lead PD activities that include learning goals, few studies position designers as co-teachers who hold substantial responsibility for helping students meet curricular goals. Our work positions researchers as co-teachers who hold responsibility for students' learning as a way of ensuring that they are accountable for providing a clear contribution to research partners.

2.2 Collaborative Learning

Collaborative learning is a social learning model that encourages students to work in groups to build knowledge together [100]. Collaborative learning can be understood through the theory of social constructivism, which suggests that students create meaning through active participation in social contexts [1, 46, 100]. Collaborative learning has several positive benefits to students, including social, psychological, and academic [53], and researchers have argued for increased collaborative learning opportunities in higher education [74]. HCI and education researchers have investigated computer supported collaborative learning (CSCL) [14, 40] and shown that it has positive effects on learning outcomes. The HCI community has investigated ways that technology can support student interactions, for example, by building interfaces for peer-to-peer discussions [81], and teacher instruction, for example, by designing teacher dashboards to support teachers' awareness of student learning [92, 95]. We adopt collaborative learning in this context because its emphasis on small group collaboration and co-construction of ideas mirrors the co-design setting, allowing our classroom to enact co-design activities in ways that align with the teaching philosophy of the classroom.

Because we adopt this learning model to examine the actions of co-teachers, it is important to understand the role of teachers in creating successful collaborative learning environments. Kaendler et al. present a framework describing how teacher competencies can support collaborative learning in classrooms [42]. This framework divides collaborative learning into three phases during which teacher competencies are deployed to support learning in each phase. The three phases of collaborative learning are pre-active, inter-active, and post-active. Teachers deploy their planning competency during the pre-active phase to plan high-quality activities. In this phase, teachers set learning goals, determine activities, and assign students to work on activities in groups. During the interactive phase, teachers use the competencies of monitoring, supporting, and consolidating students' learning to support them as they complete planned activities. Finally, in the post-active phase, teachers reflect on their own teaching practice and student's actions and progress during activities. Kaendler et al. also suggest three qualities of student interaction that should be observed during collaborative learning–collaborative activity, cognitive activity, and meta-cognitive activity.

Collaborative activity describes ways that students are actively engaging in building knowledge by sharing information and listening to each other. Cognitive activity describes ways that students are actively engaging with course content by asking questions and explaining their reasoning when answering questions. Meta-cognitive activity describes how students understand their role in the learning process by monitoring their understanding. This model considers how a single teacher might meet classroom goals, but does not consider how co-teachers share their professional knowledge to support students together across these phases. Therefore, we extend this model to co-teaching settings by understanding how teaching teams collaborate.

2.3 Co-Teaching: Collaborative Planning and Collaborative Reflection

Co-teaching involves multiple instructors sharing responsibility for students' learning in a classroom and is commonly used to support students with learning disabilities [17]. Therefore, much of the co-teaching literature describes partnerships between general educators and special educators [6, 45, 66, 69]. Co-teaching can also involve partnerships between teachers and professionals from outside of the education field, such as industry professionals [34, 65, 73], and researchers [12, 48, 71].

Co-teaching positively impacts students [49] and teachers [68]. However, co-teaching requires substantial time devoted to coordinating planning between teachers to align teaching goals and practices to suit the different learning needs of students, and can result in conflict when co-teachers do not share assumptions about the teaching environment [68]. To support collaborative planning, teaching literature has often proposed planning templates to drive the exchange of relevant information between teams. Planning templates and tools encapsulate models of what information is important to share between teams (e.g., The 'Four Knows' Model: Know your self, Know your partner, Know you Students, Know your Stuff) [45]), different granularities of time to plan around (e.g., Unit/Bi-Weekly/Daily [75]), teachers' instruction roles [91], and physical classroom arrangements (e.g., stations vs lecture seating [69]). These templates aim to facilitate sharing of relevant information quickly and efficiently between team members with limited time to meet.

While much co-teaching literature discusses collaborative planning on co-teaching teams, there is less work on collaborative reflection for these teams, where teachers reflect together on teaching experiences. Collaborative reflection in teaching literature often considers teachers reflecting on individual teaching experiences with a group of peer teachers [70] and its utility in pre-service teaching [15]. There is not an agreed-upon set of collaborative reflection principles or practices for co-teachers [25]. Existing research on collaborative reflection between co-teachers has considered an activity-system model, which focuses on how the teaching context impacts teacher experiences [28, 31]. Unlike most collaborative planning and reflection literature about co-teaching teams, our co-teaching team was composed of people from both education and non-education backgrounds. Therefore, instead of adopting an activity-system model to frame collaboration, we adopted a collaborative model that focuses on interpersonal interaction and sensemaking, the Collaborative Reflection Framework [62].

The Collaborative Reflection Framework (CRF) is a model developed by Marcu et al. that has been used in HCI to describe collaboration in educational environments [59, 63, 64]. This model describes a long-term communication loop, where team members communicate around goals and interventions, and a short-term communication loop, where team members communicate around day-to-day occurrences. The CRF describes how team members with varied roles, professional backgrounds, and lived experiences, such as teachers and parents [78], psychiatrists and occupational therapists [62], or students and educators [59], can communicate to make sense of information and track progress toward shared goals. This makes it suitable for our environment, where we had team members from different professional backgrounds. This model has primarily been applied on teams where a single person is the focus of intervention, while our work considers how team members can communicate effectively to understand the progress of a group of learners.

3 Methods

This study was conducted in partnership with the Inclusive Post-Secondary Education (IPSE) program at a university in the southern United States. The IPSE program has partnered with the university's HCI faculty in the past to teach collaborative design to their students. We proposed a version of this course where students learn User Centered Design (UCD) through a curriculum where students partner with design researchers at the university to co-design technology for adults with IDD. Designers consulted with previous instructors and faculty with expertise in learning sciences to build the curriculum and learning activities. The course was an elective open to IPSE students of any grade and was taught in Spring 2023. All research activities were approved by the university's IRB.

3.1 Students

Student participants enrolled in the university's IPSE program. The IPSE's admission requirements include a diagnosis of intellectual and developmental disability (IDD), defined by the American Association on Intellectual and Developmental Disabilities as "significant limitations in both intellectual functioning and adaptive behavior" [72]. This program requires that students have a 3rd-grade reading level, know basic mathematics, can use a tablet or computer, have no significant behavioral/emotional challenges, and are able to live and work independently for long periods of time.

In a self-report demographic survey, students reported they were 19-23 years old. Along with the shared diagnosis of IDD, students reported the following disabilities: Down Syndrome (1), ADHD (1), Learning Disability (1), Autism (2), 'Other' (2), and 'Prefer not to Say'/'No Response' (5). Demographics are reported in aggregate to conceal student identities, as the IPSE program is small. Further student demographics are reported in Table 1.

3.1.1 *Student Recruitment and Consent.*

The course was advertised through in-class announcements and at IPSE community gatherings. Once enrolled in the course, students were offered the choice to enroll in the research study.

One class session was spent describing the research study and consent process. It was emphasized that it was fully the students' choice to participate, and that participation (or lack thereof) would not affect students' course grade, standing, or relationship with co-teachers. Students were periodically reminded that they could decline to participate in the research study without negative repercussions. Of the fifteen students enrolled in the course, thirteen elected to participate in the research study.

3.2 Co-Teachers

We define co-teachers in our study as study personnel who were active in planning and teaching the course throughout the semester. There were a total of 7 co-teachers involved in this study. We divided co-teachers into two teams: Four educators and three designers. Educators were primarily concerned with the educational aims of the course, while designers were primarily concerned with co-design outcomes. Two members of the educator team, Sara and Nicole, had several years of experience educating students with IDD. Nicole, the IPSE liaison, advised the research team on the curriculum, group formation, and activity modification for individual students, and met with students on a weekly basis about classes. On the design team, everyone except Andrew (D2) had several years of experience doing user-centered design professionally in industry and/or academia. Four co-teachers were assigned a group leader role where they led a group of three

Pseudonym	ID	Gender	University Standing
Jonathan	S1	Male	Sophomore
Caroline	S2	Female	Freshman
Kadir	S3	Male	Senior
Esther	S4	Female	Junior
Marisol	S5	Female	Freshman
Lorenzo	S6	Male	Sophomore
Olivia	S7	Female	Freshman
Cameron	S8	Male	Freshman
Grant	S9	Male	Freshman
Josiah	S10	Male	Sophomore
Sierra	S11	Female	Freshman
Hunter	S12	Male	Freshman
Aaliyah	S13	Female	Junior

Table 1. *Student Demographics:* Demographics of students enrolled in our study. No participants identified with a non-binary gender.

Pseudonym	ID	Gender	University Standing	Co-Teaching Team Role	Classroom Role
Sara	E1	Female	PhD Student	Educator	Lead Educator & Group Leader
Nicole	E2	Female	IPSE Staff	Educator	IPSE Liaison
Jolie	E3	Female	MS Student	Educator	Teaching Assistant
Emily*	E4	Female	MS Student	Educator	Group Leader
Michelle	D1	Female	Faculty	Designer	Lead Designer & Group Leader
Andrew	D2	Male	BS Student	Designer	Robot Dog Investigator
Samantha	D3	Female	PhD Student	Designer	AI Job Coach Investigator & Group Leader

Table 2. *Study Personnel Demographics:* Demographics and classroom roles of study personnel whose data contributed to this study. Starred* study personnel did not participate in interview.

to five students throughout the semester. The teaching assistant supported the class by moving between teams to observe student progress and engagement, analyzing student reflections for teaching insights, and providing one-on-one support as needed. All but one co-teacher (Emily, E4) contributed an interview after the course concluded. Our results section therefore contains findings from interviews with 3 educators (E1, E2, and E3) and 3 designers (D1, D2, and D3). See Table 2 for demographic information and classroom roles.

3.3 Study Procedure

The curriculum was adapted from an existing university course on user-centered design (UCD) taught to neurotypical undergraduates at the university. UCD is a well-established design process to involve users in technology design, and serves as a basis for many prominent HCI textbooks [97]. We used the Stanford Model of Design Thinking, which consists of five phases: Empathize, Define the Problem, Ideate, Prototype, and Test [20], to guide activity progression. The classroom took a collaborative learning approach [53] because its teaching practices are harmonious with co-design activities.

3.3.1 Design Projects and Co-Design Activities. The course began with a two-week introduction to user-centered design (UCD) and the five phases of Stanford's design thinking model [20], which used an example project of designing a smartwatch as an instruction tool. Then, students applied UCD concepts to complete two co-design projects. Project one was a robot support dog for adults with IDD. Project two was an AI job coach for adults with IDD. These projects were selected because they were relevant to our students, and because researchers on these projects were interested in interacting with a single set of users for a long period of time. See Table 3 for descriptions of co-design activities completed during each project. At the end of each project, students presented a final prototype and completed an individual portfolio. These were designed to encourage consolidation and meta-cognitive reflection on students' learning. Results of these design projects are beyond the scope of this paper, and reports of design outcomes are being prepared for publication in other venues [29, 51]. Course grading was based heavily on participation to ensure student GPAs were minimally impacted by research activities.

3.3.2 Daily Class Activities. The course met twice weekly in person for 75 minutes over a sixteen-week semester. In each class, we began with a review to consolidate learning from the previous class. Then, we introduced new concepts, gave design activity instructions, and completed an example. After the class completed activities, we did a short (~10 minute) learning reflection to encourage meta-cognitive reflection.

3.3.3 Classroom Co-Design Roles. We developed this co-design classroom methodology with the aim of increasing the agency of adults with IDD in technology design. We chose a co-design approach because it respects participants' agency by supporting varied motivations [80], offering them flexibility to *follow their own interests* in participation. Furthermore, this method champions mutual learning by encouraging an exchange of information between participants and designers [80], supporting participants to *build skills* leading toward more *independent involvement in the design process*[21]. We situated co-design in a classroom to formalize the responsibility of researchers to share design knowledge with students, where the syllabus established a contract describing what students could expect to gain from participation. The design course we used as a model for our class had a course-long assignment challenging students to independently plan and execute a complete design project. We were thoughtful about the demands that this type of undertaking would place on the cognitive resources of students with IDD, as researchers note that even neurotypical participants may be overwhelmed when expected to take on too much design responsibility at once [21].

Therefore, we determined a need to divide the responsibilities of planning and executing design projects between students and designers. Student observations and IPSE liaison interactions occurring prior to this study suggested that students were interested in learning the general process of technology design and exploring new technological tools rather than scoping and defining a design problem space. Therefore, we assigned researchers to define the design space, while students were active in data collection, data analysis, and prototyping. We emphasized the importance of students' contributions in these areas by ensuring that their analytic framing guided design project directions. Members of the co-design team (educators, designers, and students) made the following contributions to co-design: Designers defined the problem space and framed research questions; Educators designed lecture materials describing the basics of UCD and partnered with designers to modify co-design activities for accessibility; Students contributed their expertise in the form of lived experiences, analyzed data collected during co-design activities, and proposed early prototypes in the form of storyboards (robot dog) and paper prototypes (job coach).

3.4 Data Collection and Analysis

3.4.1 Analysis 1: Co-teacher Participation Reflections. To understand collaborative practices of co-teachers that promoted successful learning and design outcomes in classrooms (RQ1), we conducted a semi-structured interview (1-2 hours) with 6 co-teachers (3 educators–E1, E2, and E3, and 3 designers–D1, D2, and D3). The interview had two parts: Reflection on co-teacher collaboration and activity rankings. This analysis was focused on the collaboration portion of interviews. This part of the interview was built to explore how co-teachers collaborated through long-term and short-term communication loops, as described by [62], to meet education and co-design aims. Two authors reviewed these interviews and developed codes to describe findings. Codes were refined through multiple iterations of feedback with a third author. The final code book contained six major codes: Planning, benefits, challenges, knowledge sharing, classroom roles, and potential improvements. Every code except 'potential improvements' contained sub-codes. For example, planning had two sub-codes (day-to-day and foundational), while challenges had four sub-codes (silos, time and staff, resolution, and competing interests). Two authors reached an inter-rater reliability of 0.82 on a selection of 20% of interview data from three co-teachers.

3.4.2 Analysis 2: Co-Design Activity Reflections. To understand what types of classroom activity adaptations contributed to both students' learning outcomes and high-quality co-design data (RQ2), we analyzed student data from three sources–daily learning reflections, individual portfolio reflections, and an end-of-course activity rating discussion. For the end-of-course rating, we presented students with sets of activities that were used during each design phase throughout the course. We then explored in a class discussion how activities helped them meet computational empowerment aims of building skillsets related to technology design and encouraging critical reflection of technology [37, 44]. We asked students to discuss which of these activities helped them to pay attention, learn, and enjoy class, and which they would most like to do again. Co-teacher activity reflection data was collected using the same prompts during the semi-structured interview described in Section 3.4.1. Two authors reviewed activity reflections and developed initial codes. Codes were refined through multiple iterations of feedback with a third author. The final code book had seven major themes: Cognition, classroom logistics, scaffolding, classroom ideas, personal factors, peer interactions, fun/novel experiences, experiential learning, and data quality. Two authors reached an inter-rater reliability of 0.80 on a set of 20% of 3 study personnel interviews and student reflection data.

4 Results

We begin by describing how designers and educators collaborated as co-teachers to plan and reflect on co-design activities adapted to ensure high-quality user-centered design learning and co-design research outcomes (RQ1) in sections 4.1 and 4.2. We then describe how co-design activities were adapted to ensure successful collaborative learning interactions for students with IDD, and how co-teachers supported these interactions (RQ2) in section 4.3.

4.1 Pre-Active Phase: Open Communication in Collaborative Planning

Kaendler et al. describe the pre-active phase of collaborative learning as the phase during which teachers plan for lessons by defining learning goals and developing activities to meet these goals [42]. In the pre-active phase, it was important for designers and educators to plan for class activities that created both high-quality student learning experiences and high-quality co-design products.

Proj	Design Phase	Activity Name	Description
Intro	Emp	Interview	Full class watched examples of one-on-one interviews
Intro	Emp	Demo-graphics	Full class collected demographics by counting raised hands.
All	Emp	Sm Group	Groups of 3-5 students responded to design prompts together.
All	Emp	Lg Group	Full class responded to design prompts together
RD	Emp	Survey	Student pairs asked each other about robot animals.
RD	Emp	Observa-tions	Students took turns observing and interacting with robot dogs.
AI	Emp	Tree of Life	Individuals showed their history, values, & dreams on trees.
RD	DtP	Affinity Map	Full class categorized use cases using virtual sticky notes.
AI	DtP	Persona	Small groups constructed personas based on the data from users with the motivation from themes ID'd in Affinity Map.
AI	DtP	Journey Map	Full class imagined a persona's job search journey while contributing stories about their own experiences.
Intro	Ideate	Worst Idea	Full class intentionally generated bad ideas, then used these to identify design requirements.
RD	Ideate	Collage	Individuals made a collage using pictures of technology and dogs to imagine how their robot dog should look.
AI	Ideate	Explore Existing Systems	Small Groups explored virtual reality and an AI chatbot to fuel ideas on how existing technology could be improved.
AI	Ideate	Req. Gath-ering	Full Class reflected on Explore Systems experiences to define requirements for the AI job coach
AI	Ideate	User Stories	Small groups considered personal strengths data and require-ments to imagine how an AI job coach could support them.
RD	Proto	Story Board	Small groups used play dough, drawing, and talking to gen-erate stories based on Affinity Mapping and Collage themes.
RD	Proto	Role Play	Students acted out how the robot dog should behave when it fails. Students could act or direct the mentor as the dog.
AI	Proto	Script	Students wrote scripts of how their AI job coach could sup-port them during the event described in their User Stories.
AI	Proto	Video	Students described their strengths, challenges, and script ideas, then filmed what their AI job coach should do.
AI	Proto	Paper Pro-totype	Students individually designed an interface showing their AI job coach helping them with a personalized task.
RD	Test	SWOT	Groups evaluated each others' Story Boards by identifying Strengths, Weaknesses, Opportunities, and Threats.
RD	Test	Rank	Students ranked their Role Play favorite failure response.
AI	Test	Focus Group	Students presented and evaluated their Paper Prototype to in small groups.

Table 3. Co-design Activities Across Phases. Abbreviations: Intro = Introduction/Smartwatch Project, RD = Robot Dog Project, AI = AI Job Coach Project, Emp = Empathy, DtP = Define the Problem, Proto = Prototype

Co-teachers discussed how open communication between educator and design teams, where they discussed their competing goals and exchanged professional knowledge, helped them meet their goals through foundational and day-to-day classroom planning.

Educators and designers both acknowledged the challenge of competing goals for activity outcomes, where educators prioritized student learning outcomes while designers prioritized producing high-quality co-design data. These competing aims created tension when time was limited, for example designers expressed concern about having insufficient time available to fully engage in co-design activities due to teaching, *"it was difficult to find time to get group insights or individual insights because we had to spend half of the class time teaching materials."* - Michelle (D1). Tensions also emerged when educators and designers did not coordinate their goals and plans for class. At the beginning of the course, there were instances when educators and designers did not communicate effectively about daily activities, resulting in missed opportunities. For example, the robot dog design team missed an opportunity to contribute to an activity developed by the educator team designed to teach students how to give surveys. Designers noted that it would have been helpful to contribute questions to the survey, and lamented the missed opportunity to collect data.

As educators and designers worked together, they developed a practice of explicitly discussing their goals and needs for each class before planning activities *"Here's what I need out of [the lesson] … How do we do this, and what do we each need to do to make it a successful class."* – Samantha (D3). This practice fostered positive learning and research outcomes by building transparency, making co-teachers aware of goals from across teams, and building accountability for meeting those goals. This practice aligns with the concept of Social Translucence, as proposed by Erickson et al. [22], which emphasizes the benefits of transparency in enhancing awareness and accountability within teams. Thus, adopting a practice of open communication where co-teachers acknowledged competing interests helped educators and designers develop teaching plans and activities that met classroom goals for both teams.

4.2 Post-Active Phase: Structured Reflection to Overcome Reflection Silos

Kaendler et al. describe the post-active phase of collaborative learning, during which teachers reflect critically on their performance as teachers and students' learning outcomes [42]. Our results revealed that reflection was complicated by meeting silos, where teams of educators and teams of designers met separately to discuss how well class activities addressed classroom goals. Reflecting on activities in meeting silos resulted in uneven and uncoordinated views of success, as the educator team would reflect on how well activities supported students' participation and learning, while designers reflected on whether valuable co-design data was produced. Moreover, the IPSE liaison was not formally included in reflection meetings and thus, was not able to share her knowledge of how students viewed activities or offer IPSE resources to support teachers. When stakeholders were not aligned in their interpretation of classroom activities, they could not support each others' goals.

4.2.1 Reflection Silos: Mis-Aligned Views of Success. Stakeholders reported few instances of collaborative reflection between the educator and designer teams. Instead, teams would typically meet in 'silos,' with only the other members of their team. Silos have been described in HCI in relation to healthcare teams, where team members fail to communicate and share information about patients effectively [61]. For example, Sara (E1) reported on the educator team's weekly meeting where she described how the lead educator would ask for their specific teaching observations, and a synthesis of students' daily learning reflections to understand what they did and did not like about class. Meanwhile, the design team would reflect on co-design data they collected in the previous class, synthesize results, and identify data collection needs for the next class. Each team would speculate about good next steps for class activities and prepare lesson ideas for the weekly planning meeting. When educators and designers had a united view of outcomes and next steps, they reported feeling *"very supported"* - Samantha (D3). However, when reflections between educators and designers were not well aligned, the lack of shared reflection created tension. This occurred often in relation to missed data collection opportunities and disagreement about good 'next steps' in class.

4.2.2 Reflection Silos: Missed Data Collection Opportunities. Reflection silos created a challenge because activities that produced good participation and learning engagement did not always produce good design data, and vice versa. Designers reported missed opportunities to collect data when educators did not recognize problems with trends in students' completed work. For example, the educator and design teams disagreed on student responses to the Tree of Life activity that was part of the AI job coach project. The activity was focused on jobs and included an online questionnaire about their dream job. This activity included a question that asked "How do you plan to reach your goal?" which frequently resulted in broad responses such as, *"I want to live in a[n] apartment and i want a job. I want to have a Roommate because i am really social. I want to get married because i want to be in Love. and i want to live a full happy and promising life ahead of me."* - Esther (S4). This type of response was judged to be good by educators because it was reflective and showed engagement with the question. However, the design team did not see this as a good response because it was not closely related to employment. Because the co-teaching teams reflected on this activity in silos, they were surprised to learn of each others' viewpoints when they met to plan for the next class. This issue was easily resolved by adding more context to the online questionnaire. However, the lack of communication between educators and designers resulted in a delay between when the issue was detected and when it was resolved, resulting in lost data.

We identified a further missed opportunity to collect data in an end-of-course meeting with the IPSE liaison when we described difficulties sending design work home because students often forgot to bring it back. The IPSE liaison shared that *"Our students have a study hall every single week" - Nicole (E2)* and offered to use some of this time for design homework if we taught this class again. Because the IPSE liaison was not included regularly in reflections, she was unaware of data collection efforts and was unable to support the co-teaching team using IPSE resources. Where team members did not communicate about activity outcomes and needs together, designers missed out on opportunities to collect data. Although we identify a need here to increase communication across teams, it is important to balance this need with schedule challenges. Co-teachers lamented that *"material preparation, going to class, then data and all these things, all these things took way more [time] than I expected."* – Michelle (D1). Participants made it clear that in future iterations of this co-teaching approach, it will be important to have better coordination between educators and designers. However, they also expressed concerns with the time commitment needed to coordinate co-teaching. Some participants suggested an interest in using technology to better support collaboration and communication between educators, designers, and IPSE staff in the classroom, indicating a potential avenue for technology development.

4.3 Inter-Active Phase: Supporting Interactive Knowledge Construction

This section addresses RQ2, which asked how co-design activities can be adapted for a collaborative learning setting to support user-centered design learning and CE of students with IDD in an IPSE program. Collaborative learning interactions should show three qualities: Collaborative activity, cognitive activity, and meta-cognitive activity [42]. In the sections below, we demonstrate how co-teachers supported these three qualities using teaching competencies of monitoring, supporting, and consolidating. We also consider how collaborative learning qualities support CE by inviting students to propose their own technology design ideas, develop skillsets related to technology design, and reflect on their own relationships with technology [37]. Sections are divided into 'Student' and 'Co-Teacher' sections to describe student and co-teacher roles in the classroom.

4.3.1 Collaboration and Monitoring to Understand the Role of Technology in Society.

Students: Collaboration through Idea-Sharing. Collaboration occurred when students shared ideas with one another through group discussions around technology designs. Students reported that they enjoyed group discussions because they *"got to hear other people's ideas and add my ideas."* – Caroline (S2). Group activities were designed to encourage students to contribute ideas and observations about the design problems presented in class and construct a shared understanding of how technology could address these problems. To encourage students with different communication and social dispositions, we offered class discussions in both larger and smaller groups. Jolie (E2) observed that offering different group sizes was important because *"each one is very crucial for different types of people...it gives quieter people [and] outspoken people an equal chance to voice their opinions."* Samantha (D3) observed how these environments encouraged different types of sharing, where *"large group discussions gave us good story data. People really wanted to share their stories in the large group"* while smaller groups were *"a little bit more centered around the specific concepts that we were trying to discuss."* Through large and small group interactions, students built an understanding about *"the main issue that you are trying to modify for yourself [and] also in the community as a whole"* – Esther (S4). It was important to build multiple opportunities for students to share their own ideas and lived experiences, as capturing people's expert experience in their own lives is crucial to co-design [80]. This is critical to CE as this approach encourages students to recognize how to relate their own experiences to technology development [36]. A drawback of group discussions was that the same students did most of the talking, especially in the large group. Therefore, some students' voices were heard less often than others. Building collaborative activities supported students to share experiences and explore the role that technology plays in their lives, although there was a need to identify ways to encourage more equitable sharing of ideas between students with different communication preferences.

Co-teachers: Group Monitoring to Support Communication and Participation. Co-teachers monitored students during group discussions, building familiarity with student communication styles so that they could arrange environments to facilitate communication. Close, frequent interactions between co-teachers and students in our study led to relationship-building, which can support successful communication between adults with IDD and researchers during PD [8]. In our study, one group leader observed that a student sometimes preferred to draw or write ideas instead of communicating verbally, so she ensured that he always had writing utensils available during group discussions. In another instance, the TA noticed that a student was having difficulty communicating during daily learning reflections and began sitting down with him *"to kind of help him think through his thoughts."* - Jolie (E3). Consistently monitoring student interactions led to relationships between co-teachers and students such that co-teachers learned to develop communication opportunities that were responsive to students' cues.

4.3.2 Cognitive Engagement and Learning Supports to Build Technology Design Skillsets.

Students: Cognitive Engagement through Adaptations for Participation and Learning. An important practice of UCD is the distillation of user data into problem insights. The first data analysis activity we taught in class was Affinity Mapping, a tool used by designers to organize large amounts of data into related clusters to uncover patterns in user experiences [55]. In the teaching activity, we presented a data set collected during empathizing activities from the entire class for students to cluster ($\sim$ 25 pieces of data). Students understood the principle of Affinity Mapping, reflecting on how *"finding patterns and themes was helpful because we can know what people feel"* – Caroline (S2). However, several students reported that they felt *"overwhelmed"* - Esther (S4) by the data set and thought it was *"not really easy to understand"* – Sierra (S11). In later activities, we presented students with more manageable datasets (fewer than ten pieces of data). Given these smaller data sets, students reported that they enjoyed subsequent data analysis activities like the Persona more, *"because it was easier"* - Marisol (S5). Providing manageable datasets supported students' cognitive engagement and supported their participation in the technology design skillset of analyzing user data. Adapting activities in this way helped students build proficiency in tools and methods of technology design. Proficiency in skillsets related to technology development is important to CE [36, 44]. Although this adaptation supported student participation in class, it highlights a potential difficulty for their participation in more advanced technology design if they choose to apply their skills in the future, particularly where analysis of large datasets collected through interviews and observations is necessary.

Co-Teachers: Supporting Learning through Targeted Prompts. Co-teachers observed the importance of adding prompts into activities to help keep students focused on the design problem. In early classroom activities, student assignments had general instructions–for example, students were asked to "Make a collage showing us what you want your robot dog to look like" for the Collage activity. Teachers observed that students *"were just, you know, putting things together"* - Michelle (D1) instead of thinking critically about how to apply findings from empathizing activities to inform the dog's appearance. In contrast, the User Stories activity provided targeted prompts that were personalized based on each student's reflections, and created a clear set of steps to apply insights from previous activities. Jolie (E2) described the benefits of this activity, *"You're highlighting a use case essentially for your product, and that leads into requirements to make sure that your product has what the user needs at each step to complete the action...thinking through that was very helpful for the students, because it breaks down the tasks into steps."* Targeted prompts support students by building clear direction for what to do next and helped them focus on the design problem.

4.3.3 Meta-Cognition and Consolidation to Reflect on Students' Relationship with Technology.

Students: Meta-Cognitive Self-Reflection to Better Understand Self, Goals, and Technology. Meta-cognition describes awareness and knowledge about one's own thinking and learning, including planning learning, monitoring performance, and reflecting on learning [102]. Throughout our study, students reported on ways that co-design activities encouraged them to reflect on their relationship with technology. Co-design activities challenged students to examine their own goals, strengths, and challenges, and consider how technology could help them reach their goals. For example, Hunter (S12) described how the Tree of Life helped him *"explain how I want my goals for the future."* The Tree of Life helped Hunter define his goals in order to help him think critically about how technology might fit into these goals. Olivia (S7) described how she liked User Stories because it helped her see *"the strength and weakness [I] have."* This activity helped Olivia visualize what her assets were and think about how the AI job coach can apply her strengths to overcome difficulties. Josiah (S10) described how he designed his AI job coach prototype to reinforce his self-image as a good worker, *"I feel like I can do things on my own [but] with my job coach, I have something to fall back on."* Using self-reflective activities to design technology in a way that reinforced his strengths and presumed his competence, Josiah built toward a future where he can be recognized as a good worker rather than someone in need of help, fighting ableist perspectives that may be embedded in a design created by someone outside of the disability community [83]. An important aim of computational empowerment is the reflection on the role of technology in one's own life, and the empowerment to design toward one's desired futures [37]. Co-design activities in this course encouraged students to reach this aim by encouraging meta-cognitive reflection where students defined goals, evaluated their skills, and created technology designs that help them meet their goals in ways that support their worldviews.

Co-Teachers: Positioning Students as Experts in Consolidation. Consolidation activities are designed to encourage students to reflect on learning by considering how they applied learning to group outcomes, and compare their own learning products to others [42]. The two major consolidation activities in our class were the Storyboard group presentation in front of the class (robot dog) and the Paper Prototype individual presentation to a focus group (AI job coach). Daily learning reflections showed that students were thinking about task completion on the group presentation day, describing how the best thing they did was *"making a presentation with my group"* – Grant (S9), rather than showing evidence of critically evaluating their work. However, learning reflections from the individual presentation to a focus group showed students engaging in reflection about their own projects and their role in contributing to other's projects. Students talked about exchanging ideas by presenting their own prototypes for feedback and expressed pride in how well they gave feedback, *"i fell [sic: feel] like my feedback was good when i tell my classmates."* - Marisol (S5). This activity positioned students as experts by challenging them to come up with ideas to help others, encouraging them to recognize the value in their ideas. These activities supported recognition that each person had an important contribution, *"many minds are better than one, plus we all made different types of ideas while also giving ideas about others ideas"* – Jonathan (S1). When students were positioned as experts and given an active role in activities to support consolidation, they showed a higher level of engagement with design ideas and expressed pride in sharing their ideas with peers. By participating as full members of design communities, students enacted computational empowerment aims of understanding and influencing the role of technology in one's individual world. Our IPSE liaison recalled Jonathan's (S1) reflection on his growth in feelings of empowerment after the focus group, *"I always have a lot of thoughts and I didn't think that people ever really wanted to hear what I had to say. But working in these groups, I've realized that my thoughts are good and people do want to hear them."* Consolidation activities where students acted as experts in a collaborative learning setting created opportunities for students to build empowerment as they considered how their designs and opinions could contribute to technology to change the world for themselves and others.

While interactive feedback activities supported educator goals of consolidating learning outcomes, designers related that these activities did not always meet their co-design aims. Samantha (D3) explained that although students' prototypes yielded *"a lot of the qualitative data that came up while discussing those artifacts."*, the actual presentations did not result in new insights. For the AI job coach, Samantha (D3) wanted to develop design requirements to address students' fundamental needs, and explained that *"the focus group was very question and answer, it didn't really get to the core of the design,"* so it didn't support her research aims. Based on this feedback, we identify a need to understand how to build consolidation activities which are more responsive to co-design aims.

5 Discussion

We taught a course on user-centered design (UCD) for students with IDD enrolled in an IPSE program that implemented a collaborative learning approach to education through a co-teaching partnership between designers and educators. Our findings uncovered tensions related to collaboration between co-teachers and uncovered ways of making education accessible to students with IDD. In Section 5.1, we discuss collaboration practices between co-teachers, and use the Collaborative Reflection Framework (CRF) to suggest how collaborative reflection technology can help assuage tensions between co-teachers with different aims. In Section 5.2, we discuss how students developed skillsets and identities related to technology design in students with IDD through collaborative learning activities.

5.1 Supporting Coordinated Planning and Reflection for Co-Teaching Teams

In this section, we examine the design space for socio-technical systems to support co-teacher teamwork in teaching teams. This classroom used a collaborative learning approach to education. We apply CRF to situate and discuss our findings in broader CSCW research that investigates collaboration practices across education teams [63, 78]. We suggest how technology can support co-teachers to plan effectively in the pre-active phase of teaching by facilitating communication on the long-term loop and shared reflection in the post-active phase of teaching via the short-term loop. Finally, we consider how co-teachers might manage conflicting roles and responsibilities in classrooms when they identify competing goals.

5.1.1 Increasing Goal Transparency Across Co-Teaching Teams in the Pre-Active Phase of Instruction. The CRF emphasizes the importance of determining activities and monitoring goal progress on the long term communication loop, where instructors determine appropriate interventions, apply interventions across settings, monitor and evaluate intervention effects, and communicate about progress toward goals [63]. Previous work on the CRF explores how teams communicate around goals for individual care recipients, focusing on information-sharing between team members as they target shared goals for individuals [62, 64]. Extending this to a classroom setting with many students, the long term loop includes the same basic set of activities with two exceptions. First, instead of tracking learning interventions targeting one student, a full class of students is targeted. Second, Kaendler et al.'s framework for teachers includes a step for determining classroom goals [42]. In the teaching setting that we describe, this is further complicated because we had multiple teachers with multiple classroom goals. Our interviews uncovered tensions that emerged between co-teachers trying to meet competing aims during planning activities.

During this pre-active planning phase, we found that when goals were not transparent to all team members, classroom activities did not target the needs of different team members resulting in frustration. In the beginning of the course, the lead educator planned activities with an emphasis on meeting learning goals. However, as the course went on, educators and designers worked more closely together to design activities. They adopted a practice of clearly voicing what learning and co-design outcomes they needed to achieve before planning. Previous work in HCI has discussed the importance of building sociotechnical systems that increase the transparency of user goals in order to ensure that team members are aware and accountable for meeting these goals [22]. We consider how to adapt the practice of goal transparency into the CRF framework to guide technology development for co-teaching teams.

Literature that examines goal-setting using the CRF has discussed determining the appropriate goals [63], refining operational definitions of goals [64], and ensuring that goal-setting includes the target of care [59]. However, this literature does not closely consider cases where team members do not have shared goals. In such cases, our findings revealed a need to openly discuss and acknowledge different goals in order to plan activities that consistently target the goals of different team members, or foster communication about why activities do not meet goals. To facilitate goal-sharing practices, we examined teaching literature to understand current collaboration practices of co-teaching teams.

Teaching literature describes various ways to support co-teacher coordination, suggesting that synchronous and asynchronous communication and planning templates can support successful collaboration between teachers [75]. Therefore, we propose that shared planning templates from teaching literature can be adapted to support open communication by making goals visible to all co-teachers throughout the planning process. Previous work on co-teaching planning templates suggests that templates to support planning in this environment should encode information about co-teachers, students, and goals across different timelines [45, 69, 75]. However, work on teaching templates has typically been built to suit the needs of co-teaching between professional educators. Therefore, adaptations should consider how to build support for non-teachers as well. Co-teaching partnerships between industry professionals and teachers suggest a need to include clear breakdowns of instructional practices so that non-educators understand the rhythm of classroom teaching [34] and remember to focus on learning outcomes in planning [71]. Therefore, planning templates should also address flexibility to account for knowledge gaps in educational practices among industry professionals. Artificial intelligence (AI), which may be useful in supporting co-teaching teams, has been deployed to generate lesson plan templates (e.g., [89]), and could be a useful tool to support lesson planning by generating suggestions for activities and activity modifications that meet the goals of all co-teachers.

5.1.2 Breaking Reflection Silos in the Post-Active Phase. On the short term communication loop, the CRF describes how care team members record, share, and corroborate their interpretations of daily events in order to create a shared understanding of an individual's day-to-day activities [62–64, 78]. The CRF has considered how activity data and observations collected in one setting can be shared with people in other settings who did not immediately witness the activity, for example between home and school [63, 78] or between teachers who are not co-located [62]. Sharing observations between team members allows experts from different fields to apply their expertise to observations and give direction to others on the team based on their interpretation of an individual's actions [62]. Our co-teaching team shares many features of care teams described by the CRF literature. It was comprised of members with expertise across different domains, and team members were not able to directly observe learning activities because they were assigned to support different learning groups. However, our environment had two unique features. First, co-teachers had to account for activity outcomes and learning trends across multiple students working across multiple student groups, not just one single learner. Second, co-teachers had different outcome goals, as members of the educator team were primarily interested in learning outcomes and members of the design team were primarily interested in co-design outcomes. We propose that building tools to encourage communication on the short-term loop described by the CRF can support better outcomes in teaching environments like ours, where co-teachers work in silos related to their expertise to understand how multiple learners are progressing toward competing learning outcomes.

The challenges of tracking multiple students' learning progress has been considered by technology designers who apply learning analytics to build technology for teachers. Learning analytics is "the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs" [56]. Learning analytic technologies have explored automated collection of student data during learning activities to provide teachers with information about trends in student learning [6, 30, 43, 92–95]. This technology has been applied to synthesize insights from group activities in collaborative learning environments [6, 92–95] and homework assignments [30]. Insights can be displayed through teacher dashboards, where teachers can use this information to make decisions about how to proceed with learning. One feature that has been explored in teacher dashboards is how to highlight different information to guide teacher decision-making [95]. Applied to our classroom environment, these dashboards can highlight information relevant to both learning and research outcomes. This ensures that co-teachers remain cognizant of multiple classroom goals and build accountability to track the progress of students in learning groups they are facilitating toward meeting varied classroom goals.

Marcu et al. propose that applying the CRF can help break down team communication silos by supporting flexible views of data and informal communication [61]. Therefore, dashboards produced for co-teaching teams should offer flexible exploration of data so that co-teachers can explore data related to goals they are invested in and support data sharing between teachers, such as through links to data points of interest. To enable informal conversation around data, Marcu et al. suggest that co-teachers can share insights by commenting on individual data points, for instance by providing links to data points or forums [61]. A similar system was employed by Shin et al. to enable communication between teachers and clinicians around the use of a communication device [84]. This system allowed teachers and clinicians to comment on communication data to support shared reflection and problem-solving around day-to-day device use. Teacher dashboards for this environment can be styled with similar features to support shared reflections on learning in co-teaching environments. Teacher dashboards can report directly on classroom goals related to both learning and design, and enable communication around learner data. A dashboard interface that shows data related to multiple classroom goals and invites interaction between co-teachers about classroom activities can create a foundation for coordinated reflection.

5.1.3 Centering Goals on Student Agency to Manage Conflicting Classroom Roles. Educators and designers on our co-teaching team were tasked with adopting classroom roles supporting learning and design outcomes, causing tension when these aims were in competition. To mitigate tension, we suggest that co-teachers define shared goals centered on student agency, encouraging co-teachers to recognize that design-focused and education-focused activities can be complementary pathways toward a shared outcome of supporting students with IDD to become empowered designers. Goals centered on student agency follow computational empowerment recommendations of situating students in 'protagonist' design roles [36], and follow calls in HCI literature to increase the agency of neurodiverse people in design and education spaces [29, 47, 52, 58, 59, 87, 88, 98]. Establishing a collaborative classroom culture by identifying common goals can support positive co-teaching relationships, decreasing perceived co-teacher conflict [91]. Rather than tensions building over competing aims, collaborative planning and reflection might unfold around how well activities supported student agency rather than how much data was collected or how much content was covered. We consider how developing and reflecting around shared goals of building students' agency might be achieved on both the long-term and short-term loop of collaborative reflection [61, 63, 64].

On the long-term loop, co-teachers can construct co-design project goals and learning objectives that are responsive to students' motivations and interests. In our course, we determined that coursework should maximize opportunities to learn about and practice design skills of data collection, analysis, and prototyping rather than defining a problem space or constructing design goals. This determination was informed by interactions with our IPSE liaison and observations of students before the project began. Other researchers taking this co-design education approach should similarly define goals and objectives aligned with student priorities. For example, researchers might focus on developing self-identified projects with students passionate about advocacy. This focus would support students' interests while yielding valuable insights into design objectives of the IDD community, responding to HCI research encouraging community-defined projects for underrepresented groups [32, 33]. Researchers should discover students' skills, interests, and motivations, and encourage computational empowerment by building knowledge and skills related to these areas [35, 37, 44, 86]. Kaspersen et al. propose a computational empowerment learning progression that may be useful in determining good 'next steps' for students in a co-design education environment like we propose [44].

On the short-term loop, co-teachers can improve their instructional skills by adopting a practice of critically comparing and reflecting on each other's practices [12], focusing on how members of different teams encouraged student agency in daily activities. For example, educators might observe how designers framed questions in design-focused activities to uncover students' authentic opinions without 'leading' them, a concern for design with this group [2, 8, 11]. Similarly, designers might observe how educators supported students with varied learning profiles by employing strategies like representing information in different ways during education-focused activities [79], to ensure students understood design fundamentals well enough to participate in co-design activities confidently. Co-teachers can then apply these insights to support their dual roles of design facilitator and student educator. Establishing a practice of agency-focused critical co-observation and reflection can support teachers to skillfully support students' growth during both design-focused and education-focused activities. Developing a collaborative teaching environment where designers and educators establish shared goals focused on student agency and develop cross-disciplinary skillsets through critical observation can work toward supporting students with IDD to become independent, empowered designers.

5.2 Expanding Computational Empowerment to Higher Education for People with IDD using a Collaborative Learning Lens

In this section, we consider ways that co-design activities can be adapted for collaborative learning environments by building the three elements of collaborative learning activities, which are collaboration, cognition, and meta-cognition [42]. We discuss how adapting co-design activities according to these principles supports computational empowerment aims of encouraging students to consider the roles they want technology to play in their lives and build technology for those roles [37].

5.2.1 Collaboration: Communication Supports for Students with IDD. Encouraging active participation is central to both collaborative learning and co-design environments, as it is important that all group members can understand and contribute to knowledge construction. HCI researchers have highlighted a number of co-design adaptations to support authentic contributions by people with IDD to participatory design. Among these include using concrete, visual materials in activity prompts [2, 16, 24, 77], inviting participation through a variety of means [16], and focusing on using strengths to enable authentic participation [7]. However, these methods focus on communicating ideas to the researchers, whereas collaborative learning emphasizes the importance of communication between peers. Our findings contribute to understanding how adaptations can be deployed to support peer-to-peer collaboration. We uncovered two opportunities for supporting collaboration via peer-to-peer interactions in students with IDD: Building rotating roles into groups, and introducing accessible technology to support communication in group learning collaboration.

Teachers observed that students with different communication dispositions thrived in different kinds of groups. They observed that louder students often shared large groups whereas quieter students were more active in small groups. Furthermore, they recognized that different types of group sizes yielded different kinds of data, where students were more likely to share stories in large groups and focus on design elements in small groups. To ensure more balanced sharing and interact with students' ideas, we suggest a rotating set of student role assignments. For example, one student from each group could be assigned a group leadership role such as contributing a story to be shared in the large group discussion, commenting on others' ideas, or leading a design activity in small group. Research on rotating leadership shows that rotating responsibility for online knowledge building leads to increases in students' intentionality toward learning, and that acting as leaders can lead to greater knowledge gains for weaker students [60].

Our findings also showed that there were some students who did not wish to communicate verbally in groups at all, or who sometimes found it difficult to put ideas together verbally. Introducing technology to support students' contributions can support group collaboration by enabling additional communication avenues for these students. Jeong and Hmelo-Silver presented how computer-supported collaborative learning (CSCL) technology can support asynchronous peer-to-peer communication and collaboration through tools like knowledge forums and community databases [39]. However, tools are often heavily text-based and ask students to navigate complex visuals, for example Scardamalia's Knowledge Forum [81]. These interfaces may be made more accessible by inviting students to contribute in ways they are most comfortable in (e.g., links, text, voice recording, photos), or by building in reaction icons so students can respond to each others' ideas non-verbally. Work by Bayor et al. used familiar interface icons that adults with IDD showed competency in to develop an accessible video-sharing interface [7]. Designers could adopt a similar practice, offering familiar reaction emojis similar to messaging and social media apps to react to others' ideas (e.g., thumbs up for accept, question mark for questions, etc). Defining different avenues for contributing ideas, and rotating leadership responsibility contributes to CE by encouraging students to adopt an active role in learning about technology design and sharing their ideas for the future.

5.2.2 Cognition: Tools for Accessible Data Analysis. In our class, students were able to successfully identify themes across data points in activities such as Affinity Mapping and Persona. However, they reported feeling overwhelmed by large amounts of data. This is a challenge given that user data created in UCD activities tends to be very large because it is composed from long interviews and observations. Recent advances in AI have made it possible to perform automated data analysis on datasets commonly produced in user-centered design work, such as interview transcripts or survey responses, and have been integrated into some commercially available tools [67, 76] in the form of text and visualization summaries. Building data analysis software with AI integration that simplifies data analysis for people with IDD can support students with IDD to understand themes in user data and participate in the more cognitively complex aspects of user-centered design. However, in designing the outputs of AI data analytics, it is important to consider factors that will make this data both easy to understand for this group while building interactive tools to create a feeling of ownership of the products, for example by building accessible visualizations [99] and including opportunities to manipulate and direct AI output [57]. A set of accessible data analysis tools can support students with IDD to critically engage with data, an important feature of CE teaching environments [44].

5.2.3 Meta-Cognition: Building Student Identities as Technology Designers Through Equal Exchange of Ideas. Our classroom took a computational empowerment approach that challenged students to take on identities as designers by working alongside professionals to co-design technology. Our findings showed that consolidating learning through interactive presentations and critiques of design products was important to CE as students reflected on the importance of their voice and opinions on design outcomes after participating in these activities. However, we identified a need to incorporate design aims into these presentations. We propose a consolidation activity where students and designers are positioned as co-professionals, where they present and critique each other's design ideas as equals. This activity preserves and reinforces the positioning of students as experts by inviting them to exchange feedback with professional designers, while creating an opportunity for designers to get input on their own ideas from students. We suggest that after presentation and feedback activities, students be encouraged to consider the experience of presenting work, and giving and receiving feedback with others. Self-efficacy work shows that intentional reflection around your own successes and challenges, as well as that of others you identify with, contributes to a belief that you can be successful [3]. Therefore, introducing a reflection tool that explicitly asks students to consider their role and performance as part of a design team with other professionals can encourage them to reflect and strengthen their own identity as designers. This aligns with the aims of co-design to involve participants at every stage of the design process, while further fueling students' development of a self-identity as technology designers by positioning them as equals to professional designers in the exchange of ideas.

6 Limitations

Intellectual disability describes a broad range of people and abilities. This study only included a subset of that group–those eligible for the IPSE program we partnered with. All of our students had basic reading, writing, math, and verbal communication skills. Students were all interested in pursuing higher education at a technical university and selected this course as an elective. Therefore, the findings of this work should be applied cautiously to people who have different skillsets and interests. The accommodations and activities that we recommend may need to be reconsidered, or adjusted for different groups of people with IDD. Future work exploring co-design activity modifications to support learning for students with IDD is needed to understand how adaptations can best support learners with IDD, for example by considering how universal design for learning and co-design values might be aligned to guide activity development in a co-design education setting [79].

There is also an inherent power differential in a classroom which interrupts the democratic values of co-design. Remaining cognizant of this, we emphasized that grades were based heavily on participation rather than work quality, and attempted to make activities fun and engaging to ensure that research participation did not negatively impact grades. This created an unexpected limitation on education opportunities, as our IPSE liaison reflected that by making the course easy to pass, we limited students' ability to self-reflect on their efforts. In future co-design coursework, she recommended making grading more challenging to offer higher stakes. Researchers have emphasized the importance of bringing authentic risk of failure into IPSE classrooms to challenge students in the same way as neurotypical students [13]. Balancing authentic risk with avoiding negative consequences of research participation should be considered in future research applications of this educational model. Regarding research outcomes, students and mentors sometimes reflected that students were bored in class or seemed like they had low 'buy-in' and were just finishing assignments instead of truly considering design. This limitation could be addressed by continued improvement in activity planning, or by adding in a question on the daily reflection about how focused they felt in class to determine the value of design insights generated on days when students had low motivation.

Finally, the authors of this paper all identify as neurotypical. Our co-design methods and findings are biased by our own viewpoints as neurotypical researchers and by our positionality as teachers rather than truly equal design partners. We based our coding scheme on student feedback to combat this bias, however, some bias is likely to have entered our analysis nonetheless.

7 Conclusion

This work describes a classroom model in which educators and designers acted as co-teachers for students with IDD who were learning user-centered design (UCD) in a collaborative learning setting which aimed to teach UCD through a process of co-designing technology. We adapted co-design activities for a collaborative learning setting, taking a computational empowerment approach to technology instruction where students developed identities as technology designers whose opinions and actions were important to building technology for the future. Our findings showed that it was important for co-teachers to practice open communication around their competing goals and engage in collaborative reflection on outcomes of teaching activities. During design activities, it was important for students to interact with each other to exchange ideas, participate in challenging and cognitively accessible learning, and present the results of their design projects. We propose tools and classroom practices to promote co-teacher communication around goals and collaborative reflection between co-teachers. We suggest that co-teachers align goals around student agency and engage in critical co-observations to manage competing roles as both design facilitators and educators. Finally, we consider how technology can support students' computational empowerment by increasing the accessibility of user-centered design, and how class activities can supports students' self-identities as technology designers.

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References

[1] Roya Jafari Amineh and Hanieh Davatgari Asl. 2015. Review of constructivism and social constructivism. *Journal of social sciences, literature and languages* 1, 1 (2015), 9–16.

[2] Eamon Aswad, Emma Murphy, Claudia Fernandez-Rivera, and Sarah Boland. 2022. Towards an inclusive co-design toolkit: perceptions and experiences of co-design stakeholders. In *International Conference on Computers Helping People with Special Needs*. Springer, 284–292.

[3] Albert Bandura. 1977. Self-efficacy: toward a unifying theory of behavioral change. *Psychological review* 84, 2 (1977), 191.

[4] Wolmet Barendregt, Tilde M Bekker, Peter Börjesson, Eva Eriksson, and Olof Torgersson. 2016. Legitimate participation in the classroom context: Adding learning goals to participatory design. In *Proceedings of the The 15th International Conference on Interaction Design and Children*. 167–174.

[5] Wolmet Barendregt, Peter Börjesson, Eva Eriksson, Olof Torgersson, Tilde Bekker, and Helle Marie Skovbjerg. 2018. Modelling the roles of designers and teaching staff when doing participatory design with children in special education. In *Proceedings of the 15th Participatory Design Conference: Full Papers-Volume 1*. 1–11.

[6] Tammy Barron, Marilyn Friend, Lisa Dieker, and Shalece Kohnke. 2022. Co-teaching in uncertain times: Using technology to improve student learning and manage today's complex educational landscape. *Journal of Special Education Technology* 37, 3 (2022), 439–446.

[7] Andrew A Bayor, Margot Brereton, Laurianne Sitbon, Bernd Ploderer, Filip Bircanin, Benoit Favre, and Stewart Koplick. 2021. Toward a competency-based approach to co-designing technologies with people with intellectual disability. *ACM Transactions on Accessible Computing (TACCESS)* 14, 2 (2021), 1–33.

[8] Filip Bircanin, Margot Brereton, Laurianne Sitbon, Bernd Ploderer, Andrew Azaabanye Bayor, and Stewart Koplick. 2021. Including adults with severe intellectual disabilities in co-design through active support. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. 1–12.

[9] Noora Bosch. 2022. Design of the Participatory Learning Experience: Teachers' new roles as designers of engaging design and maker-based learning experiences. In *Interaction Design and Children*. 452–457.

[10] Claus Bossen, Christian Dindler, and Ole Sejer Iversen. 2016. Evaluation in participatory design: a literature survey. In *Proceedings of the 14th Participatory Design Conference: Full papers-Volume 1*. 151–160.

[11] Margot Brereton, Laurianne Sitbon, Muhammad Haziq Lim Abdullah, Mark Vanderberg, and Stewart Koplick. 2015. Design after design to bridge between people living with cognitive or sensory impairments, their friends and proxies. *CoDesign* 11, 1 (2015), 4–20.

[12] Lyndsay R Buckingham, Alfonso López-Hernández, and Birgit Strotmann. 2021. Learning by Comparison: The Benefits of Co-Teaching for University Professors' Professional Development. In *Frontiers in Education*, Vol. 6. Frontiers Media SA, 776991.

[13] Jennifer L Bumble, Christopher RJ Worth, Lindsay S Athamanah, Magen Rooney-Kron, April Regester, and Jonathan Lidgus. 2022. "Messy Inclusion": A call for dignity of risk in inclusive postsecondary education. *Inclusive Practices* 1, 2 (2022), 64–69.

[14] Juanjuan Chen, Minhong Wang, Paul A Kirschner, and Chin-Chung Tsai. 2018. The role of collaboration, computer use, learning environments, and supporting strategies in CSCL: A meta-analysis. *Review of Educational Research* 88, 6

(2018), 799–843.
[15] Marc Clarà, Teresa Mauri, Rosa Colomina, and Javier Onrubia. 2019. Supporting collaborative reflection in teacher education: A case study. *European Journal of Teacher Education* 42, 2 (2019), 175–191.
[16] Ryan Colin Gibson, Mark D. Dunlop, and Matt-Mouley Bouamrane. 2020. Lessons from expert focus groups on how to better support adults with mild intellectual disabilities to engage in co-design. In *Proceedings of the 22nd International ACM SIGACCESS Conference on Computers and Accessibility*. 1–12.
[17] Sara Cothren Cook, Kimberly A McDuffie-Landrum, Linda Oshita, and Bryan G Cook. 2017. Co-teaching for students with disabilities: A critical and updated analysis of the empirical literature. In *Handbook of special education*. Routledge, 233–248.
[18] Sasha Costanza-Chock. 2020. Design Practices:"Nothing about Us without Us". *Design Justice* (2020).
[19] Bronwyn Cumbo and Neil Selwyn. 2022. Using participatory design approaches in educational research. *International Journal of Research & Method in Education* 45, 1 (2022), 60–72.
[20] M Ann Garrison Darrin and William S Devereux. 2017. The Agile Manifesto, design thinking and systems engineering. In *2017 Annual IEEE International Systems Conference (SysCon)*. IEEE, 1–5.
[21] Ana Maria Bustamante Duarte, Nina Brendel, Auriol Degbelo, and Christian Kray. 2018. Participatory design and participatory research: An HCI case study with young forced migrants. *ACM Transactions on Computer-Human Interaction (TOCHI)* 25, 1 (2018), 1–39.
[22] Thomas Erickson and Wendy A. Kellogg. 2000. Social Translucence: An Approach to Designing Systems That Support Social Processes. *ACM Trans. Comput.-Hum. Interact.* 7, 1 (mar 2000), 59–83. https://doi.org/10.1145/344949.345004
[23] Eva Eriksson and Olof Torgersson. 2021. "The concept of learning goals will always be in my head"-Aligning and Applying Learning Goals in Participatory Design in a School Context. In *Interaction Design and Children*. 153–159.
[24] Claudia Fernandez-Rivera, Sarah Boland, Eamon Aswad, John Gilligan, Dympna O'Sullivan, and Emma Murphy. 2022. AccessDesign: An inclusive co-design toolkit for the creation of accessible digital tools. (2022).
[25] Dian Fluijt, Cok Bakker, and Elke Struyf. 2016. Team-reflection: The missing link in co-teaching teams. *European journal of special needs education* 31, 2 (2016), 187–201.
[26] Katie Gaudion, Ashley Hall, Jeremy Myerson, and Liz Pellicano. 2015. A designer's approach: how can autistic adults with learning disabilities be involved in the design process? *CoDesign* 11, 1 (2015), 49–69.
[27] Barbara Göbl, Elisabeth Anna Guenther, Fares Kayali, and Christopher Frauenberger. 2023. Situating computational empowerment in formal education: A multi-perspective view. *International Journal of Child-Computer Interaction* 38 (2023), 100604.
[28] Jacob Hackett, Megan Bang, Arielle Goulter, and Maritess Battista. 2019. Crossing risky boundaries: Learning to authentically and equitably co-teach through design and practice. *Teaching and Teacher Education* 86 (2019), 102889.
[29] Kaely Hall, Parth Arora, Rachel Lowy, and Jennifer G Kim. 2024. Designing for Strengths: Opportunities to Support Neurodiversity in the Workplace. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems*. 1–14.
[30] Priya Harindranathan and James Folkestad. 2019. Learning Analytics to Inform the Learning Design: Supporting Instructors' Inquiry into Student Learning in Unsupervised Technology-Enhanced Platforms. *Online Learning* 23, 3 (2019), 34–55.
[31] Tellervo Härkki, Henriikka Vartiainen, Pirita Seitamaa-Hakkarainen, and Kai Hakkarainen. 2021. Co-teaching in non-linear projects: A contextualised model of co-teaching to support educational change. *Teaching and Teacher Education* 97 (2021), 103188.
[32] Christina Harrington, Sheena Erete, and Anne Marie Piper. 2019. Deconstructing community-based collaborative design: Towards more equitable participatory design engagements. *Proceedings of the ACM on Human-Computer Interaction* 3, CSCW (2019), 1–25.
[33] Gillian R Hayes. 2011. The relationship of action research to human-computer interaction. *ACM Transactions on Computer-Human Interaction (TOCHI)* 18, 3 (2011), 1–20.
[34] Aleata Hubbard and Katie D'Silva. 2018. Professional learning in the midst of teaching computer science. In *Proceedings of the 2018 ACM Conference on International computing education research*. 86–94.
[35] Netta Iivari. 2020. Empowering children to make and shape our digital futures–from adults creating technologies to children transforming cultures. *The International Journal of Information and Learning Technology* 37, 5 (2020), 279–293.
[36] Ole Sejer Iversen, Rachel Charlotte Smith, and Christian Dindler. 2017. Child as protagonist: Expanding the role of children in participatory design. In *Proceedings of the 2017 conference on interaction design and children*. 27–37.
[37] Ole Sejer Iversen, Rachel Charlotte Smith, and Christian Dindler. 2018. From computational thinking to computational empowerment: a 21st century PD agenda. In *Proceedings of the 15th participatory design conference: Full papers-Volume 1*. 1–11.

[38] George M Jacobs. 2015. Collaborative Learning or Cooperative Learning? The Name Is Not Important; Flexibility Is. *Online Submission* 3, 1 (2015), 32–52.

[39] Heisawn Jeong and Cindy E Hmelo-Silver. 2016. Seven affordances of computer-supported collaborative learning: How to support collaborative learning? How can technologies help? *Educational Psychologist* 51, 2 (2016), 247–265.

[40] Heisawn Jeong, Cindy E Hmelo-Silver, and Kihyun Jo. 2019. Ten years of computer-supported collaborative learning: A meta-analysis of CSCL in STEM education during 2005–2014. *Educational research review* 28 (2019), 100284.

[41] Suhas Govind Joshi and Tone Bratteteig. 2016. Designing for prolonged mastery. On involving old people in participatory design. *Scandinavian Journal of Information Systems* 28, 1 (2016), 1.

[42] Celia Kaendler, Michael Wiedmann, Nikol Rummel, and Hans Spada. 2015. Teacher competencies for the implementation of collaborative learning in the classroom: A framework and research review. *Educational Psychology Review* 27 (2015), 505–536.

[43] Reet Kasepalu. 2020. Overcoming the difficulties for teachers in collaborative learning using multimodal learning analytics. In *2020 IEEE 20th International Conference on Advanced Learning Technologies (ICALT)*. IEEE, 393–395.

[44] Magnus Høholt Kaspersen, Daniel Graungaard, Niels Olof Bouvin, Marianne Graves Petersen, and Eva Eriksson. 2021. Towards a model of progression in computational empowerment in education. *International Journal of Child-Computer Interaction* 29 (2021), 100302.

[45] Elizabeth B Keefe, Veronica Moore, and Frances Duff. 2004. The four "knows" of collaborative teaching. *Teaching exceptional children* 36, 5 (2004), 36–42.

[46] Beaumie Kim. 2001. Social constructivism. *Emerging perspectives on learning, teaching, and technology* 1, 1 (2001), 16.

[47] Jennifer G Kim, Taewan Kim, Sung-In Kim, So-youn Jang, Eun Bin Lee, Heejung Yoo, Kyungsik Han, and Hwajung Hong. 2022. The workplace playbook VR: exploring the design space of virtual reality to foster understanding of and support for autistic people. *Proceedings of the ACM on Human-Computer Interaction* 6, CSCW2 (2022), 1–24.

[48] Mi Song Kim. 2019. Developing a competency taxonomy for teacher design knowledge in technology-enhanced learning environments: a literature review. *Research and Practice in Technology Enhanced Learning* 14 (2019), 1–24.

[49] Margaret E King-Sears, Abraham Stefanidis, Sheri Berkeley, and Vasilis Strogilos. 2021. Does co-teaching improve academic achievement for students with disabilities? A meta-analysis. *Educational Research Review* 34 (2021), 100405.

[50] Janet L Kolodner. 2002. Facilitating the learning of design practices: Lessons learned from an inquiry into science education. *Journal of Industrial Teacher Education* 39, 3 (2002), 9–40.

[51] Ha-Kyung (Hidy) Kong, Derek Xie, Ankith Chandra, Rachel Lowy, Arielle Maignan, Sehoon Ha, Chung Hyuk Park, and Jennifer G. Kim. 2024. Co-designing Robot Dogs with and for Neurodivergent Individuals: Opportunities and Challenges. *ASSETS* (2024).

[52] Ha-Kyung (Hidy) Kong, Saloni Yadav, Rachel Lowy, Daniella Ruzinov, and Jennifer Kim. 2024. Understanding Online Job and Housing Search Practices of Neurodiverse Young Adults to Support Their Independence. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems*. 1–13.

[53] Marjan Laal and Seyed Mohammad Ghodsi. 2012. Benefits of collaborative learning. *Procedia-social and behavioral sciences* 31 (2012), 486–490.

[54] Christopher A Le Dantec and Sarah Fox. 2015. Strangers at the gate: Gaining access, building rapport, and co-constructing community-based research. In *Proceedings of the 18th ACM conference on computer supported cooperative work & social computing*. 1348–1358.

[55] Katie Li, Ashutosh Tiwari, Jeffrey Alcock, and Pablo Bermell-Garcia. 2016. Categorisation of visualisation methods to support the design of Human-Computer Interaction Systems. *Applied ergonomics* 55 (2016), 85–107.

[56] Phillip Long. 2011. *Proceedings of the 1st international conference on learning analytics and knowledge*. ACM.

[57] Ryan Louie, Andy Coenen, Cheng Zhi Huang, Michael Terry, and Carrie J Cai. 2020. Novice-AI music co-creation via AI-steering tools for deep generative models. In *Proceedings of the 2020 CHI conference on human factors in computing systems*. 1–13.

[58] Rachel Lowy, Lan Gao, Kaely Hall, and Jennifer G Kim. 2023. Toward inclusive mindsets: Design opportunities to represent neurodivergent work experiences to neurotypical co-workers in virtual reality. In *Proceedings of the 2023 CHI conference on human factors in computing systems*. 1–17.

[59] Rachel Lowy, Chung Eun Lee, Gregory D Abowd, and Jennifer G Kim. 2023. Building Causal Agency in Autistic Students through Iterative Reflection in Collaborative Transition Planning. *Proceedings of the ACM on Human-Computer Interaction* 7, CSCW2 (2023), 1–26.

[60] Leanne Ma, Samuel Tan, Chew Lee Teo, and Muhamad Ansar B Kamsan. 2017. Using rotating leadership to visualize students' epistemic agency and collective responsibility for knowledge advancement. Philadelphia, PA: International Society of the Learning Sciences.

[61] Gabriela Marcu. 2016. Breaking down silos to promote collaborative reflection in healthcare. In *2016 International Conference on Collaboration Technologies and Systems (CTS)*. IEEE, 617–618.

[62] Gabriela Marcu, Anind K Dey, and Sara Kiesler. 2014. Designing for collaborative reflection. In *Proceedings of the 8th International Conference on Pervasive Computing Technologies for Healthcare*. 9–16.

[63] Gabriela Marcu, Allison Spiller, Jonathan Arevalo Garay, James E Connell, and Laura R Pina. 2019. Breakdowns in home-school collaboration for behavioral intervention. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. 1–12.

[64] Gabriela Marcu and Allison N Spiller. 2020. Collaborative aspects of collecting and reflecting on behavioral data. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. 1–13.

[65] Jane Margolis, Jean Ryoo, and Joanna Goode. 2017. Seeing myself through someone else's eyes: The value of in-classroom coaching for computer science teaching and learning. *ACM Transactions on Computing Education (TOCE)* 17, 2 (2017), 1–18.

[66] Margo A Mastropieri, Thomas E Scruggs, Janet Graetz, Jennifer Norland, Walena Gardizi, and Kimberly Mcduffie. 2005. Case studies in co-teaching in the content areas: Successes, failures, and challenges. *Intervention in school and clinic* 40, 5 (2005), 260–270.

[67] MaxQDA. 2024. https://www.maxqda.com/

[68] Emily L Mofield. 2020. Benefits and barriers to collaboration and co-teaching: Examining perspectives of gifted education teachers and general education teachers. *Gifted Child Today* 43, 1 (2020), 20–33.

[69] Tanya Moorehead and Kelly Grillo. 2013. Celebrating the reality of inclusive STEM education: Co-teaching in science and mathematics. *Teaching Exceptional Children* 45, 4 (2013), 50–57.

[70] Eileen Murray. 2015. Improving teaching through collaborative reflective teaching cycles. *Investigations in Mathematics Learning* 7, 3 (2015), 23–29.

[71] Rebecca Nicholson, Tom Bartindale, Ahmed Kharrufa, David Kirk, and Caroline Walker-Gleaves. 2022. Participatory Design Goes to School: Co-Teaching as a Form of Co-Design for Educational Technology. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*. 1–17.

[72] American Association on Intellectual and Developmental Disabilities. 2023. Defining Criteria for Intellectual Disability. https://www.aaidd.org/intellectual-disability/definition#.VgrjLHnJC71

[73] Tina J Ostrander. 2015. Making learning relevant for the real world: co-teaching with an industry professional. *ACM Inroads* 6, 2 (2015), 44–49.

[74] Theodore Panitz and Patricia Panitz. 1998. Encouraging the use of collaborative learning in higher education. *University teaching: International perspectives* (1998), 161–201.

[75] Sharon M Pratt, Sarah M Imbody, Lindsay D Wolf, and Amanda L Patterson. 2017. Co-planning in co-teaching: A practical solution. *Intervention in School and Clinic* 52, 4 (2017), 243–249.

[76] Qualtrics. 2024. https://www.qualtrics.com/

[77] Sneha Raman and Tara French. 2022. Enabling genuine participation in co-design with young people with learning disabilities. *CoDesign* 18, 4 (2022), 431–447.

[78] Olivia K Richards, Adrian Choi, and Gabriela Marcu. 2021. Shared Understanding in Care Coordination for Children's Behavioral Health. *Proceedings of the ACM on Human-Computer Interaction* 5, CSCW1 (2021), 1–25.

[79] David H Rose, Wendy S Harbour, Catherine Sam Johnston, Samantha G Daley, and Linda Abarbanell. 2006. Universal design for learning in postsecondary education: Reflections on principles and their application. *Journal of postsecondary education and disability* 19, 2 (2006), 135–151.

[80] Elizabeth B-N Sanders and Pieter Jan Stappers. 2008. Co-creation and the new landscapes of design. *Co-design* 4, 1 (2008), 5–18.

[81] Marlene Scardamalia. 2004. CSILE/Knowledge forum®. *Education and technology: An encyclopedia* 183 (2004), 192.

[82] Marie-Monique Schaper, Rachel Charlotte Smith, Mariana Aki Tamashiro, Maarten Van Mechelen, Mille Skovhus Lunding, Karl-Emil Kjæer Bilstrup, Magnus Høholt Kaspersen, Kasper Løvborg Jensen, Marianne Graves Petersen, and Ole Sejer Iversen. 2022. Computational empowerment in practice: Scaffolding teenagers' learning about emerging technologies and their ethical and societal impact. *International Journal of Child-Computer Interaction* (2022), 100537.

[83] Ashley Shew. 2020. Ableism, technoableism, and future AI. *IEEE Technology and Society Magazine* 39, 1 (2020), 40–85.

[84] Donghoon Shin, Jaeyoon Song, Seokwoo Song, Jisoo Park, Joonhwan Lee, and Soojin Jun. 2020. TalkingBoogie: collaborative mobile AAC system for non-verbal children with developmental disabilities and their caregivers. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. 1–13.

[85] Laurianne Sitbon and Shanjana Farhin. 2017. Co-designing interactive applications with adults with intellectual disability: A case study. In *Proceedings of the 29th Australian conference on computer-human interaction*. 487–491.

[86] Rachel Charlotte Smith, Marie-Monique Schaper, Mariana Aki Tamashiro, Maarten Van Mechelen, Marianne Graves Petersen, and Ole Sejer Iversen. 2023. A research agenda for computational empowerment for emerging technology education. *International Journal of Child-Computer Interaction* (2023), 100616.

[87] Katta Spiel, Christopher Frauenberger, Os Keyes, and Geraldine Fitzpatrick. 2019. Agency of autistic children in technology research—A critical literature review. *ACM Transactions on Computer-Human Interaction (TOCHI)* 26, 6

(2019), 1–40.

[88] Katta Spiel and Kathrin Gerling. 2021. The purpose of play: How HCI games research fails neurodivergent populations. *ACM Transactions on Computer-Human Interaction (TOCHI)* 28, 2 (2021), 1–40.

[89] Teachology.ai. 2024. https://www.teachology.ai/

[90] ThinkCollege.net. 2022. Join us on May 1, 2023 for #IPSEDay2023! https://thinkcollege.net/resources/join-us-on-may-1-2023-for-ipseday2023

[91] Jacqueline S Thousand, Richard A Villa, and Ann I Nevin. 2006. The many faces of collaborative planning and teaching. *Theory into practice* 45, 3 (2006), 239–248.

[92] Anouschka Van Leeuwen and Jeroen Janssen. 2019. A systematic review of teacher guidance during collaborative learning in primary and secondary education. *Educational Research Review* 27 (2019), 71–89.

[93] Anouschka Van Leeuwen, Jeroen Janssen, Gijsbert Erkens, and Mieke Brekelmans. 2015. Teacher regulation of cognitive activities during student collaboration: Effects of learning analytics. *Computers & Education* 90 (2015), 80–94.

[94] Anouschka Van Leeuwen and Nikol Rummel. 2020. Comparing teachers' use of mirroring and advising dashboards. In *Proceedings of the tenth international conference on learning analytics & knowledge*. 26–34.

[95] Anouschka Van Leeuwen, Nikol Rummel, and Tamara Van Gog. 2019. What information should CSCL teacher dashboards provide to help teachers interpret CSCL situations? *International Journal of Computer-Supported Collaborative Learning* 14 (2019), 261–289.

[96] Maarten Van Mechelen, Marie-Louise Wagner, Gökçe Elif Baykal, Rachel Charlotte Smith, and Ole Sejer Iversen. 2021. Digital design literacy in k-9 education: experiences from pioneer teachers. In *Interaction Design and Children*. 32–42.

[97] Lauren Wilcox, Betsy DiSalvo, Dick Henneman, and Qiaosi Wang. 2019. Design in the HCI classroom: Setting a research agenda. In *Proceedings of the 2019 on Designing Interactive Systems Conference*. 871–883.

[98] Rua M Williams and Juan E Gilbert. 2020. Perseverations of the academy: A survey of wearable technologies applied to autism intervention. *International Journal of Human-Computer Studies* 143 (2020), 102485.

[99] Keke Wu, Emma Petersen, Tahmina Ahmad, David Burlinson, Shea Tanis, and Danielle Albers Szafir. 2021. Understanding data accessibility for people with intellectual and developmental disabilities. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. 1–16.

[100] Xigui Yang. 2023. A Historical Review of Collaborative Learning and Cooperative Learning. *TechTrends* (2023), 1–11.

[101] Jason C Yip, Kiley Sobel, Caroline Pitt, Kung Jin Lee, Sijin Chen, Kari Nasu, and Laura R Pina. 2017. Examining adult-child interactions in intergenerational participatory design. In *Proceedings of the 2017 CHI conference on human factors in computing systems*. 5742–5754.

[102] Barry J Zimmerman. 2002. Becoming a self-regulated learner: An overview. *Theory into practice* 41, 2 (2002), 64–70.

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