Research Article

An Initial Investigation Into the Feasibility of the Communication Matrix Professional Development Program for Educational Professionals Working With Students With Complex Communication Needs

Emily D. Quinn,[a] [iD] Alexandria Cook,[a] Jack Wiedrick,[b] and Charity Rowland[a]

Purpose: The goal of this study was to investigate the initial feasibility of the Communication Matrix Professional Development Program (CMPDP), an online program created to help educational professionals teaching students with complex communication needs.
Method: A one-group pretest–posttest design was employed with 102 educational professionals and their students with complex communication needs. Students (M_{age} = 12.5 years, SD = 4.8 years) had severe expressive communication impairments characterized by an expressive vocabulary of < 10 words. The online CMPDP included webinars, coursework, and engagement with an online community of practice. We examined the students' expressive communication skills measured by the Communication Matrix Assessment and Individualized Education Program (IEP) goal quality measured by the Design to Learn IEP Goal Development Guide before and after their teachers and speech-language pathologists participated in the intervention.
Results: Students showed small but significant increases on the Communication Matrix Assessment. The average increase in scores was 10.6, z = 5.37, 95% confidence interval (CI; [6.65, 14.54]), Glass's delta = 0.37. The mean gain in scores for IEP quality was not significant (0.82, z = 2.43, 95% CI [0.14, 1.49], Glass's delta = 0.28).
Conclusions: Results demonstrate the initial feasibility of the CMPDP for educational professionals and their students with complex communication needs. Findings must be interpreted cautiously as the study design has methodological limitations including lack of a control condition and a potential for correlated measurement error and demand characteristics.
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Students with complex communication needs (CCN) cannot use speech alone to meet their daily communication needs (Brady et al., 2016; Light et al., 2019). Many students with CCN have severe expressive communication impairments and use augmentative and alternative communication (AAC) to participate in school (Forbes, 2018; Reichle et al., 2019). AAC involves the different modes of communication used to supplement or replace speech including body movements, gestures, sign language, eye gaze, picture exchange systems, and touching picture symbols or letters on a communication device (Beukelman & Light, 2020). AAC interventions have significant positive effects on the social, language, and literacy skills of children with CCN (Ganz et al., 2012; Machalicek et al., 2010; Therrien et al., 2016). However, the benefits of these interventions may remain unrealized because many professionals lack the knowledge and skills to conduct appropriate AAC assessments, design AAC interventions, and support AAC use in the classroom (Da Fonte & Boesch, 2016; Johnson & Prebor, 2019).

[a]Institute on Development and Disability, Department of Pediatrics, Oregon Health & Science University, Portland
[b]Biostatistics & Design Program, OHSU-PSU School of Public Health, Oregon Health & Science University, Portland
Correspondence to Emily D. Quinn: quinnem@ohsu.edu

Preparing educational professionals to teach students with CCN and support their communication development in schools is a persistent challenge (Douglas, Light, & McNaughton, 2013; Meder & Wegner, 2015). Professional development (PD) programs can mitigate knowledge gaps and improve the education quality of students with CCN (Douglas et al., 2018). There is a pressing need for PD activities grounded in an appropriate assessment of students with CCN (Dietz et al., 2012; Light et al., 2019). A systematic evaluation is necessary to develop an educational plan for students with CCN. Yet, few speech-language pathologists (SLPs) and special education teachers are prepared to evaluate students with CCN (Lund et al., 2017; Pennington et al., 2020).

Several studies have highlighted SLPs' and special education teachers' knowledge and skills deficits regarding assessment for students with CCN. A recent systematic review of qualitative research synthesized findings from 10 studies conducted with 144 educational team members (including 22 SLPs and 20 special education teachers) to describe their perspectives on supporting school-age children with CCN who used AAC (Chung & Stoner, 2016). Across studies, the lack of professional expertise regarding evaluation was a primary challenge among teams (Chung & Stoner, 2016). In Andzik et al. (2019), 14 special education teachers were interviewed regarding their experiences providing AAC services in schools. Teachers reported they had limited access to AAC training, and 43% ($n = 6$) used behavioral observations as their primary method to conduct summative assessments of student AAC use. In qualitative interviews with 25 SLPs, Dietz et al. (2012) found general practice SLPs focus on identifying the individual's communication impairments rather than assessing their communication needs and participation in daily interactions. Dietz et al. (2012) also determined that SLPs have a strong interest in assessment protocols and decision-making guidelines to assist in the AAC evaluation process (Dietz et al., 2012). In Lund et al. (2017), interviews were conducted with eight SLPs with AAC expertise, which revealed that the SLPs did not adhere to all components of the Participation Model (Beukelman & Light, 2020), considered a best practice in AAC evaluation. A survey of 277 school-based SLPs revealed that SLPs had low confidence in assessment procedures for students with severe physical impairments and for students from culturally and linguistically diverse backgrounds (Sanders et al., 2021). In short, this evidence suggests there is a demand for PD programs focused on assessment.

Effective approaches to PD in AAC include trainings, webinars, and practice-based coaching (Kent-Walsh et al., 2015; McMillan & Renzaglia, 2014). Providing PD online has several benefits. Online PD alleviates disparities in training opportunities for educational professionals in rural or underserved communities (Erickson et al., 2012; Rude & Miller, 2018). It connects special educators with colleagues who have different areas of expertise, and it reduces professional isolation (Cook et al., 2017). Online instruction is flexible with regard to educators' schedules, allowing for self-paced and consumer-directed learning. Online opportunities for instruction and interaction are especially relevant under conditions where public health risks make in-person events impossible, such as the COVID-19 pandemic.

There is emerging evidence regarding online PD programs that aim to improve educational professionals' knowledge, skills, and use of evidence-based AAC strategies with students who have CCN. Project Core is an intervention consisting of free PD modules, instructional planning guides, self-reflection checklists, and online resources for educational professionals to implement the model (Geist, 2020). In a pilot study of Project Core, 128 professionals, including special education teachers and para-educators, and 144 students with CCN participated in the intervention. Preliminary findings suggested that students had significant increases in Communication Matrix Scores after professionals completed the Project Core intervention (Geist et al., 2019). Douglas, McNaughton, and Light (2013) used a single-case design experiment to evaluate an online PD program targeting paraeducators who work with students with CCN ($N = 3$ paraeducator–student dyads). PD was focused on training the paraeducators to provide communication opportunities, wait for communication, and respond to the students' communication. Investigators found that after completing the program, the paraeducators provided a greater number of communication opportunities during play, and the students increased their frequency of communication acts. There was a functional relation (intervention effect) between the online training and the communication opportunities provided by caregivers and child communication skills. To date, online PD intervention research has centered on developing teachers', paraeducators', and SLPs' intervention practices without emphasis on improving assessment practices for students with CCN.

Measuring the Impact of Online PD Programs

Various methods exist for measuring the impact of online PD programs designed for educational professionals instructing students with CCN. Educational professional outcome measures examine completion of the PD program and changes in educational practices. They often include procedural fidelity measures, sometimes referred to as implementation fidelity, which evaluates a professional's adherence to specific procedures (Ledford & Wolery, 2013). Feasibility, acceptability, and appropriateness outcomes are evaluated to assess potential for programs to be adopted at scale (Proctor et al., 2011).

Student outcome measures examine changes in communication, language, academic, and developmental domains. These measures frequently include direct observational assessments, informant-report measures, criterion-referenced assessments, and standardized assessments (Brady et al., 2012, 2020). An Individualized Education Program (IEP) is a legal document mandated by the Individuals with Disabilities Education Act (2004), which outlines a student's performance, annual educational goals, progress monitoring, and educational accommodations required. IEPs are important because they dictate the supports and services that a

student receives. In this study, the quality of IEP goals related to communication was examined as a distal outcome to capture any changes in the child's communication goals.

Online Communities of Practice

Online communities of practice are a specific model of online PD that brings together team members on an online platform to learn new skills, reflect on their own practice, and problem-solve collaboratively through discussion and sharing (McLoughlin et al., 2018; Patton & Parker, 2017; Wenger, 1998). They offer a promising and timely approach for providing online PD to special education teachers and SLPs (Courduff & Szapkiw, 2015; Quinn et al., 2019). Communities of practice are embraced by implementation science researchers who study the systematic process of adopting evidence-based practices into routine practice (Bauer et al., 2015; McLoughlin et al., 2018). A community of practice is seen as an effective implementation strategy or method for increasing adoption of evidence-based practices in classroom settings (Buysse et al., 2003; Hodges & Cady, 2013). Online communities of practice have existed formally through the American Speech-Language-Hearing Association Community (e.g., Special Interest Group 12: Augmentative and Alternative Communication) and informally through social networks like Reddit, Facebook groups, WhatsApp, and e-mail lists. However, there is little research examining the efficacy of online communities of practice for educational professionals teaching students with CCN.

Online communities of practice are well established in health care. In Valaitis et al. (2011), researchers investigated an online community of practice for nurses working with homeless persons. Through surveys and focus groups, they found that nurses used the community to share stories, validate practices, and adapt best practices to their specific context. In a meta-analysis of online communities of practice used in health care settings, McLoughlin et al. (2018) found that the online communities were effective in promoting evidence-based practices and encouraging a sense of community and empowerment and can facilitate a reduction in professional isolation despite issues with participation, trust and privacy, and technical ability.

This Study

This study is a preliminary investigation of the feasibility and acceptability of the Communication Matrix Professional Development Program (CMPDP), an online PD program that includes an online community of practice, including evaluations by educational professionals regarding expressive communication in their students and IEP goal quality after the program. We explored three research questions: (RQ1) Do students' expressive communication skills increase after their educational professionals complete the CMPDP? (RQ2) Does IEP goal quality increase after educational professionals complete the CMPDP? (RQ3) What are stakeholder's perspectives on the feasibility and acceptability of the CMPDP? We hypothesized that students' expressive communication skills would increase following the intervention

as Geist et al. (2019) and Douglas, McNaughton, and Light (2013) found. We also hypothesized that IEP goal quality would increase following the intervention because the CMPDP addressed creation of communication-related IEP goals for students with CCN.

Method

Development of the CMPDP

The CMPDP was iteratively developed over the course of a 5-year project using the Bertram et al. (2015) implementation stages framework, which includes four sequential stages: exploration, installation, initial implementation, and full implementation. The first three implementation stages were completed prior to this study. During the exploration stage, we held a kick-off meeting with the research team and educational consultants, identified needed CMPDP instructional materials and resources, developed the materials, and partnered with a web-development team to build an online community of practice. During the installation stage, we provided an initial training for educational consultants, selected and prepared schools in which we would conduct pilot testing of the CMPDP, and solicited feedback from educational professionals. During the initial implementation stage, we piloted the CMPDP procedures including using a Moodle Online Course Management system to organize instruction. Then we solicited feedback from educational professionals and administrators.

This study occurred during the full implementation stage and involved investigating the feasibility of the fully developed CMPDP. The goal was for the full implementation phase to be self-directed and require self-study, reflection, and collaboration with fellow educational professionals through the online community of practice. This stage involved less contact with the researchers to explore the potential sustainability of the program, as many programs have strong effects when delivered with fidelity by researchers, with only modest or minimal effects when researchers are no longer involved in the intervention's implementation (Klingner et al., 2013; Sugai & Horner, 2019).

Design

A one-group pretest–posttest design was used to explore the preliminary feasibility and acceptability of the CMPDP, educational professionals' measures of their students' expressive communication skills, and IEP goal quality after the program.

Participants and Recruitment

The study was conducted at and approved by the institutional review board of Oregon Health & Science University (IRB00001517). Participants included 102 educational professionals who were paired with a target student in their class or caseload. Educational professional inclusion criteria were (a) full- or part-time employment in an early intervention, early childhood special education, or elementary,

middle, or high school special education program and (b) provision of communication intervention for the selected target student with CCN. Student inclusion criteria were (a) enrollment in special education services (early childhood special education, elementary, middle, or high school), (b) diagnosis of a communication disorder associated with a severe or multiple disability as indicated by the IEP, and (c) severe expressive communication impairment with an expressive vocabulary of 10 or fewer intelligible spoken words per parent or educational professional report. Students were heterogeneous in terms of disability etiology and chronological age, but similar in terms of their expressive communication skills, indicated by their teachers and confirmed by IEPs.

Participants were recruited over 2 academic years (2015–2016 and 2016–2017) from two school districts located in Missouri and Illinois. School district administrators expressed interest in the study and agreed to support recruitment. Administrators signed a memorandum of understanding outlining the school district and research teams' responsibilities.

A total of 26 schools participated in the study. In Missouri, students and educational professionals ($n = 53$ student and educational professional dyads) came from five self-contained schools for students with significant disabilities in the St. Louis Metropolitan Region. In Illinois, students and professionals ($n = 49$ dyads) came from special education classrooms in 19 schools providing special education services in the Chicago Metropolitan Region. In Illinois, there were two schools ($n = 2$ dyads) for which we did not have classroom information. Table 1 summarizes the demographics and enrollment of the participating educational agencies in St. Louis and Chicago, respectively. For each school district, the project purchased up to $5,000 worth of instructional materials and AAC equipment for participating students. No renumeration was provided to professionals.

Across school sites, 102 students, 52 special education teachers, 47 SLPs, and 102 parents participated (three professionals did not identify their role). SLPs had an average of 14.26 years of experience, while teachers had an average of 11.80 years of experience at study entry. Of the 102 professionals, 83% identified as female, 5% as male, and 12% did not answer the question. Additionally, 82% of the professional participants self-identified as White, 2% as Black or African American, 2% as Asian, and 14% did not answer. While the focus of our study is not race or gender, in our demographics forms, we collected information on self-identified (in the case of the professionals) or parent-identified (in the case of students) race and gender in order to give a full picture of the people who are represented as participants in our study and any disparities they may face as a result of racism in education, hiring, and retention necessary for employment as an SLP or educator (Baker et al., 2018; Guiberson & Vigil, 2020).

Participating students were an average of 12.5 years old (range: 3–20 years, $SD = 4.8$). Parents identified their children's gender, with 57% of children identified as male, 39% as female, and 5% of parents did not answer. Parents also identified their children's race, identifying 9% of children as Asian, 16% as Black or African American, 55% as White, 10% as more than one race, and 11% as unknown or not answered. For the majority of the students (82%), the primary language spoken at home was English, whereas Spanish was spoken in 6% of homes. Several other languages were spoken in only one home (Cantonese, Polish, Russian, and Tagalog), and 9% of parents did not answer. A wide range of diagnoses was represented by the students, including Angelman syndrome (5%), autism spectrum disorder (29%), cerebral palsy (7%), chromosomal deletion/abnormality (2%), Down syndrome (6%), intellectual or developmental delay (6%), multiple severe disability (16%), epilepsy/seizure disorder (2%), and several other disorders that were experienced by only one student. Students' average total score on the Communication Matrix at study entry was 44.42 ($SD = 28.87$).

A small number of professionals ($n = 5$ SLPs; $n = 1$ special education teacher) left the study. Of this group, two SLPs did not complete the intervention because their target students passed away. The remaining four participants chose to remove themselves from the study. In an exit survey, one participant cited not having enough time as their reason for leaving. Another participant noted "Many changes occurred at the school that needed to be dealt with."

Two educational consultants were hired as project staff to recruit participants and facilitate research activities. One consultant was assigned to each school district. Each consultant had a master's degree in special education and over 30 years of experience working with educational professionals and students with CCN. These experienced consultants had established relationships with the community and the administrative leadership of each school. They developed relationships with the administrative leadership during the initial stages of implementation to develop knowledge of the school culture, mission, and priorities. Consistent

Table 1. School characteristics.

Region	Title 1 status	Total school enrollment	Participant count	Inclusive status by school	Hispanic/Latinx	White	Black/African American	American Indian	Asian	Multiple races
St. Louis	No	68	13	0/1	1.5%	85%	10%	0%	4.5%	1.5%
St. Louis	Yes	2774	40	0/5	2.0%	76.5%	15.1%	0.1%	3.3%	3.1%
Chicago	No	6287	39	9/11	11.3%	69.2%	2.5%	0.1%	13.0%	3.8%
Chicago	Yes	2268	8	5/7	19.8%	59.0%	4.4%	0.5%	13.7%	2.9%

Note. All percentages were based on weighted averages based on the total enrollment for each school at the time of writing this article (U.S. News & World Report Education, 2021). Please see Supplemental Material S1 for more information about school characteristics.

with implementation science methods, consultants with knowledge of school environment and culture were selected to (a) promote wide-scale adoption of the intervention, and (b) allow for greater customization of the implementation strategies for individual schools, such as regionally specific resources, and examples matched to student grade and developmental level (Cook & Odom, 2013; Fixen et al., 2005; Klingner et al., 2013).

Intervention Materials and Procedures

To address the critical need for research on PD programs and communities of practice, we developed the CMPDP composed of an online learning course and community of practice (see Quinn et al., 2019). The CMPDP is designed to support educational professionals in selecting appropriate educational goals for students with CCN as well as encouraging the use of the community to enhance their communication interventions. Through online coursework and discussion, professionals gain knowledge about assessing students with CCN, including how to administer, score, and use the results of the Communication Matrix (Rowland, 2011), an early communication assessment for individuals with presymbolic and early symbolic skills.

Overview of Procedures

At study entry, consultants held an introductory meeting with the educational professionals to introduce the CMPDP and help them create an account to access the intervention through Moodle, an online learning platform. Educational professionals completed the Course Preparation for the Moodle. This included completing a short demographics questionnaire and providing a copy of their student's current IEP to the research team. During an initial in-person meeting, consultants summarized the intervention activities, answered participant questions, and provided

technical support for the Moodle course. After the introductory meeting, the consultants guided participants through Moodle by holding two 6-hr in-person meetings and 4-hr-long virtual meetings. Throughout the school year, consultants provided technical support to the educational professionals and sent reminders to participants to complete study activities. Participants were asked to complete four online modules with embedded learning activities at their own pace (see Table 2).

In this study, formal instruction focused on learning to use an expressive communication assessment, the Communication Matrix, and to develop communication-related IEP goals. Participants were not taught a series of specific intervention strategies, although they were encouraged to utilize the online community of practice to learn about research-based instructional strategies to use with their students with CCN.

The research team developed an online learning portal with Moodle software to guide educational professionals through the CMPDP activities (see Supplemental Material S2). Moodle allowed the researchers to organize the educational professionals' learning activities, assign activities, collect participant responses, and track participant progress. The online course included the four modules described below.

Module 1 (Introduction to the Program)

This module explained the goals of the program and oriented the professionals to the Moodle features. Professionals used the Moodle to submit a baseline IEP. They were directed to an introductory webinar (90 min) about the Communication Matrix Assessment, asked to read background information about the assessment, and required to take a quiz to demonstrate their learning. This quiz was intended to ensure that participants understood the fundamentals of administering the Communication Matrix. Participants were required to pass the quiz by answering at

Table 2. Scope and sequence of Communication Matrix professional development program.

Moodle Module	Task
Module 1 (Introduction) approximately 4–6 hr	• Send a copy of the student's current Individualized Education Program (IEP) or Individual Family Service Plan (IFSP). • Receive training on using the online Communication Matrix by taking a webinar and attending face-to-face training sessions. • Use the Communication Matrix to assess the student.
Module 2 (Using the tools) approximately 2–3 hr	• Complete a Custom Report. • Explore the Community of Practice and post a comment or question.
Module 3 (Developing IEP goals) approximately 2–3 hr	• Reflect on IEP/IFSP goals through the IEP Development Guide and guided questions.
Module 4 (Culminating exercise) approximately 4–6 hr	• Serve as a Guest Host on the Community website either on your own or with a group of your colleagues. • Provide feedback on your satisfaction with training and the Community website. • Use the Communication Matrix to assess the student. • Reflect on IEP/IFSP goals through the IEP Development Guide and guided questions. • Send us a copy of the student's updated IEP/IFSP.

Note. Time approximations include the time spent with consultants guiding participants through the Moodle.

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least 80% of the questions correctly, before administering the Communication Matrix with their target student.

Communication Matrix Assessment. The Communication Matrix Assessment is an interactive online evaluation of expressive communication skills for students at the earliest stages of communication development (Rowland, 2011). It includes 24 questions and is intended to provide a summary of the expressive communication behaviors an individual uses to communicate to refuse objects, obtain objects, engage socially, and provide or seek information. It is organized by seven levels of communication complexity describing preintentional presymbolic and early symbolic behaviors. It covers all modes of communication, including AAC.

Introductory webinar. The webinar is a 90-min narrated presentation, which includes instruction on using the Communication Matrix Assessment to evaluate a student and to select educational goals using the custom report that is available through the website. It is delivered through CMPDP Module 1 online and asynchronously.

Module 2 (Using the Communication Matrix Tools)

This module introduced the Communication Matrix Assessment and tools to support evaluation and intervention planning for students with CCN. Professionals were instructed to complete a Communication Matrix Assessment for their target student, share assessment results with the parent, use the Custom Report writing tool, and post a comment or question on the community of practice.

Custom report. The Custom Report is a report-writing framework for educational professionals. It provides structured prompts that help the user individualize a report with suggestions about (a) demographic information, (b) previous and current assessment results, (c) the primary communication level at which the student is expressing themselves, (d) the percentage of possible communicative messages expressed at each level, (e) the overall score on the Communication Matrix (maximum score = 160), (f) categories of behaviors used to communicate, (g) a summary of progress, and (h) recommendations for intervention strategies.

Communication Matrix Community of Practice. We developed an online community for parents, educational professionals, and other stakeholders who wish to improve communication interventions for individuals with CCN (Quinn et al., 2019; see Supplemental Material S3). Participants interacted with three features: member biography, community forum, and collections.

Member biographies contain personal information such as a photo, a narrative statement, areas of specialty, and interests. Participants were asked to create a member biography.

The community forum is where community members may browse, search, and write posts that may include text, images, videos, and links. Users can share questions or instructional practices. Comments to these posts create dialogue between community members. The forum includes information filters and a search function that allows users to search by topic of interest to access timely, personalized learning. Members who are unable to find answers to their questions in existing posts may post them to the community at large. Participants were directed to contribute at least two posts to the community forum.

Collections are created by guest hosts who have expertise in speech-language pathology or related fields and/or personal experiences with individuals with CCN. Guest hosts often wrote about research-based instructional practices that they had first-hand experience with either as a researcher, practitioner, or parent. Collections are archived, providing a knowledge base generated from an interdisciplinary perspective to guide practice. Participants were asked to collaborate with fellow professionals to create a collection.

Module 3 (Developing IEP Goals)

This module focused on the IEP goal writing process. Professionals were asked to watch and read background information on the Design to Learn IEP Development Guide (Rowland et al., 2015), reflect on their IEP/IFSP communication-related goals for the target student, and post a comment or question on goal writing to the forum. The Design to Learn IEP Development Guide (Rowland et al., 2015) is a series of 28 questions developed for practitioners to reflect on the utility and appropriateness of the student's plan and goals related to communication. It was based on the SMART criteria, which refer to goals that are specific, measurable, attainable, results oriented, and time bound, and a review of actual IEPs of students with CCN (Bovend'Eerdt et al., 2009; Rowland et al., 2015).

Module 4 (Culminating Exercise)

This module emphasized monitoring progress, revising student goals, and using the community of practice to share resources and discuss strategies for improving student communication skills. Participants were directed to complete a second Communication Matrix Assessment on the target student, review the assessment results, suggest revisions to the student's communication-related IEP goals, and share a copy of a second IEP. Additionally, professionals were asked to collaborate with fellow participants at their respective school sites on a collection of posts for the community of practice.

Procedural Fidelity

To assess the professional's adherence to the intervention steps, we calculated a fidelity score based on the following six equally weighted criteria: viewing of the webinar, completion of the first Communication Matrix Assessment, completion of the second Communication Matrix Assessment, completion of the Custom Report, inclusion of Custom Report recommendations, and posting of at least one entry to the Community. Procedural fidelity was coded on a 6-point scale (from 0 = *no steps were completed* to 6 = *all steps were completed*). Forty-one participants completed all six steps, 21 completed five steps, 18 completed four steps, nine completed three steps, four completed two steps, and nine completed one step. The average fidelity score was 4.6 out of 6 (SD = 1.6), with a range of 1–6.

Primary Outcome Measures

Communication Matrix Total Score

Our primary outcome measure for students was their total score on the Communication Matrix Assessment, reported by their educational professionals. The Communication Matrix is conducted by answering 24 yes or no questions about early communication skills. For example—*Does this individual intentionally show you that he or she doesn't want a certain thing or a certain activity? If yes, what does your child do to refuse or reject something?*—followed by a list of specific behaviors that might be used to convey this message. Evaluators select *not used* (0), *emerging* (1), or *mastered* (2) for each behavior. Total scores on the Communication Matrix represent proficiency across the 24 questions. Total scores range from 0 to 160 possible points. In Rowland (2011), four studies are described that test reliability in Communication Matrix assessments completed by professionals with interobserver agreement scores ranging from 83% to 93% and an average test–retest reliability of 89%.

Independent Rating of IEP Goal Quality

Educational professionals submitted a baseline IEP during the initial in-person meeting with educational consultants and submitted a follow-up IEP as Module 4: Culminating Activity. Ten items from the Design to Learn IEP Development Guide (Rowland et al., 2015) were selected to serve as an outside rating of IEP quality by coders (see Supplemental Material S4). The items were selected specifically because they focused on individual goals and could be rated by coders with no background knowledge of the student. These items were based on the SMART criteria (i.e., the goals being specific, measurable, attainable, results-oriented, and time-bound; Wright & Wright, 2002). Each coder was an SLP and researcher with experience developing IEPs for students with CCN. Coders were naïve to pre/post designation of the IEP. Each communication-related goal was rated on the 10-point scale. If a student had more than one goal, the ratings were averaged across goals.

Implementation Outcomes

Educational Professional Ratings of the Community of Practice

Professionals were asked to assess the feasibility, acceptability, and their satisfaction with the community of practice. They completed a professional satisfaction survey, rating the following components on measures of utility and usability. Professionals were also asked how often they used specific features of the Community and to answer open-ended questions about the community of practice. Means and standard deviations were calculated to summarize professional satisfaction.

Analytical Plan

Key concerns affecting the appropriate analysis of the collected outcome data were missing responses and the clustered nature of the data. Educational professional–student dyads were nested in schools, nested within school districts. It was also important to assess the potential for confounding in the outcome measures due to differences in two covariates: Title 1 status and procedural fidelity. Title 1 of Every Student Succeeds Act (ESEA, 2015) provides financial aid to local education agencies and schools with high proportions of students from low-income backgrounds (at least 40% of enrollment). Information on Title 1 status was provided by the school district or by using the Illinois Report Card website (Illinois State Board of Education, 2019). We controlled for Title 1 status between schools because we hypothesized that schools with a greater proportion of students at socioeconomic risk may be at risk for worse expressive communication outcomes (Fisher, 2017). We controlled for procedural fidelity because we hypothesized that differences in procedural fidelity might moderate changes in expressive communication skills between dyads. Specifically, we hypothesized that students would have smaller improvements in expressive communication when their educational professionals had low fidelity to the intervention (Ledford & Wolery, 2013).

To address these concerns, we adopted an analytical approach using generalized estimating equations (GEE; Ziegler, 2011), which allows for analysis of all outcome responses at each time point, irrespective of whether each dyad contributed both pre- and postmeasures, and still properly accounts for the longitudinal correlation in repeated assessments of the same dyad, producing an appropriate estimate of the average change in scores between the pre- and post-intervention assessments (Ziegler, 2011). Importantly, we were able to include adjustments for the two potential confounders to assess their influence on the outcomes, something that would not be possible using a purely within-subjects regression approach. Although GEE models are typically described as having a population-average interpretation, when the form of model is linear for the conditional mean, the interpretations of the parameters estimated by GEE and standard random-effects models or other likelihood-based linear models coincide (Hubbard et al., 2010). This means that the average across individuals is the same as the predicted value for the "average individual." In this study, GEE is used as a tool to estimate a sample mean (the *M* change in pre–post scores in the cohort), conditional on values of covariates while accounting for the clustering and longitudinal structure of the data. GEE models used the identity link with assumed unstructured working covariance, the Gaussian within-cluster error model and the Huber–White robust standard errors (White, 1980).

Both the missing data and clustered data concerns were serious enough to warrant sensitivity analyses using alternative methods to assess the robustness of the results to differing choices of analytical approach. For analysis of the primary outcomes, two of the 102 enrolled dyads were dropped because Title 1 status for their schools during the intervention period could not be ascertained. Of the remaining 100 dyads, 15 were missing both time points for either or both primary outcomes, and a further 37 were missing at least one time point for at least one outcome. Little's MCAR (Missing

Completely At Random) test was used to look for evidence of informative missingness patterns (Little, 1988, 1995).

The clustered structure of the data was not amenable to hierarchical modeling due to large imbalances in cluster sizes and confounding of school or district levels with other factors, such as school year and Title 1 status, which emerged because of the vagaries of enrollment location and timing. Given these challenges, the most appropriate analysis is a within-dyad (i.e., paired) comparison because it accounts for all dyad-level confounding. However, this approach has the disadvantages of requiring complete response data and an inability to assess the influence of dyad-level variables, such as procedural fidelity. Thus, we opted to use the aforementioned GEE approach for our primary outcome analyses but followed up with sensitivity analyses on just the complete data using two complementary within-participant approaches: the distribution-free sign test to assess significance of changes in scores and a within-subjects regression model to quantify the change magnitudes (Allison, 2009; Sprent & Smeeton, 2007). Additionally, the GEE analyses were performed in two ways: (a) adjusted only for length of follow-up (measured by distance in days between assessment dates) and (b) adjusted additionally for Title 1 status (coded 0/1) and procedural fidelity, coded 1 = *partial fidelity* (1–4 on the original scale), 2 = *near fidelity* (5), and 3 = *complete fidelity* (6).

Results
Missing Values

Of the 100 dyads included in the analysis, five (5%) did not complete any assessments of the primary outcome variables (Communication Matrix total score and IEP goal quality score). However, nearly all of the remaining 95 completed one or both Communication Matrix assessments: 69 (73%) completed both assessments, and 21 (22%) completed only the baseline. Missingness of follow-up was somewhat more common for the IEP goal quality score: 58 (61%) of the 95 completed both assessments, 31 (33%) completed only the baseline, one (1%) completed only the follow-up (with no baseline), and five (5%) failed to complete either. Accordingly, five dyads provided assessments for the Communication Matrix but not for IEP goal quality, five provided only IEP goal quality assessments and none for the Communication Matrix, and five provided neither: however, the vast majority (85%) of dyads contributed to both, and 48 (51%) of the 95 who contributed to either contributed completely to both, with no missing values. Individual patterns of missing values were varied and did not appear to be systematic. Data were missing more often at follow-up than at baseline. There was a tendency, which was more prominent for IEP goal quality, to have missing data at follow-up in dyads with lower procedural fidelity scores (most dyads with missing values had only partial procedural fidelity, rarely complete). This is perhaps an expected pattern — dyads that find it more difficult to adhere rigorously to the intervention may also find it more difficult to find time to complete assessments, especially in the middle of the school year. However, there was no evidence

that dyads scoring higher or lower at baseline were more likely to go missing at follow-up (partial R^2 for baseline score to predict subsequent missingness is ~0 for each outcome), and the joint distribution of missing values across outcomes is consistent with an MCAR assumption for this data: Little's MCAR test on the missing outcomes yields a (chi-square) test statistic of 8.4 on 8 degrees of freedom ($p = .4$), suggesting no violation of MCAR. Visual inspection of missingness patterns gives the same impression; that they are unrelated to study variables. We did not find any reason to suspect that our results were biased because of the missing data.

Students' Expressive Communication Skills

Pre-intervention Communication Matrix scores yielded a mean of 44.42 ($SD = 28.87$), while post-intervention Communication Matrix scores yielded a mean of 55.94 ($SD = 24.28$) out of a total of 160 possible points. Positive changes in score represent improvement in communication skills (increases), and negative changes represent worsening (decreases). We found that that among the students whose score changed (12% did not change), 89% increased their Communication Matrix total scores and 11% decreased. A sign test of 89% versus the expected proportion of 50% under the null hypothesis gives $p < .0001$. See Supplemental Material S5 for the Communication Matrix total score trajectory by Title 1 status and procedural fidelity. Using GEE modeling, we estimated the mean gain with a model adjusting for time, procedural fidelity, and Title 1 status. Age was not included in the model due to that fact that age was not correlated with Communication Matrix score in our sample (first Matrix score $r(85) = 0.15$, $p = .156$; second Matrix score $r(67) = −0.002$, $p = .984$). The mean gain in raw total score was 10.60, $z = 5.37$, 95% confidence interval (CI; [6.65, 14.54]). This suggests that, averaged across all degrees of procedural fidelity and Title 1 status, the students gained roughly 10 ± 5 points after participating in the intervention. The Glass's delta measure of standardized effect size is 10.60/28.6 = 0.37, which represents a small effect. Model-adjusted estimates of baseline and post-intervention mean scores (accounting for the influence of procedural fidelity and variable duration of intervention across dyads) were 49.41 and 58.78, respectively, yielding an overall percent change of +19% between baseline and follow-up. The average of individual percent changes in those who completed both assessments was +23%. Figure 1 depicts the mean gain in Communication Matrix total score across levels of procedural fidelity and Title 1 status. The average number of days between Communication Matrix assessments was 175.74 ($SD = 82.61$), or approximately 6 months.

Sensitivity analyses on models of the mean change in Communication Matrix total score showed that the GEE estimates were robust to applying or withholding covariate adjustments (mean gain 10.6 ± 2.0 with adjustments vs. 9.6 ± 2.2 without) and were also close estimates of the subject-specific mean change estimated by the within-subjects regression model (10.1 ± 2.0); the latter accounts for both observed

Figure 1. Average gains on Communication Matrix Assessment: The overall estimate, shown in the figure header, represents the sample-weighted mean gains across the covariate subgroups; the bar height and orientation represent the average gain magnitude and direction for each subgroup; and the sample size per subgroup is shown to the right of each bar. All subgroups showed at least some positive gain. CI = confidence interval.
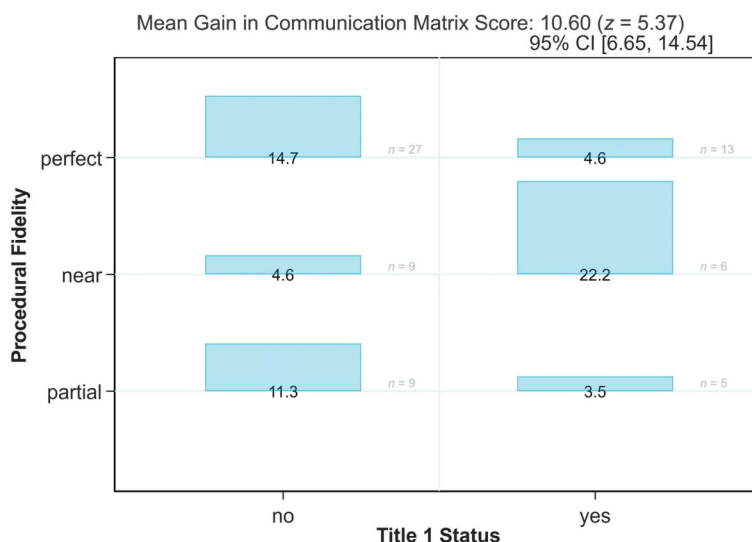
and unobserved heterogeneity between subjects. Thus, our specific choice of GEE model over these other alternatives was not influential on the findings.

IEP Goal Quality

We conducted counts of professional-student dyads whose IEP goal quality scores either improved or worsened. Among the dyads whose score changed (12% did not change), 65% of those dyads improved and 35% worsened. A test of 65% against the expected proportion of 50% under the null hypothesis gives $p = .024$., but the average amount of gain was quite small relative to the scale (which ranges from 10 to 30). Using GEE modeling, we estimated the mean gain as 0.82, $z = 2.43$, 95% CI [0.14, 1.49], adjusting for time, procedural fidelity, and Title 1 status. See Supplemental Material S6 for the IEP goal quality score trajectory by Title 1 status and procedural fidelity. This suggests that averaged across all degrees of procedural fidelity and Title 1 status, professional–student dyad scores increased less than 1 point (just 4% of the range) on average after participating in the intervention. Glass's delta is $0.82/2.9 = 0.28$, which represents a small effect. Figure 2 shows the M gain in IEP goal quality score across levels of procedural fidelity and Title 1 status. Unlike with Communication Matrix scores, for IEP goal quality scores, the direction of change was not consistent across covariate subgroups. The average number of days between IEPS/IFSPs was 349.21 ($SD = 70.26$) or approximately 12 months.

As above, sensitivity analyses on models of the mean change in IEP goal quality score showed that the GEE estimates were robust to covariate adjustments (M gain 0.82 ± 2.4 with adjustments vs. 0.80 ± 2.1 without) and were

reasonably close estimates of the subject-specific mean change estimated by the within-subjects regression model (0.73 ± 1.8).

Implementation Outcomes

Professional Ratings of Acceptability of the CMPDP

Seventy-three educational professionals (71.5%) completed the professional satisfaction survey, which covered five components of using the community of practice. As shown in Table 3, participants scored all statements between 3.00 and 4.00 (on a 5-point scale) except for the first four statements under Community Activity. These were the only statements related to each participant's actual activity on the forum. These statements were rated between 2.40 and 2.74. Table 4 outlines the participants' responses to the optional open-ended questions about the CMPDP.

Discussion

The goal of the current study was to explore the preliminary feasibility and acceptability of the CMPDP with 102 educational professionals and students with CCN. We hypothesized that students' expressive communication skills, measured by the Communication Matrix, would increase following the intervention. Communication Matrix scores showed gains over the intervention period; at least some average gain was seen within each subgroup we looked at. Across all students, Communication Matrix scores increased on average by 10 points, controlling for Title 1 status and procedural fidelity. We also hypothesized that IEP goal quality, measured by the Design to Learn IEP Goal Development guide, would improve following the intervention.

Figure 2. Average gains on Individualized Education Program (IEP) Goal Quality: The overall estimate is shown in the figure header, and the covariate subgroup means are shown as bars in the figure, where the bar height and orientation represent the gain magnitude and direction for each subgroup, and the sample size per subgroup is shown to the right of each bar. Changes tended to be small and nonsystematic. CI = confidence interval.
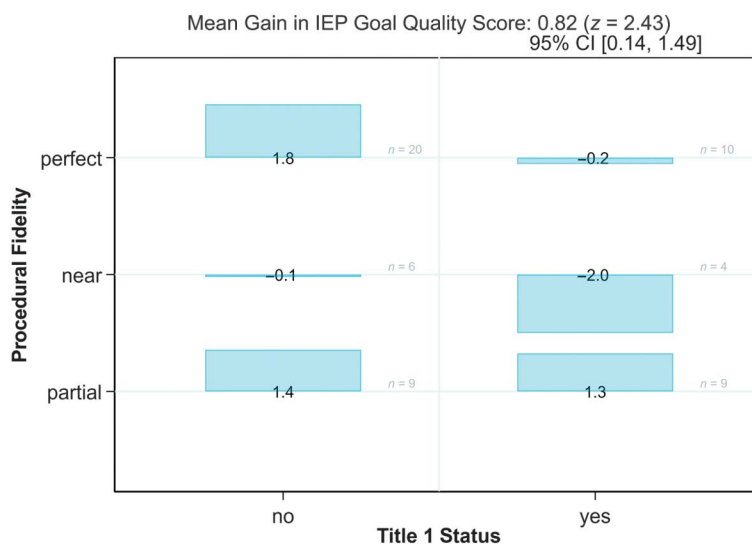

Mean Gain in IEP Goal Quality Score: 0.82 (z = 2.43)
95% CI [0.14, 1.49]

Table 3. Participant satisfaction.

Question	Average score	SD
The Communication Matrix Community as a whole[a]:		
Signing up was easy.	4.00	1.17
I understand how to use tags to categorize posts and to search.	3.67	1.20
I like getting updates from the Community though e-mail.	3.21	1.12
This will help me better serve my students.	3.79	1.08
I would recommend this Community to other professionals.	3.74	1.15
The forum[a]:		
It is easy to use this component.	3.69	1.16
I will use this component frequently.	3.19	1.04
This component will help me better serve my students.	3.69	0.96
I would recommend this component to other professionals.	3.74	0.97
The community library[a]:		
It is easy to use this component.	3.60	1.06
I will use this component frequently.	3.13	1.06
This component will help me better serve my students.	3.57	0.94
I would recommend this component to other professionals.	3.54	0.99
Shared science[a]:		
It is easy to use this component.	3.59	0.99
I will use this component frequently.	3.03	0.90
This component will help me better serve my students.	3.41	0.93
I would recommend this component to other professionals.	3.46	0.94
Community activity[b]:		
I have posted to the forum.	2.74	0.85
I use tags when I post.	2.36	1.34
I have commented on post(s).	2.49	1.00
I have liked (starred) post(s).	2.40	1.30
I have found something useful on the Community.	3.70	1.07
I have used the Matrix filter.	2.59	1.56
I have used the search function.	3.47	1.16
I have enabled e-mail updates.	2.31	1.90

Note. Seventy professionals completed the professional satisfaction survey.

[a]Scale ranges from 1 (*Strongly disagree*) to 5 (*Strongly Agree*). [b]Scale ranges from 1 (*Never*) to 4 (*Often*).

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Table 4. Participant responses to open-ended questions.

Theme	Examples
Time	P163 "As many things when you are an educator time is always the factor to get to try and use new resources."
	P193 "As so many things presented to educators the forum is helpful# yet limited time may get in the way of using it."
	P107 "I wish I had time to access communication matrix community more frequently. I simply need more planning time to benefit from this community."
Ease of use	P93 "Easy to navigate. Good tool if you have a specific question or need more information."
	P87 "I like how organized the FORUM is and how it's a way to see ideas in regards to communication from a variety of people."
	P160 "The forum is easy to use and I hope more people use it."
Difficulty of use	P122 "I really like the Communication Matrix however the forum is a little difficult to use and just navigate. It took me a while to find the "subjects," "button."
	P168 "There should be an easier way to find threads and posts that you "like"— we had a hard time finding posts we follow and posts we "like."
	P172 "I felt that it was complicated to figure out how to post the information that we wanted to share."
Relevance to practice	P159 "It is helpful to read suggestions and strategies for students' with similar communication abilities as the students on my therapy caseload."
	P207 "I really like that I am able to search for anything related to my students (e.g., vision impairment, Rett syndrome, etc.)."
	P203 "Great tool for looking in to resources for difficult students."
	P87 "A couple of years ago I had a student with Angelman's syndrome and I would of loved to know about this section to look up information in regards to children with Angleman's and how they communicate."
Irrelevance to practice	P207 "The disorders available in the shared science do not currently apply to myself or my caseload of students."
	P85 "I have served the severe-to-profound population for my entire career. I didn't see too many posts that were helpful to me. I also didn't have a great amount of time for the forum this year."
	P50 "I do like seeing the ideas that people share and things that they have learned. I wish there were more responses from the community as it relates to adding to the form."

Average IEP goal quality scores did not appear to shift meaningfully over the intervention period, although scores for many individual professional–student pairs improved. However, without a control group, it is difficult to determine whether increases can be attributed to the program or maturation.

An increase of 10 points on the Communication Matrix represents that, on average, students expressed 5–10 new emerging and/or mastered communication behaviors, such as: gaining the ability to greet someone by waving, generalized use of two-dimensional symbol to request a specific item, or showing emerging use of a manual sign to ask a question. A 10-point gain in total score could be achieved in many different ways, including: communicating 10 new messages at an emerging level, gaining mastery in expressing 10 messages that had previously been communicated at an emerging level, or expressing five new messages at a mastered level. This result held true averaged across level of fidelity and Title 1 status. As shown in Figure 1, the group that showed the most gains were participants with near fidelity in Title 1 schools (average gain of 22.2 points). These preliminary findings may indicate the intervention would work well in Title 1 schools and fidelity need not be perfect, but with small sample sizes in each group, and without a control group, further research is required to provide support for this conclusion.

Average IEP goal quality rating did not improve during the course of the study regardless of Title 1 status or fidelity. Any increase on the quality of communication goals developed attributable to the training may have been mitigated by a number of factors. The IEP goal development measure may not be sensitive enough to detect change over the course of a year. Perhaps the connection between assessment results and implications for IEP goals was not made explicit enough in the training exercises. Additionally, the use of goal banks for educational programming is common (More & Barnett, 2014). It is possible that some professional participants were required to use goal banks or found it easier to use them. Such goals are not necessarily designed to adhere to the SMART criteria that guided the metric by which the goals were scored. Finally, the goals with which some students began the school year may have been written by different professionals during the previous school year. Thus, a simple comparison between initial and subsequent IEP goals may have been inappropriate.

Few participants completed all study activities (40%). Despite strong administrative support for the project, when surveyed about their experiences, participants mentioned they lacked protected time to accomplish study activities. This is consistent with prior research, as educational professionals consistently list time constraints as a major barrier to supporting AAC use in the classroom (Kent-Walsh

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& Light, 2003; Myers, 2007). This community-based research conducted in authentic educational settings exemplifies both the promise and limitations of disseminating and promoting the adoption of new PD tools into routine practice.

When asked open-ended questions about the community of practice, some participants found suggestions and ideas on the website helpful to their practice, while others had limited success finding information relevant to for their students. Others felt the operations, specifically posting to the community, were difficult to use. Participant satisfaction ratings were high; overall participant responses indicate the community of practice could be optimized with changes to the website interface.

While the sample age range was large, all students had similar levels of communication at study entry. They all experienced severe communication impairments with expressive vocabularies of less than 10 words. Age was not correlated with outcomes, which may be due to the fact that all of the students in the study were in the overall beginning states of communication development. There may not have been enough of a range of communication ability for age to increase outcomes.

This study makes an important contribution to research on individuals with CCN in two important ways. First, this this project explored the preliminary feasibility PD program focused on expressive communication assessment for students with CCN. To our knowledge, this is the first study to examine a PD program for teachers and SLPs focused on early communication assessment. Second, this study integrated multiple approaches to PD, instruction, online coursework, and an online community of practice. Online coursework paired with an online community of practice has the potential to increase opportunities for educators and SLPs to receive training (Erickson et al., 2012; Rude & Miller, 2018) and to network with professionals working with similar populations (Cook et al., 2017). As the global effects of the COVID-19 pandemic increasingly limit conventional professional training opportunities, the use of technology to educate and connect becomes relevant to all communities.

Limitations

The results of the study should be interpreted in light of important methodological limitations. The initial feasibility of the CMPDP program was explored in a single-group pretest–posttest design, which does not control for important threats to internal validity. The lack of a control comparison and low power to assess the influence of dyad-level confounding factors limits the conclusions that can be drawn from the research. Specifically, it is not clear to what extent the gains in the Communication Matrix scores can be attributed to the intervention, and how much is related to maturation, instruction students received during the school year, interventions pursued outside of school, and measurement error. Any increase in communication skills could be due to maturation and measurement error. We were unable to measure the interventions or therapies students received outside of school or their contribution to

the results. All participants demonstrated basic knowledge and skills on Communication Matrix Assessment administration though passing a quiz (80% accuracy or better). However, we were unable to independently verify scores on the Communication Matrix. This may have resulted in inaccurate measures of communication skills. Changes in the pretest and posttest scores may be due to the fact that participants were more accurate using the Communication Matrix Assessment on a second administration. Educational professionals may have been susceptible to correlated measurement error and demand characteristics, since the intervention was educator implemented and the Communication Matrix was completed by educational professionals. This may have resulted in inaccurate (positively biased) measures of communication skills. A final limitation is the potential of scores to regress to the mean.

Results of this study may not generalize to populations who are diverse in terms of race and gender, as we did not have a sample representative of these populations. According to the American Speech-Language-Hearing Association (2020), the majority of SLPs identify as women (95.5%) and White (91.5%). Billingsley et al. (2019) found that 82.1% of special educators identify as White and not Hispanic or Latino. Our sample reflects this lack of diversity.

Future Directions

Replication with a control group and a larger sample size is needed to establish the preliminary feasibility of the CMPDP. Future research should explore different outcome measures to evaluate meaningful improvement in teacher educational practices and student outcomes. While this study was designed to require little outside time by the professionals, future studies may benefit from using direct measurement of student communication skills by researchers naïve to condition. Specifically, researchers may use observational assessments like the Communication Complexity Scale (Brady et al., 2012) to obtain a direct measure of students' expressive communication skills. It is difficult to measure change in educational practices with attention to the most meaningful changes for the student. Future studies should investigate other methods for measuring educational professionals' modifications in practice.

In addition to addressing the methodological limitations of this study, there are two important directions for future research on PD. First, practice-based coaching is a highly effective approach to PD and has been shown to improve instructional practices of special education teachers and SLPs (Artman-Meeker et al., 2015; Romano & Woods, 2018; Snyder et al., 2015). Although there is empirical support for training communication partners of individuals with CCN including teachers, parents, and educational assistants, research thus far has not closely examined the efficacy of specific coaching frameworks or delivery types (Kent-Walsh & McNaughton, 2005, Kent-Walsh et al., 2015; O'Neill et al., 2018). Studies need to be completed that focus on how to incorporate coaching in a way that is accessible to busy educational professionals. Second, a focus on engagement

and utilizing the resources that educational professionals are already using would be a useful future direction. Researchers would benefit from exploring already existing forms of communities of practice, such as social media groups, and professional learning communities with a focus on how best to incorporate these resources to best benefit students' communication skills. The research would benefit from investigating what qualities work best to encourage educational professionals to use the most effective treatments and techniques.

Conclusions

A new online PD program and community of practice was successfully completed by a relatively large and diverse cohort of education professionals who provided communication intervention for children with CCN in public schools. Although increases in communication assessment scores were reported for most students across the school year, the lack of a control condition makes it challenging to determine whether these changes were due to maturation or demand characteristics.

Acknowledgments

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