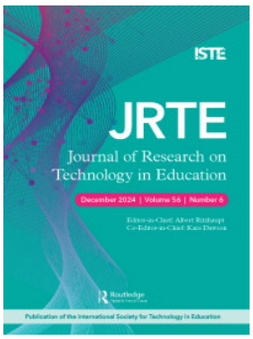

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Building robust teacher-led professional learning communities for computer science educators: Insights from CSTA chapters in the U.S.

Lijun Ni[a], Yan Tian[a], Tom McKlin[b], Jason Bohrer[c] and Jake Baskin[c]

[a]Department of Educational Theory and Practice, University at Albany, State University of New York, Albany, New York, USA; [b]The Findings Group, Decatur, Georgia, USA; [c]Computer Science Teachers Association, Chicago, Illinois, USA

ABSTRACT

The rapid expansion of K-12 computer science education highlights the urgent need for well-prepared teachers. The Computer Science Teachers Association (CSTA) facilitates the development of local teacher professional learning communities (PLCs) through CSTA chapters. This study investigated the types of support CSTA chapters provide, how teacher leaders establish local PLCs and engage teachers of computer science, and the challenges encountered in this process. The investigation included multi-year focus group interviews with chapter leaders and teacher member surveys. The findings reveal that CSTA chapters serve as vital resources of professional support, amplify teachers' voices, and nurture their professional identities in teaching computer science. This study provides a nuanced understanding of local PLCs for computer science educators, informing future endeavors in teacher preparation and development.

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Computer science teachers; professional learning communities; CSTA chapters; teacher identity

Introduction

The rapid expansion of computer science education at the K-12 schools calls for more professional development (PD) and professional learning communities (PLCs) to support teachers in developing the knowledge and expertise for teaching computer science as an important discipline (Code.org et al., 2023; Koshy et al., 2023; Ni, Bausch, et al., 2021). Computer science educators face unique challenges in developing their computer science teaching expertise and professional identity. First, to expand computer science education at the K-12 level, more and more in-service teachers are asked to take on responsibilities in teaching computer science, regardless of their educational backgrounds (Koshy et al., 2021; Yadav et al., 2016). Many teachers are self-taught or need to actively seek professional development to build up their computer science teaching capacity. Second, as many states are in the middle of developing new policies, standards, and certification processes for computer science education (Code.org et al., 2023), teachers in those states must first become certified to teach in other content areas before they are allowed to teach computer science. However, these teachers often lack computer-science-focused preparation, as the subject has not been consistently taught as a content area in most teacher education programs. Third, unlike "core" subjects such as English or Mathematics where teachers commonly have peers or instructional coaches nearby, computer science remains a relatively new subject at K-12 schools and many computer science teachers work alone as they are often the only

CONTACT Lijun Ni lni@albany.edu Department of Educational Theory and Practice, University at Albany, State University of New York, Albany, NY, USA

computer science teachers in their schools (Basu et al., 2021; Code.org et al., 2023). These unique situations faced by computer science teachers necessitate professional connections and learning opportunities to alleviate teacher isolation and foster the development of computer science teaching expertise and professional identity for those with diverse professional backgrounds.

PLCs are widely recognized as an effective approach to supporting teachers' professional learning (Fishman et al., 2022; Ni, McKlin, et al., 2021; Owen, 2015). Given the unique challenges faced by computer science teachers, local PLCs can play an important role in alleviating those challenges by providing places where teachers can connect and support each other in their shared pursuit of developing computer science content knowledge and teaching expertise (Cutts et al., 2017; Goode et al., 2020; Sentance & Humphreys, 2018). Computer Science Teachers Association (CSTA, www.csteachers.org) is the largest organization in North America intended to support K-12 teachers of computer science by providing guidance, resources, PD programs, and PLCs. Besides building a computer science teacher PLC at the national level, CSTA supports teachers in developing local PLCs in the form of CSTA chapters. CSTA and its network of over 100 local chapters with 20,000 members (by 2023) represent the only distributed community of computer science teachers without ties to a specific curriculum or professional development provider.

This study is part of a three-year project dedicated to building a network of local PLCs for the professional growth of computer science educators in the United States. Probing these local PLCs (i.e. CSTA chapters) contributes to a deeper understanding of the lives of computer science educators, based on which our computer science education community may devise programs or resources to provide tailored support. Specifically, this study seeks to answer three research questions: (1) What types of support do CSTA chapters provide to computer science teachers? (2) How do chapter leaders build the local PLCs and engage computer science teachers? (3) What challenges do CSTA chapters encounter in building robust local PLCs? While primarily focusing on the perspectives of chapter leaders, the study also incorporates the viewpoints of chapter members to comprehensively explore the first two research questions.

Literature review

Overview of professional learning communities

In teacher education, PLCs have become a popular model of effective professional development (Darling-Hammond et al., 2017; Fishman et al., 2022; Ni, Bausch, et al., 2021). Broadly defined, a PLC consists of "a group of people sharing and critically interrogating their practice in an ongoing, reflective, collaborative, inclusive, learning-oriented, growth-promoting way operating as a collective enterprise" (Stoll et al., 2006, p. 223). In PLCs, an important knowledge source is teachers' classroom practices and experiences, based on which teachers and educators engage in reflections, exchange feedback, and collaboratively devise more productive instructional designs and teaching practices (Stoll et al., 2006; Woodland, 2016).

Successful PLCs focus on student learning, involve teachers in collaborative and continuous learning, and build up teachers' sense of agency and confidence in adopting new practices (Darling-Hammond et al., 2017; Vescio et al., 2008). From the situated learning perspective, teacher learning takes place as one actively participates and is assimilated into a "culture of practice" (Lave & Wenger, 1991, p.95) that focuses on continuously and collaboratively developing a shared understanding of effective instructional strategies (Sentance & Humphreys, 2018). PLCs can support teachers with various backgrounds and at different professional stages to learn together (Sentance & Humphreys, 2018).

Professional learning communities for computer science educators

While there is a current need for more research on PLCs for computer science educators (Goode et al., 2020; Ni, Bausch, et al., 2021), there are a handful of studies worldwide that

explored different approaches to establishing PLCs for computer science educators. These studies suggest that PLCs can improve the way teachers approach and deliver computer science content. Notably, Computing at School (CAS) is a dedicated community serving computer science teachers at all levels (Brown et al., 2014). In 2015–2018, CAS established the Network of Teaching Excellence in Computer Science, in which experienced computer science teachers were recruited and trained to organize local hubs or PLCs to serve the needs of local schools (Sentance et al., 2014; Sentance & Humphreys, 2018). These local PLCs provided high-quality PD, which enhanced computer science teachers' confidence and enabled them to implement new knowledge and skills in their teaching practices (Sentance et al., 2014; Sentance & Humphreys, 2018). Similarly, the Professional Learning and Networking in Computing (PLAN C) was established to build the capacities of secondary school computer science teachers in delivering a redesigned curriculum. Under PLAN C, pairs of lead teachers from different regions received training from researchers and subsequently set up local PLCs. These PLCs served as forums for local computer science teachers to meet and discuss, boosted teachers' confidence, and supported teachers in aligning their attitudes and practices with the revised curriculum (Cutts et al., 2017).

In the U.S., a few studies have designed and investigated PLC-based computer science PD programs. These programs are centered around a specific curriculum, such as Exploring Computer Science (Goode et al., 2020; Ryoo et al., 2015), or a particular programming tool like Scratch (Haduong & Brennan, 2019; Hamner et al., 2016). These PLCs initiated and established by PD providers have been instrumental in supporting computer science teachers in several ways: (1) breaking the professional isolation and encouraging collaboration; (2) providing ongoing support for teachers during and after PD; (3) strengthening teachers' computer science content knowledge and especially pedagogical content knowledge (Goode et al., 2020; Haduong & Brennan, 2019; Hamner et al., 2016).

Fostering computer science teacher identity in PLCs

From a teacher identity perspective, teachers' learning is an ongoing process of developing and refining one's professional identity as teachers build a framework that guides their decision-making in various situations (Beijaard, 2019; Rodgers & Scott, 2008). A robust teacher identity significantly impacts teachers' motivation, job satisfaction, and retention (Day et al., 2006). However, establishing a sense of professional identity is particularly challenging for K-12 computer science educators in the United States. First, while significant progress has been made, computer science education still needs well-defined learning standards, comprehensive curricula, or dedicated teacher education programs (Code.org et al., 2023). Second, computer science teachers often work in an isolated fashion and carry multiple teaching responsibilities, especially K-8 computer science teachers and teachers in rural areas (Basu et al., 2021; Code.org et al., 2023). Establishing local PLCs emerges as a crucial strategy to support the development of computer science teachers' professional identities.

From a situated learning perspective, teachers' identity development is situated in their participation in various social contexts (Cherrington, 2019). The process of identifying takes place as one develops self-understandings within immediate and social-historical contexts (Schutz et al., 2020). For many computer science teachers, local PLCs serve as a primary professional community where they engage in discussions with fellow educators who share the common goal of enhancing computer science teaching and learning. Through actively participating in local PLCs and interacting with peers, computer science educators adopt beliefs, values, and practices that are prevalent within each group (Schutz et al., 2020). As a teacher takes on larger and larger responsibilities within the social group, the teacher moves from peripheral to central participation in a PLC (Haduong & Brennan, 2019). The peer negotiations and involvement in local PLCs serve as the foundation for a teacher to gauge the meaning and strength of one's professional identity (Cherrington, 2019).

CSTA chapters as local PLCs

Existing studies on PLCs for computer science teachers indicate that PLCs may be structured around specific PD programs (Cutts et al., 2017; Falkner et al., 2017), computer science curricula (Goode et al., 2020; Ryoo et al., 2015), or programming tools (Haduong & Brennan, 2019; Hamner et al., 2016). Some PLCs feature strong leadership and internal structure (Cutts et al., 2017; Hamner et al., 2016; Sentance et al., 2014), while others function as communities of peers (Falkner et al., 2017; Goode et al., 2020; Haduong & Brennan, 2019). In this study, a unique approach is taken. Computer science teachers from diverse backgrounds voluntarily assume leadership roles and establish local PLCs in the form of CSTA chapters. These chapters aim to engage local computer science educators and collaboratively develop their computer science teaching capacity. Notably, while other PLCs often operate in a top-down manner, CSTA chapters are initiated and sustained at the grassroots level. Additionally, these PLCs adapt their operational methods to cater to the unique needs of computer science educators in different areas across the United States.

In the context of a nation as vast and diverse as the United States, literature on the structure and operation of PLCs for computer science educators remains elusive. Existing studies in this area have primarily focused on initiatives organized by PD providers, centered around a specific curriculum or tool, and tailored to a relatively homogenous group of teachers (e.g. Cutts et al., 2017; Goode et al., 2020; Haduong & Brennan, 2019; Hamner et al., 2016; Ryoo et al., 2015). Little is known about local PLCs primarily led, organized, and sustained by K-12 computer science educators teaching various grade levels in different school settings. In this study, drawing upon the diverse experiences of computer science teachers and teacher leaders in their roles as classroom teachers, PLC participants, and PLC leaders, we intend to empirically understand how CSTA chapters, functioning as local PLCs, support computer science teachers.

Methods

This study utilized a mixed-method approach to address our three research questions. We gathered data from chapter leader focus groups over three years (2020–2022) and supplemented this with member feedback surveys administered in 2021 and 2022. Qualitative analysis was conducted on the focus group interview transcripts, while basic statistical analysis was applied to the member survey responses. The survey results were used to triangulate the qualitative findings from the chapter leaders' focus groups.

Participating CSTA chapters

This study involved 10 CSTA chapters across the United States, representing 11.5% of the 87 U.S. chapters. The chapters were purposefully selected based on geographic location, scale, number of members (Table 1), and developmental stage (Table 2). In 2020, five chapters (Cohort I) participated in the study as part of the larger project; in 2021 and 2022, five more chapters (Cohort II) joined with Cohort I.

These 10 chapters were at varied developmental stages based on their self-evaluations In the summer of 2021 and 2022, chapter leaders conducted self-evaluations using the chapter success rubric (CSTA, n.d.), which was developed by the CSTA national. This rubric guides chapters in self-reviewing their progress toward three organizational goals: (1) building community, (2) providing PD and support, and (3) establishing an operational foundation. Each goal was further delineated into multiple indicators as detailed in Table 2. For each indicator or element, the CSTA national specified a set of criteria for chapters to evaluate and rate themselves on a 4-level scale (Level 1: Needs Improvement; Level 2: Minimum Expectations; Level 3: Meets Target; Level 4: Exceeds Target). For instance, regarding regular activities, a chapter's level is determined by the number of meetings or events per year (Level 1: three or fewer; Level 2: four; Level 3: five

Table 1. Characteristics of the participating chapters.

Chapter (cohort)	Geographic region	Scale	Number of members in 2022	Inception year
A (I)	Northeast	State	90	2016
B (II)	Northeast	State	48	2010
C (II)	Northeast	Regional	229	2010
D (I)	Midwest	State	314	2017
E (II)	Midwest	State	125	2009
F (I)	South	Regional	55	2020
G (II)	South	State	191	2010[a]
H (I)	West	State	76	2019
I (II)	West	Regional	23	2020
J (I)	West	Regional	103	2013

Note. [a]Chapter G had been inactive and was rebooted in 2021.

Table 2. Participating chapters' 2022 self-ratings using the chapter success rubric.

CSTA chapter		A	B	C	D	E	F	G	H	I[a]	J
Building Community	Regular Activities	4	1	4	3↓	2↑	2↑	2↓	1↓	2	4
	Participation	3	1	3↑	2↑	2↑	2↑	2	1↓	2	1↓↓
	Virtual Communication	3	2	2↓↓	2	2	3↑	1↓	2	3	2
	Satisfaction	3	2	4↑↑	3↑	3↑	3↑	2	2	2	3↑
	Recruitment (< 100 members)	3	1↑	na	na	na	2↓	2↑↑	1↓↓	2	2↓↓
	Retention (>= 100 members)	4	na	3↑	3	3↓	na	2↑	na↓	4	na↓↓
	Member Representation	3↓	1	3↓	3	4	3	2	3	4	3↑
	Advocacy (optional)	3	2↑↑	na	na↓↓	4	2↑↑	Na	na↓↓	3	4
Providing PD and Support	Networking	2	2	2	3	3↑	2	2	2	2	4
	PD	2	2	4↑	4↑	3↑	3↑	3↓	1↓↓	3	4
	Communication	4↑	2	4↑	3↓	3↓	4↑	2	1↓↓	1	3↑
	Mentor (optional)	2	2↑↑	na	na	na	na	2↑↑	na↓↓	na	na
Establishing Operational Foundation	Found Documents	4	1↓	4↑	2↑	3↑	3↑	4↑	2↓↓	3	3↑
	Leadership	4	2	3	3↑	2↑	3↑	3	1↓	1	2
	Web Presence	3	3	3↓	3↓	3↑	4↑↑	3↑	2↓	3	4↑
	Relation with CSTA National	2↓	3↑	4	4	4↑↑	4	3	2↓↓	2	4
	Finances	3↑	2↓	4	2↑	3↑	2↑	4↑↑	2↓↓	1	2↓
	Fundraise (optional)	3↑	na	4	3↑↑	na	na↓↓	3↑↑	3	na	3↓

Notes. [a]Chapter I as a new chapter has no data in 2021. An unavailable rating is indicated by "na." ↑ or ↓ indicates the rating increased or decreased by one level from its 2021 rating. ↑↑ or ↓↓ indicates the rating changed by two or more levels from its 2021 rating, e.g. 1 to 3, 2 to "na."

to seven; Level 4: eight or more). For new member outreach, Level 1 means no outreach activities; Level 2 indicates informal outreach on social media or in conversations; Level 3 needs efforts in targeted outreach to fill in gaps in membership representation; and Level 4 requires a formal presence at regional non-CSTA events.

Table 2 presents the chapter success rubric ratings for the participating chapters in 2022 and shows how these ratings differ from those in 2021. These 10 chapters were at distinct developmental stages. Chapter B and Chapter H, in early developmental phases, rated themselves at Level 1 (Need Improvement) on 5 and 6 elements respectively. In contrast, Chapter A and Chapter C demonstrated higher levels of development with most of their ratings at Level 3 (Meets Target) or Level 4 (Exceeds Target). Over the past two years, these chapters experienced various changes. Chapter E and Chapter F improved their ratings on 10 and 11 elements respectively, whereas Chapter H experienced a decline in ratings across most categories. Chapter H, a state-level chapter, had geographically dispersed members and experienced a significant lack of resources due to the impact of the COVID-19 pandemic.

Typically, there are four core leadership positions within each CSTA chapter: president, vice president, treasurer, and secretary. Chapters with ratings at Levels 1 and 2 in leadership may

not have sufficient leaders to take up all core roles, while chapters at Levels 3 and 4 may have more roles and leaders in the leadership team. In addition, chapters at Levels 3 and 4 in leadership hold annual elections to keep or change leadership team members. In this study, there were two to six leaders in each leadership team from the 10 participating chapters. Most chapter leaders were concurrently practicing computer science educators. There was considerable diversity in terms of their tenure as chapter leaders. Some leaders served for more than three years and remained on the leadership team from 2020 to 2022. They might have stayed in the same position or have undertaken varied leadership roles, providing a multifaceted understanding of their chapters' functioning. Other participants entered or exited their roles midway through this period, offering a unique perspective on evolving chapter dynamics.

The demographics of the members in the participating chapters were largely consistent with the demographics of CSTA members nationally. In the participating chapters, most members were white (75.09%), followed by Black/African American (8.18%), Asian (3.53%), Hispanic or Latino/a/x (2.23%), Native Hawaiian or other Pacific Islanders (1.12%), American Indian or Alaska Native (.74%). There were 58% women, 35% men, and less than 1% non-binary members. Approximately 50% taught at Grade 9–12, 31.41% at Grade 6–8, 19.14% at Grade 3–5, and 14.68% at Grade PreK-2. Half of these members had more than five years of computer science teaching experience, while 29% were in their second-fourth year, 6% were in their first year, and another 7.62% had no prior computer science teaching experience.

Data collection

Chapter leader focus groups

During the summers of 2020–2022, we conducted focus group interviews with the leaders from 10 participating chapters about their experiences as computer science teacher leaders and members of the CSTA chapter leader community. In 2020, leaders from five chapters (Cohort I) participated in the focus groups; in 2021 and 2022, five more chapters (Cohort II) joined, resulting in focus groups with all 10 chapters each year. In 2020, we conducted five focus groups, and in 2021, 10 groups. In each focus group, a range of two to six leaders from the same chapter were interviewed. Due to COVID-19, all interviews in 2020 and 2021 were conducted virtually on Zoom. In 2022, two large focus groups were conducted in person during the CSTA Annual Conference in Chicago, organized by cohort. At least one leader from all but one participating chapter participated and a total of 19 leaders were interviewed in 2022. Sample interview questions included "How would members of your chapter describe the benefits of joining the chapter?" or "What would you like to improve? Any challenges your chapter is facing?" The interviews were video-recorded in 2020–2021 and audio-recorded in 2022. The recordings were transcribed verbatim.

Member surveys

In 2021 and 2022, CSTA National designed and distributed member feedback surveys among its members. The survey included Likert-scale items and open-ended questions, organized into three independent sections: (1) demographics, (2) chapter engagement, and (3) chapter activities planning. This study drew on the second section to understand the extent of teachers' engagement in their chapters. The 10 participating chapters collected a total of 538 surveys, with the section of chapter engagement fully completed. Specifically, 270 surveys (14.95% of all surveys collected nationwide) were collected in 2021, and 268 surveys (13.54%) were collected in 2022. The 2021 survey included eight 5-point Likert-scale items and an open-ended question, while the 2022 survey included seven 4-point Likert-scale items (with the neutral option removed) and the open-ended question. This study included only the six shared items and the open-ended question (see Appendix A), using chapter members' feedback to triangulate the perspectives of chapter leaders.

Data analysis

To answer the research questions, we conducted thematic analyses on chapter leader focus groups conducted in 2020–2022, supplemented with descriptive analysis of member feedback surveys collected in 2021 and 2022. Using an "open and axial" coding strategy (Williams & Moser, 2019), one researcher first familiarized herself with the 2020 focus group transcripts and generated initial codes. These initial codes were reviewed and aligned with elements from the chapter success rubric. Similar initial codes were combined. For instance, codes related to co-organizing PD meetings, collaborating with state agencies, and partnering with local universities for PD workshops were all grouped under "collaboration with other chapters or organizations." Uncertainties about the codes were resolved through discussions.

Using the updated codes, the remaining transcripts were coded. In addition to coding transcripts, memos were created to document observed patterns and representative quotes. The codes and memos were then shared with the whole project team.

After the initial coding, two researchers collaboratively reviewed and refined the codes, sorting them into potential themes. During this process, codes were checked for independence or exclusivity. Similar codes were grouped underneath one potential theme. For instance, "regular communication," "regular chapter activities," and "meeting teachers' needs" were grouped under the theme "building reliability with members." These potential themes were evaluated against the interview extracts and research questions for consistency and sensibility. Table 3 presents the finalized codebook.

The purpose of including the member feedback surveys was to triangulate the qualitative findings from the chapter leaders' focus groups. As mentioned earlier, the 2021 member feedback survey used a 5-point scale, while the 2022 survey used a 4-point scale. To combine the data, the 2021 survey responses were converted to a 4-point scale. Each item was evaluated concerning which code or theme it measured from the chapter members' perspective. The item's mean and standard deviation were checked to see how much chapter members' ratings deviated from the neutral/middle level. Positive ratings from most chapter members indicated consistency between their perspectives and those of the chapter leaders, while negative ratings suggested a discrepancy. For example, the item, "I feel connected to a local community of computer science teachers," assessed chapter members' sense of connectedness, and related to the theme of "breaking isolation." With a mean score of 2.78 ($SD = 0.87$), most chapter members were positive about the statement, which supported the credibility of the codes generated from the chapter leaders' focus groups.

The open-ended question about the type of support gained through CSTA chapter participation elicited 266 valid responses. A word cloud was created to visualize word frequency in these responses. Most responses aligned with the theme of "providing connection and resources," so the word cloud will be presented in the section focusing on this theme. Responses related to other themes will be reported or summarized elsewhere accordingly.

Results

This section presents the results revealed by the analyses of chapter leaders' focus groups and chapter members' feedback survey responses. The findings for the first two research questions are discussed from the viewpoints of chapter leaders followed by the perspectives of chapter members. The third research question is addressed solely from the perspectives of chapter leaders.

Types of support provided by local CSTA chapters

Our results revealed that these teacher-led local PLCs (CSTA chapters) supported computer science educators professionally by (1) providing connections and resources, (2) amplifying computer science teachers' voices, and (3) supporting computer science teachers' professional identity development.

Table 3. The codebook for analyzing chapter leaders' focus groups.

RQ	Theme	Code	Definition	Extract examples
1. Support from CSTA chapters	Provide connections and resources	Break isolation	CSTA Chapters break isolation and connect CS teachers.	"We are a group of compatriots. We can oftentimes help you remove yourself from that silo that you've been operating in and shows that you're not alone."
		Offer resources & PD	Chapters provide resources, information, and PD opportunities.	"The secondarily (benefit) is learning… We've got teachers that come to every single (session) for that community but also just to learn as much as they can about stuff."
	Amplify teachers' voices	Elicit and share teachers' perspectives	Chapters elicit and share teachers' voices to advocate CS education and change policies	"We were trying to work with [name] in [State] Department of Education on licensure, making our voice known about what we disagreed with regarding licensure process that they were putting out. And things that we would like to see and liked."
	Develop CS teacher identity	Build confidence & a growth mindset	Participation helps build teachers' confidence and shift their mindset for teaching CS.	"I tell teachers, I just literally have to put my hand on the mouse to try to navigate and figure out where to go…In the professional world. There are always bugs. We just need to help relay the idea this is part of the process. You're still doing it right, even if it goes wrong."
		Engage CS teachers in self-reflections	Self-reflection helps remove stereotypes, recognize, or build a CS teacher identity.	"We actually changed the identity of some of those teachers… they now see themselves more on that CS spectrum because of that level understanding that we give them. A huge component (was) getting through the nerd stigma."
		Mentorship and peer support	Support teachers to develop CS expertise and sense of belonging *via* mentorship and peer support	"We match people up quite often…that will start getting things going for that person… The thing is to help build up their confidence and their connections. Then on their own reached that point where they're saying, 'I'm math teacher and I also am a CS teacher'."
2. How chapters engage CS teachers	Build reliability with members	Regular communication	Regular newsletters or posts help with engagement.	"We're posting often enough that they know we're active… [The social media presence] inherently tells them like 'okay, they're available, they're accessible'."
		Regular activities	Regular chapter activities help maintain participation.	"We are consistent in holding meetings… committed up front to saying we're holding meetings on the third Tuesday… so that people can plan and get it on their calendar."
		Meeting teachers' needs	Keeping activities relevant and accommodating.	"We'll make sure that whatever resources they need that they can use in the classroom right away, we will make sure that that's what they are receiving from us."
	External Partnership	External collaboration	Collaborate with other chapters or organizations to achieve goals.	"Being able to offer that support, those trainings and build up those skill sets is really important. We can lean on those other organizations and connect people to them."
	Inclusive culture	Inclusive community culture	Chapter leaders ensure an inclusive and welcoming environment to attract and engage teachers.	"You are a teacher of CS. It doesn't matter what else you're teaching…It is important to feel validated about what you're doing. In our meetings, especially with elementary and middle school teachers, we try to make them feel more comfortable."
3. Challenges in building CSTA chapters	Member recruitment	Teachers of CS not joining	Lacking CS identity prevents teachers from joining CSTA.	"How do we reach people who don't personally identify as a CS teacher but actually really are? Maybe there is a math teacher who also teaches computer science."
		Outreach issues	Various titles or career pathways makes identification harder.	"The marketing is especially challenging because people wear many hats… we have to figure out how to say 'you belong here. And we need you'."
	Leadership growth and transition	Leadership support	Teachers lack experience, training, & support for running a CS PLC.	"Having one place where you've got everything together …would be great especially (for) somebody never being a chapter leader before.
		Leadership sustainability	Limited time/energy prevents the growth of leadership team.	"We need to work on distributing the leadership roles across the board and growing the leadership so that we aren't burning out…"
	Building group identity	Group (chapter) identity	Chapters struggle with clear goals/a consistent identity while leveraging stakeholder support.	"There are pockets of really great stuff happening in our state…Do we partner up with one of our sister organizations? Is something we can fly solo on? …We have to answer (those questions) and it will help us to find our role in our state."

Providing connections and resources

First and foremost, CSTA chapters emerged as vital places where computer science teachers break isolation and make connections, exchange information, and bounce ideas off with peers. Computer science teachers, often feeling like "isolated islands," found these communities invaluable. Along with the isolation were the unique struggles that many new computer science teachers experienced. With little or no formal educational background in computer science, they were tasked with teaching this new subject without much guidance. At local CSTA chapters, computer science teachers found camaraderie and rapport, shared their struggles, and helped each other. A teacher leader from Chapter H described her feelings before and after joining the chapter, which was typical among new computer science teachers:

> I don't have a computer science background and trying to figure out what classes to go to, what PD to go to, and what resources are out there for me has been a non-stop struggle. As soon as you start getting a community of teachers around you, it becomes a lot easier to figure out what resources can help you become a better teacher, can help your students, and can help your pathway.

The member feedback survey results indicated that chapter members' experience was consistent with their chapter leaders' perceptions. Teachers reported an average rating of 2.78 ($SD = 0.87$) and 3.07 ($SD = 0.78$) out of 4.00 on the survey items "I feel connected to a local community of computer science teachers" and "I have someone or some way to ask questions and receive support" respectively. This theme was further corroborated by written responses to the open-ended question in the member feedback survey, which asked what support teachers received from their chapter. A word cloud of the responses (Figure 1) suggests that computer science teachers primarily gained resources, ideas, support, and PD opportunities from their local CSTA chapters. Typical answers included, "The CSTA chapter has brought connections and resources we didn't have before," "We support one another regularly with lesson ideas and current resources," and "Joining [the chapter] allowed me to brainstorm about teaching computer science (CS). As the only CS teacher in my school, this is VERY important."

Amplifying computer science teachers' voices

Local CSTA chapters played a crucial role in connecting computer science teachers with peers, higher education institutions, and educators in non-teaching positions, both regionally and nationally. These connections amplified teachers' voices within the broader educational community. For example, leaders from Chapter E shared that their chapter collaborated with the state Department of Education on the licensure process for computer science teachers. Similarly, Chapter A leaders mentioned that they adopted a model from their state's superintendents' association, designating regional representatives to collect information about what computer science looked like in each school, and shared the information with policymakers.

Many teacher leaders developed productive connections with leaders of other chapters and representatives from various organizations. As conduits for teacher voices, these PLCs channeled computer science teachers' voices to other organizations and thus allowed them to advocate computer science education and devise plans and materials to deliberately address these teachers' PD needs. For example, in the member feedback survey, one teacher said: "Our chapter helped connect me to statewide committees… and advocate for professional development. The chapter asked us to lend our voices to the testimony presented in favor of a computer science bill in our state."

Supporting computer science teachers' professional identity development

One of the significant roles of CSTA chapters was nurturing computer science teachers' professional identity. From the teacher leaders' perspectives, developing confidence in teaching computer science and a growth mindset was fundamental for building computer science teachers' professional identity. To boost confidence in new teachers of computer science, many chapters promoted

Figure 1. Word cloud of teachers' responses on chapter supports they received.

the idea that "all teachers are computer science teachers." To drive this idea home, many chapters would "start with low-ceiling activities and gradually demystify the teachers' stereotype of computer science as a difficult area of study." As an example, Chapter F offered grade-based computer science lessons to teachers of other subjects, introducing simplified computer science ideas such as "algorithm is just the computer science word for directions." As teachers learned that debugging was a normal, even encouraged, process in computer science, they drew parallels and transferred this idea to their own learning and teaching. This shift helped them gradually abandon the "sage-on-the-stage" view on teaching in favor of the "teaching as facilitating" approach, fostering a growth mindset. With a growth mindset, many teachers' confidence increased, and concern about lacking a computer science background was alleviated, thus removing one stubborn barrier to the development of their professional identity as computer science teachers. The experience of a teacher leader from Chapter J illustrated this:

> I never considered myself to be a techie… what I'm getting from the training that we've been doing, is that computer science isn't an innate ability. It's an ability; it's like a muscle that the more you exercise it, the better you get at it… Now I can't deny that I am a techie.

Some teachers transferred the growth mindset to their professional identity development. In one remarkable case, a teacher leader said: "I may not have all the answers, but we could figure it out together. And that has become my approach now, to me even being identified as a computer science teacher." With a growth mindset, building a professional identity for teaching computer science became an ongoing process versus something one statically had or not. This reformed view empowered teachers to become the agents of their professional identity and capacity development as computer science teachers.

Some chapters supported their members in developing a sense of computer science teacher identity by engaging them in self-reflection. Teacher leaders recognized the value of reflection in nurturing identity and actively advocated for a self-reflective approach to teachers' professional learning. One Chapter J leader, a seasoned computer science educator, described how reflection helped him with his identity-building:

> When I read that word (computer science teacher identity) initially… I started reflecting upon myself… Hearing that (concept) just flipped me completely as far as my professional identity… I was just really fascinated by the concept because it's so right on. I think there are so many of us who just don't realize what we are doing, but we are already doing it.

Furthermore, CSTA chapters played a crucial role in supporting computer science teachers' identity development by engaging teachers in mentoring and peer support to develop CS teaching expertise and a sense of belonging. Within these PLCs, novice computer science educators found more experienced mentors who traversed similar paths and were willing to guide them. The guidance and encouragement from seasoned computer science teachers proved invaluable in shaping the professional identity of newer computer science teachers. A teacher leader from Chapter J reflected on her journey from a self-doubting computer science teacher to an assertive computer science teacher:

> Imposter syndrome was something that I've struggled with from day one. But I've been supported by (another teacher leader), who has afforded me tons of opportunities or who will gently nudge me to try to do something so that I can at least learn, so I can build on my confidence of (and) my value as a CS educator…(It took) a year and a half for me to come to a realization that I am a computer science person, that I am an educator (of computer science).

How CSTA chapters engage computer science teachers

To engage and effectively support computer science teachers, chapter leaders strived to (1) build trust with their members through regular communication and chapter activities that meet teachers' needs, (2) establish collaborative and close connections with other chapters and educational organizations, and (3) cultivate a welcoming and inclusive PLC culture.

Building trust through regular communication and chapter activities that meet teachers' needs

First, chapter leaders prioritized building credibility and reliability with regular communication and activities. Many chapter leaders expressed their appreciation toward regular newsletters from CSTA national. These newsletters were instrumental, providing crucial updates on events, computer science learning tools, policies and standards, grant opportunities, and research findings. This positive experience inspired them to maintain communication with chapter members. Several chapters, like Chapter A, bolstered their outreach by maintaining active profiles on multiple platforms. Chapter A's robust social media presence, with over a thousand followers, facilitated widespread engagement, particularly during the pandemic. A leader of Chapter A shared, "They (teachers) know we are out there- 'they (chapter leaders) are available; they are accessible'." Moreover, regularity in events with accessible schedules was a cornerstone of these efforts. Members reported that meeting schedules were overall accessible to them ($M = 2.76$; $SD = 0.80$). One teacher further commented, "I've loved every meeting! The content and camaraderie have been appreciated. Holding quarterly meetings was good with our busy lifestyle."

Moreover, local CSTA chapters fostered trust by proactively eliciting and meeting the professional learning needs of CS teachers. During the COVID pandemic, virtual events attracted more participants, particularly remote members who benefited from the convenience of online meetings. Recognizing this, most chapter leaders kept some events fully online or hybrid even as the pandemic subsided, ensuring continued accessibility for distant educators. Local chapters kept teachers' professional needs in mind and tailored events accordingly. Chapter J, for instance, facilitated events where teachers could test new computing curricula or tools as learners before teaching them. The same chapter also planned activities around significant events such as robotics competitions and created resources for teachers. In a counterexample, a teacher leader from Chapter D postponed a grant initiative because of the hesitancy exhibited by members. According to a Chapter G leader, obtaining direct feedback from members ensured the "cohesiveness" between the leadership team and their members.

Members were overall satisfied with their chapters' activities ($M = 2.96$, $SD = 0.72$) and highlighted personalized PD experiences in response to the open-ended survey question. For instance, one teacher said, "The micro:bit hackathon was a ton of fun and gave me ideas on how to bring physical computing into my classroom!" Additionally, another two teachers valued their chapters for unpacking standards and providing opportunities to try out related materials and activities. Furthermore, CSTA chapters helped teachers navigate the certification process and eventually helped these teachers acquire computer science certifications.

Establish collaborative and close connections with other chapters and educational organizations

In contrast to transient PD programs, CSTA chapters offered sustained support to computer science teachers. These local PLCs also fostered long-term relationships with external organizations, ensuring continuous and reliable support for their members. These external collaborations were initially rooted in individual teacher leaders' connections and then expanded as more educators broadened their networks. Thus, these partnerships persisted over leadership transitions. By partnering up with other computer science educational organizations, CSTA chapters provided rich networking opportunities and access to high-quality PD for computer science educators.

Depending on each chapter's unique situation, the partner organizations and the foci of the collaborations were different. For example, in the northeast region, Chapters A, B, and C collaboratively developed a regional computer science educator network. They took turns hosting CSTA Regional Conferences, which supplemented CSTA Annual (National) Conferences. This initiative allowed local teachers to more frequently network, share ideas, and "see what the surrounding states are doing." Similarly, Chapter J developed partnerships with organizations like Code.org and non-CSTA PLCs within the same state. Through collaborative efforts, they delivered a series of high-quality workshops and helped "connect these dots" within the computer science education community. Despite serving smaller groups, both Chapters H and I maximized their unique characteristics. Chapter H engaged with other smaller or unconventional chapters, such as a non-continental U.S. chapter and foreign chapters, fostering diverse discussions. Chapter I collaborated closely with a national lab to apply for grants, organize workshops, and promote computer science education in that region.

Cultivating a welcoming and inclusive PLC culture

Acknowledging the challenges faced by new teachers, who often lacked a computer science background and might feel uncomfortable about joining the chapter, teacher leaders proactively fostered a welcoming and inclusive culture within their PLCs. Members rated high ($M = 3.01$, $SD = 0.71$) on the item "My perspective is welcomed and honored in my chapter." To achieve this, chapter leaders actively listened to members' concerns and empathized with their struggles. For example, in Chapter G, most leaders transitioned from business to computer science teaching. One chapter G leader said, "I was in a position to have empathy for our chapter members because we have lived the struggles that they are facing." Similarly, a Chapter E leader encouraged participation by appreciating diverse perspectives. During a PD session, she noticed an anxious art teacher who voiced her discomfort, "I just don't know anything. I don't know how you know what to do." To ease her discomfort and encourage participation, the teacher leader said, "You are showing me how the kids look at things, which I don't always see because I've taught it for so long."

The ratings ($M = 2.56$, $SD = 1.05$) on "I can name the leaders of my chapter." indicated CSTA members' partial recognition of their chapter leaders. Nonetheless, members expressed gratitude for their chapter leaders' support in the member feedback survey. Many teachers appreciated their chapter leaders' exceptional efforts in delivering high-quality PD content and fostering a cohesive teacher community.

Challenges in building and sustaining local PLCs

Chapter leaders perceived the following as the main challenges in establishing and sustaining local CS teacher PLCs: (1) member recruitment, (2) leadership development and transition, and (3) building group (chapter) identity.

Member recruitment

Manifold issues led to this challenge. In many schools, especially at K-8 schools and rural settings, the emerging need to teach computer science fell onto the shoulders of teachers who primarily taught other subjects or had other responsibilities. Many teachers self-identified as "teachers who teach computer science" rather than computer science teachers. The lack of a professional identity in computer science education prevented them from seeking or joining those PLCs of local computer science educators, with the assumption that they did not belong. Hence, how to bring these teachers on board remained a huge challenge. Moreover, the lack of certification programs, standardized qualifications, and defined titles for computer science educators further complicated recruitment efforts. Teachers could have various titles while teaching computer science. One teacher leader characterized this struggle:

> A big thing for recruitment is knowing whom you are supposed to recruit. Among elementary teachers, you don't know who is teaching it. It could be any teacher or the integrator…With the high schools you (could) reach out to CTE directors, but not all schools have that…Then with non-traditional or charter schools, they are going to have a different title.

Leadership development and transition

Most teacher leaders assumed chapter leadership roles alongside their primary responsibilities as classroom teachers, without a predefined leadership structure, especially in newly established chapters. As a result, they needed guidance on fundamental roles and organizational functions. Establishing a clear framework for leadership roles could help new chapter leaders manage their workload effectively and prevent burnout. For example, one chapter leader learned from experience that it was necessary to have an administrative role that "can be purely supportive and lift some of the work, when necessary," to run a higher-caliber chapter. Such kind of experiences from established chapters could be shared with newer ones, facilitating a collaborative learning environment across chapters.

Chapter leaders also faced challenges in balancing their existing teaching responsibilities with the demands of their leadership roles. This strain on time and effort made it difficult to develop a robust leadership team. As an example, inactive chapters, like Chapter G, needed to rebuild trust and reconnect with local computer science teachers, which required significant effort. Currently, serving a large state, Chapter G hoped to set up a statewide network with liaisons from different regions. It was up to the chapter leaders to tackle the issues in developing regional teacher leaders, which could directly impact their chapter's community-building efforts. Another leader from a different chapter also shared her insights on leadership transitions:

> As much as some teacher leaders loved the work, not growing a strong bench of new leaders was unhealthy for the PLC in the long run, since this created a vicious cycle where teachers observed the leadership role to be permanent and were less likely to get involved.

Group (chapter) identity

Computer science is relatively new in schools. CSTA chapter leaders struggled with establishing a group (chapter) identity while engaging with diverse stakeholders. On one hand, CSTA chapters aimed to convey an inclusive message encouraging more teachers of other subjects to teach computer science and join CSTA chapters. Simultaneously, chapters needed to advocate for computer science's importance as a core educational area and send computer science-focused

messages to school administrators and other stakeholders to garner their support. Notably, leaders from Chapter A extensively discussed the challenges in defining their identity and roles while navigating various contexts:

> Computer science is still very new to schools… it is exceptionally new for us as an organization to define… What does computer science mean to [Chapter Name] versus what does computer science mean to [State Name] like our Department of Education versus what does computer science mean as we disseminate it throughout our districts… Having a flexible definition of what computer science is (helped)…but trying to consolidate that all under one organization is a challenge.

Summary and discussion

In this study, we investigated how CSTA chapters supported computer science educators as local PLCs and how to build robust teacher-led PLCs from the perspectives of those on-the-ground computer science teacher leaders and teachers, using longitudinal data from chapter leader focus groups and member feedback surveys. In this section, we summarize the main findings, discuss the implications, and reflect on the limitations of this study.

Summary of findings

First, this study identified several key areas of professional support that CSTA chapters provided for computer science educators: offering professional connections, resources, and learning opportunities; amplifying teachers' voices within the broader education community; and nurturing teachers' professional identity as computer science teachers by boosting confidence, promoting a growth mindset, encouraging self-reflection, and fostering community engagement. The CSTA member survey responses revealed a close alignment between the reviews of computer science teachers and chapter leaders.

Second, CSTA chapter leaders strived to engage computer science educators and build strong local PLCs through trust-building, collaborations with other educational organizations, and fostering an inclusive culture within their chapters. The findings demonstrated the importance of regular communication and chapter activities that served their members' learning needs and leveraging external resources to achieve chapter goals. Responses to the CSTA chapter member feedback survey also indicated that computer science teachers' perspectives resonated with those of teacher leaders.

Third, CSTA chapters still faced challenges in member recruitment and leadership sustainability, echoing what other researchers found in building a network of local PLCs for computer science teachers in the UK (Cutts et al., 2017; Sentance & Humphreys, 2018). Additionally, we found that sometimes these local PLCs struggled to establish a clear sense of chapter or group identity as they leveraged various resources and interacted with diverse stakeholders.

Implications for future practice

Our findings on these teacher-led local PLCs for computer science educators are consistent with prior research findings on curriculum-driven PLCs, both emphasizing the role of PLCs in connecting isolated teachers and enhancing their confidence in teaching computer science (Cutts et al., 2017; Goode et al., 2020; Ryoo et al., 2015). Additionally, our study underscores the importance of CSTA chapters as local PLCs in fostering collaboration, continuous learning, and professional identity for computer science educators with diverse backgrounds and teaching experiences (Cutts et al., 2017; Ni, McKlin, et al., 2021; Sentance & Humphreys, 2018). These local PLCs were the platforms on which computer science teachers got connected to other educators and organizations across the state or nation, which enriched their professional learning and empowered their participation in the larger computer science education community. We

offer three suggestions for initiatives dedicated to preparing and developing strong computer science educators in the United States.

First, it is essential to leverage local PLCs, such as CSTA chapters, to expand PD efforts and support the growth of the preK-12 computer science teaching workforce in the United States. Although there are increasing efforts to offer computer science PD to meet the growing demand for computer science education, many existing PD programs are short-term, curriculum-driven, or primarily focus on content knowledge, often lacking continuous support and community-building elements (Menekse, 2015; Ni, Bausch, et al., 2021). Our findings highlight the significant role that CSTA chapters play in consistently engaging and developing computer science teachers by fostering connections, offering resources and PD opportunities, and supporting their professional identity development. Therefore, it is vital to collaborate with local PLCs, like CSTA chapters, to reach and continuously support computer science teachers. The needs of these computer science educators often evolve as they progress in their careers; the professional support they require when first joining the chapter may differ from what they need as their expertise grows. Therefore, local PLCs must remain adaptable and responsive to the unique and evolving needs of their members.

Second, it is also critical to establish a trustworthy, collaborative, and inclusive community environment for computer science educators. These educators often face unique challenges, such as their isolation, the lack of a computer science background, and the need to develop a distinct mindset and professional identity specific to teaching computer science (e.g. Goode et al., 2020; Ni, McKlin, et al., 2021; Ryoo et al., 2015). Our findings reveal that strong CSTA chapters underscore the importance of building trust and reliability among their members and fostering an inclusive culture where all teachers, regardless of backgrounds or levels of computer science expertise, feel valued and supported. Therefore, it is essential for our computer science education community to cultivate a welcoming environment that encourages more K-12 educators to engage in and contribute to computer science education.

Third, it is important to coordinate efforts across multiple stakeholders and focus on addressing the challenges voiced by teacher leaders. Our study highlights several key challenges or obstacles in developing and sustaining local PLCs for computer science education, including member recruitment, leadership development and sustainability, and group identity. Addressing these challenges requires more coordinated efforts from a range of stakeholders, including state policymakers, school administrators, CSTA national, and other computer science education organizations. For instance, increased advocacy and policies dedicated to computer science education can help school administrators better recognize the value of computer science education and those PLCs for computer science educators, such as CSTA chapters. This recognition would likely lead to stronger support for their teachers' participation in these PLCs as a valid and essential professional development activity, encouraging both current and prospective computer science educators to engage more actively. Such support could be fruitful in teachers' professional growth and thus strengthening computer science education at their schools.

Limitations and future work

We acknowledge this study has limitations. First, we primarily investigated the perspectives of computer science teacher leaders (chapter leaders), who were more likely to have positive experiences (Cutts et al., 2017). Although we incorporated inputs from computer science teachers through CSTA chapter member surveys, our understanding was confined to the perceptions of those teachers who participated in the survey. Additionally, this study is the very first attempt to understand local teacher PLCs in the context of computer science education in the United States. We selected 10 chapters as a sample of the CSTA chapters in the U.S. to seek some initial understanding of how these chapters function in supporting and engaging computer science educators. These findings are summative and may not be transferable to other chapters or PLCs

in different regions. We acknowledge that the context in which each chapter operates significantly influences its development and outcomes, and this variability was not fully explored in this study. Future studies should dive deeper into the dynamic, contextual nature of individual chapters and the members they serve to gain deeper insights into their development and better address the evolving needs of their members.

Nonetheless, this study presents initial insights into the development of local PLCs led by computer science educators in the United States. This study contributes to a deeper understanding of the support local PLCs can offer in the professional development of computer science educators, the strategies employed by teacher leaders in developing robust PLCs, and the challenges these local PLCs face. The findings are valuable for designing PD programs and developing PLCs for computer science educators. Further research is needed, particularly focusing on the contextual nature of those successful or unsuccessful CSTA chapters to understand their developmental and operational models, and to inform our (computer science) education community to establish robust PLCs.

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Notes on contributors

Lijun Ni is an assistant professor in the Department of Educational Theory and Practice, at the University at Albany, State University of New York. She studies how we can prepare and support teachers in infusing computer science into their classrooms and engage students of diverse backgrounds in learning computational thinking and skills.

Yan Tian is a curriculum and instruction doctoral candidate at the Department of Educational Theory and Practice, at the University at Albany, State University of New York.

Tom McKlin leads The Findings Group (TFG), which has a long history of researching and evaluating computer science education projects.

Jason Bohrer is the Chapter Relation Lead of the Computer Science Teachers Association. He is a former computer science and English teacher.

Jake Baskin is the Executive Director of the Computer Science Teachers Association. He is a former high school computer science teacher, department chair, and professional development provider with the Chicago Public Schools.

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Appendix A

Chapter engagement items in the member survey and participating members' ratings.

	Items	*Mean* (*SD*)
1	The days and times of most chapter events are accessible to me, given my schedule.	2.76 (0.80)
2	I feel connected to a local community of computer science teachers.	2.78 (0.87)
3	I have someone or some way to ask questions and receive support.	3.07 (0.78)
4	Overall, I feel satisfied with the activities of my chapter.	2.96 (0.72)
5	My perspective is welcomed and honored in my chapter.	3.05 (0.70)
6	I can name the leaders of my chapter.	2.56 (1.05)
7	(Open-ended question) Share a success: how has your chapter helped you the most in the last year?	Not applicable

Note: $N = 538$ for Items 1–6, and $N = 266$ for Item 7.