Understanding Professional Identity of Computer Science Teachers: Design of the Computer Science Teacher Identity Survey

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ABSTRACT

Motivation: Recent efforts to expand K-12 computer science education highlight the great need for well-prepared computer science (CS) teachers. Teacher identity theory offers a particular conceptual lens for us to understand computer science teacher preparation and professional development. The emerging literature suggests that teacher identity is central to sustaining motivation, efficacy, job satisfaction, and commitment, and these attributes are crucial in determining teacher retention. While the benefits associated with a strong sense of teacher identity are great, teachers face unique challenges and tensions in developing their professional identity for teaching computer science.

Objectives: This exploratory study attempts to operationalize computer science teacher identity through discussing the potential domains, proposing and testing a quantitative instrument for assessing computer science teachers' professional identity.

Method: We first discussed the potential domains of computer science teacher identity based on recent teacher identity literature and considerations on some unique challenges for computer science teachers. Then we proposed the computer science teacher identity scale, which was piloted through a national K-12 computer science teacher survey with 3,540 completed responses. The survey results were analyzed with a series of factor analyses to test the internal structure of the computer science teacher identity scale.

Results: Our analyses reveal a four-factor solution for the computer science teacher identity scale, which is composed of CS teaching commitment, CS pedagogical confidence, confidence to engage students, and sense of community/belonging. There were significant differences among the teachers with different computer science teaching experiences. In general, teachers with more computer science teaching experience had higher computer science teacher identity scores on all four factors.

Discussion: The four-factor model along with a large national dataset invites a deeper analysis of the data and can provide important benchmarks. Such an instrument can be used to explore developmental patterns in computer science teacher identity, and function as a pedagogical tool to provoke discussion and reflection among teachers about their professional development. This study may also contribute to understanding computer science teachers' professional development needs and inform efforts to prepare, develop, and retain computer science teachers.

CCS CONCEPTS

• **Social and professional topics** → Professional topics; Computing education; K-12 education.

KEYWORDS

Computer Science Teachers, Teacher Identity, Identity Survey, Community, Confidence

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1 INTRODUCTION

Current efforts to expand K-12 computer science education highlight the great need to prepare and support computer science teachers. The Computer Science Teachers Association (CSTA) coordinates a network of over 90 local chapters in 48 states and Puerto Rico with over 27,000 members worldwide to create local, teacher-led community and professional development. Historically CSTA chapters have served the needs of teachers who teach a majority of standalone computer science courses. However, the dramatic growth in computer science education over the last few years has been driven by teachers from other subjects learning to teach computer science as both standalone courses and as content integrated into other courses. The majority of CSTA teacher members (about 80%, based on its membership data) teach courses in other subjects in addition to computer science [10]. More and more teachers are

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facing the challenges or tensions of professionally identifying their major teaching roles for computer science.

1.1 Teacher Identity

Teacher (professional) identity is broadly defined as "being recognized as a certain kind of teacher by self or others" [4, 16]. The emerging literature on teacher identity suggests that the development of a professional identity is an important component of the process of learning to become a teacher [5, 7]. Many studies have highlighted the importance of supporting the development of teacher identity in both teacher preparation and professional development [4, 6, 12, 34]. Overall, teacher identity is considered central to sustaining their motivation, efficacy, job satisfaction, and commitment, and these attributes are critical in determining teacher retention [8, 12, 40]. A strong and stable professional identity is positively related not only to emotional well-being [23, 44] but also to the quality of teaching [2, 6]. We contend that fostering professional identity for computer science teaching is an important step toward high-quality and consistent computer science learning experiences. Teacher identity is also often seen as a lens through which to explore or address many topics and issues in the domain of teaching and teacher education [5]. Computer science (CS) teacher identity can be a critical indicator informing efforts to prepare, develop, and retain computer science teachers.

1.2 Challenges for Building Computer Science Teacher Identity

While the benefits associated with a strong sense of teacher identity are great, computer science teachers face unique challenges in developing their professional identity as computer science teachers. First, computer science education standards are evolving and lack the maturity that standards in core subject areas possess, which leads to shifting computer science curricula and standards as well as emerging certification requirements and attainability to teach computer science [9, 39]. The evolving standards make it difficult for teachers to define the key academic disciplines of computer science and how to teach them. Teachers may also be confused about whether they are or how they can become certified/qualified computer science teachers.

Second, many teachers lack subject-specific preparation for teaching computer science [11, 42]. The demand for expanding computer science education also puts pressure on teachers in other areas to learn to teach computer science. Many new computer science teachers have had minimal professional learning or are self-taught in computer science content and have learned to teach computer science in the classroom. These teachers do not always see themselves as computer science teachers or perceive themselves to have the ability to effectively teach the computer science subject matter. Teacher identity research indicates that most teachers derive their identity first of all from the subject they studied [36]. The lack of subject-specific preparation can indicate the need for professional development, but can also influence how teachers build their professional identity for teaching computer science.

Third, the majority of computer science teachers are often isolated without other computer science teachers within the same school to share their teaching experiences and practice [18, 43]. Teachers can lack the opportunities for collegial dialogues and connections, which are an important mechanism that fosters teacher learning and the formation of teacher identity [41].

Overall, many of those currently teaching computer science have come to the profession in ways that prevent them from developing an identity as a computer science teacher in the same way as a teacher in a core subject area (like math or English): many have not spent years studying the content, they struggle to define the requirements for professional certification or advancement, and they are isolated in their building. Importantly, (teacher) identity is not a fixed construct but is under constant renegotiation as conditions change [4, 17]. An individual works hard to establish a unified identity to protect a sense of self amidst changing circumstances. One circumstance that may fragment a teacher's identity is shifting responsibilities to a new content area like computer science. Asking a teacher to begin teaching a computer science course or to integrate computer science/computational thinking into an existing curriculum, may fragment a teacher's identity and trigger an internal negotiation to incorporate the new role into an existing sense of self.

1.3 Research Aims

A prior study [31, 32] conducted an initial exploration of high school computer science teachers' perceptions about their professional identity and potential factors that contributed to these perceptions. That study found that computer science teachers often held different teacher identities, and these identities indicated varied perspectives related to their motivation, self-efficacy, and commitment in teaching computer science. For example, some of these teachers did not see computer science as part of their primary teaching responsibilities and were uncertain about continuing to teach it. Some teachers were not confident, and many of them were isolated and did not feel a sense of belonging as a computer science teacher [32]. More recent efforts have focused on creating computer science teacher communities, or fostering professional learning communities addressing the issue of teacher isolation [11, 18, 30, 37]. This study is a collaborative effort with CSTA to create mechanisms to understand the needs of and support those who teach computer science. CSTA's network of chapters is ideally positioned to build strong local communities, and in turn support teachers as they adapt their identity to include seeing themselves as computer science teachers.

To support the development of well-prepared computer science teachers, our computer science education community could benefit from further understanding of teacher professional identity for computer science. This exploratory study attempts to operationalize computer science teacher identity through discussing potential domains and proposing a quantitative instrument for assessing computer science teachers' professional identity. Such an instrument can be used to explore developmental patterns in computer science teacher identity, and function as a pedagogical tool to provoke discussion and reflection among teachers about their professional development. The instrument can also be used by researchers and educators to better understand, support, and strengthen the professional identity of computer science teachers through teacher preparation and professional development.

2 BACKGROUND

2.1 Domains of Teacher Identity

Teacher identity has been conceptualized from various research perspectives [4, 6, 19]. For example, Hong [23] examined preservice and beginning teachers' professional identity in relation to their decision to leave the teaching profession. That study identified six factors that constituted teacher identity: commitment, emotion, efficacy, knowledge & beliefs, value, and micropolitics. Friesen & Besley [15] examined three aspects of teacher identity: self-categorization, confidence in becoming a teacher, and natural inclination towards children & teaching, focusing on the associations between aspects of personal identity and social identity of student teachers.

More recently, Hanna et al. [19] conducted a systematic review into existing quantitative instruments of teacher identity. Despite the use of various conceptualizations in these studies, the analysis of available instruments revealed six domains representing the set of meanings for teacher identity among 59 components in 20 different studies: (1) motivation (Why am I teaching), (2) self-image (How do I see myself as a teacher), (3) self-efficacy (How capable do I believe I am to organize and perform my daily teaching activities), (4) task perception (What is my task as a teacher), (5) commitment (How committed am I to the profession), and (6) job satisfaction (How satisfied am I with my job). Based on the above teacher identity construct, Hanna et al. [20] conducted a follow-up study to design and validate the Teacher Identity Measurement Scale for assessing primary student teachers' professional identity focusing on the first four of those six domains. As Hanna et al. [19, 20] suggested, empirical research on teacher identity could focus on specific domains underlying this complex construct. In this study, we use the above six domains of teacher identity to guide the examination of computer science teacher identity, with specific consideration for computer science teachers.

2.2 Computer Science Teacher Identity Construct

Computer science teacher identity was first examined in a prior study [31, 32] focused on three dimensions: attitudes and values, motivation and commitment, belonging and affiliation. Computer science teacher identity was further broken down into six components:

(1) Self-identification: Self-identify as a CS teacher;

(2) Community/sense of belonging: Teachers' sense of belonging to a community/group of CS teachers;

(3) Interest/value: Teachers' interest in teaching CS and beliefs in the values of teaching CS;

(4) Confidence: Teachers' confidence in teaching CS;

(5) Learning/striving to teach well: Teachers' willingness to learn/change and grow the CS program;

(6) Commitment/retention: Teachers' commitment to staying teaching computer science.

The above six facets of computer science teacher identity can generally fall into five of the six domains of teacher identity recommended by Hanna et al. [19]: *self-image, motivation, task perceptions, self-confidence, and commitment*. In this study, we also focus on the specific aspects of teachers' perceptions about teaching computer science. Therefore, some of the components (or their specified meaning) of the six teacher identity domains [19] are not directly applicable or less relevant to our research focus (such as motivation to work with kids, satisfaction with job salaries, etc.). We adopt the prior computer science teacher identity framework [31, 32] and slightly rephrased it to include the following six aspects, with components from Hanna et al.'s [19] teacher identity domains marked in italic: **Self-Identification** (*self-image*), **Community/Sense of Belonging** (*self-image*), **Interest and Value of Teaching Computer Science** (*motivation*), **Learning/Striving to Teach Well** (*task perceptions*), **Confidence in Teaching Computer Science** (*self-efficacy*), and **Commitment to Teaching Computer Science** (*commitment*). In particular, we list **Community/Sense of Belonging** as an individual domain separated from **self-identification**, considering the isolation of computer science teachers and recent efforts on building computer science teacher communities.

The introduction describes multiple challenges for building computer science teachers' professional identity, which is related to content knowledge and preparation, professional credentials, and teacher isolation. Here, we operationalize computer science teacher identity in four ways that are unique to computer science education. First, computer science teacher identity implies that teachers perceive that they "belong" in the computer science education community and, secondly, that they are "committed" to the profession of computer science education. Third, those who identify as computer science teachers are motivated to learn about the evolving field of computer science, and feel confident in their ability to engage students in the unique pedagogical processes of learning computer science (e.g., how to cope with error messages and use debugging as an opportunity for learning). Finally, those who identify as computer science teachers are also those who are committed to democratizing computer science and making both computer science education and career opportunities available to all students regardless of gender, ability, or ethnicity.

3 METHODS

3.1 Instrument Design

Based on the above proposed computer science teacher identity framework, we adapted applicable questions on *self-image*, *motivation*, and *self-efficacy* from the Teacher Identity Measurement Scale [19] for the first four computer science teacher identity components and specified those items for computer science. For example, we modified the statement "I truly enjoy teaching" to "I truly enjoy teaching computer science." Acknowledging some of the unique challenges for computer science teachers (e.g., the evolving nature of the computer science field and thus the need for continual learning as a computer science teacher), we proposed new items for the components of Learning/Striving to Teach Well and Commitment to Teaching Computer Science. Example items include "I attend professional development to help me keep up with the latest developments in computer science teaching" and "I advocate for more students to take courses in computer science." For this same domain of *task perception*, we chose to not include items for perceptions on education and teaching in general (e.g., "In my class,

Table 1: Proposed Computer Science Teacher Identity Scale Items

Self-Identification (*Self-Image*)[1]
1. I truly enjoy teaching computer science. 2. I see myself as a computer science teacher. 3. I have actively looked for opportunities to teach computer science.
Community/Sense of Belonging (*Self-Image*)[1]
1. I feel part of a community of computer science teachers. 2. I frequently talk to peers about computer science teaching. 3. I enjoy sharing ideas about teaching computer science.
Learning/Striving to Teach Well in Computer Science (*Task Perception*)[1]
1. I work hard to be the best computer science teacher that I can be. 2. I attend professional development to help me keep up with the latest developments in Computer Science teaching. 3. I advocate for more students to take courses in computer science.
Confidence in Teaching Computer Science (*Self-Efficacy*)[2]
Instructional Strategies: When teaching computer science, 1. How well can you implement alternative strategies in your computer science classroom? 2. To what extent can you gauge student comprehension of what you have taught? 3. How much can you do to adjust your lessons to the proper level for individual students? Engagement: 4. How much can you do to get students to believe they can do well in computer science? 5. How much can you do to help your students value learning computer science? 6. How much can you do to foster student creativity in computer science?
Interest and Value of Teaching Computer Science (*Motivation*)[3]
Why do you want to teach computer science? 1. Because teaching computer science is important to me. 2. Because computer science is an important life skill for my students. 3. Because I enjoy teaching computer science.
Commitment to Teaching Computer Science (*Commitment*)[1]
1. I see teaching computer science as a primary responsibility for my job. 2. I plan to continue as a computer science teacher for at least the next five years. 3. Choosing to become a computer science teacher was a good decision.

Note. [1]Response Options = 1.Strongly disagree, 2.Disagree, 3.Neither agree nor disagree, 4.Agree, 5.Strongly agree. [2]Response Options = 1. Not at All Confident, 2. Slightly Confident, 3. Somewhat Confident, 4. Fairly Confident, 5. Very Confident. [3]Response Options = 1.Not Important, 2. Slightly Important, 3. Moderately Important, 4. Very Important, 5.Extremely Important.

students should be quiet and pay attention"), or motivation of becoming a teacher in general (e.g., interest in working with children). Meanwhile, we added three items for commitment. Table 1 lists the proposed items for the six components of computer science teacher identity.

We then shared these initial items with our CSTA team collaborators for feedback on the feasibility of including these items in the national Computer Science Teacher Survey. The national Computer Science Teacher Survey measures numerous constructs, and teacher identity is only one component. Like any survey, it is constrained by the number of items respondents are willing to answer. Still, the survey provided a unique opportunity for feedback from computer science teachers across the country. These conditions required that we limit the number of items for each identity construct and that we use items from other areas of the survey to measure overlapping constructs. For example, confidence is an identity construct and also a broader construct of interest to the survey team. For that reason, we have many confidence items and relatively few items to represent other constructs. Table 2 lists the 22 computer science teacher identity questions included in the national Computer Science Teacher Survey.

3.2 Participants and Procedure

The national Computer Science Teacher Survey was administered by CSTA, in partnership with the Kapor Center. The survey was widely distributed through multiple channels. CSTA sent dedicated email messages to all of its members, as well as over 300 partner organizations and individuals. CSTA also shared blog posts about the

Table 2: Piloted Computer Science Teacher Identity Scale Items

Self-Identification (Self-Identity)[1]
1.I truly enjoy teaching computer science.
2. I see myself as a computer science teacher.
3. I have actively looked for opportunities to teach computer science.
Community/Sense of Belonging (Community)[1]
1. I feel part of a community of computer science teachers.
2. I frequently talk to peers about computer science teaching.
3. I enjoy sharing ideas about teaching computer science.
Learning/Striving to Teach Well in Computer Science (Learning)[1]
1. I work hard to be the best computer science teacher that I can be.
2. I advocate for more students to take courses in computer science.
Confidence in Teaching computer science (Confidence)Please select which category best describes your confidence in the following topics:[2]
1. Teaching computer science content/concepts
2. Using inquiry-based strategies
3. Using culturally relevant pedagogy to support student learning
4. Teaching students from diverse backgrounds
5. Teaching students with disabilities
6. Using a variety of assessment strategies
7. Adjusting lessons to the proper level for individual students
8. Facilitating conversation around the impacts and ethics of computing
9. Most computer science teachers know more about computer science content than I do.[1]
10. Helping students believe they can do well in computer science[3]
11. Helping students value learning computer science[3]
12. Motivating students who show low interest in computer science[3]
Commitment to Teaching Computer Science (Commitment)[1]
1. I plan to continue as a computer science teacher for at least the next five years.
2. Choosing to become a computer science teacher was a good decision.

Note. [1]Response Options = Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, Strongly Agree. [2]Response Options = 1. Not at all Confident, 2. Slightly Confident, 3. Somewhat Confident, 4. Fairly Confident, 5. Very Confident. [3]Response Options = Not much, Very little, Some, Quite a bit, A great deal.

importance of the survey on the CSTA website, in their newsletters, and on social media accounts. CSTA worked with their chapter leaders to encourage member completion on an ongoing basis, using a chapter leader dashboard.

From May through July 2020, 3,693 K-12 computer science teachers in the U.S. participated in the survey. CSTA has recently published the Computer Science Teacher Landscape Report, which presents survey results on the backgrounds of computer science teachers and the support and resources needed to implement culturally relevant computing pedagogical practices [28]. For the purpose of the current study, we used data from 3,540 teachers who answered all the computer science teacher identity questions. Table 3 presents the gender and race information of these 3,540 respondents, which was closely aligned with the demographic characteristics of the whole survey population. The majority of these teachers were white (75%) and women (63%), situated predominantly in high-income, urban, and less racially diverse schools. The majority of respondents taught in public schools (78%), with 27% serving grades PreK-5, 37% serving grades 6-8, and 55% serving grades 9-12.

Among these teachers, 52% of them reported they had at least half of their teaching responsibility for computer science. 54% had 11+ years of classroom experience, but considerably fewer teachers (16%) reported 11+ years of experience in computer science classrooms. A total of 48% of these teachers had taught computer science for more than 5 years, 37% had taught computer science for 2-4 years, and 13% were in their first year of teaching computer science. 52% of these teachers took some computer science classes during their college education, 27% did not take any computer science classes, while 15% majored in computer science and 5% had a computer science minor. More than half of these teachers (58%) were CSTA members.

Table 3: Teacher Demographics (Gender and Race)

Race Gender	Female 2197 (62.75%)	Male 1231 (35.16%)	Non-Binary14 (.40%)	Prefer not to answer 59 (1.69%)
American Indian or Alaska Native 87 (2.46%)	53 (1.51%)	32 (.91%)	2 (.06%)	0 (0%)
Asian (East, South, Southeast) 191 (5.40%)	118 (3.37%)	71 (2.03%)	1 (.03%)	1 (.03%)
Black or African American 270 (7.63%)	200 (5.71%)	69 (1.97%)	2 (.06%)	0 (0%)
Hispanic or Latino/a/x 278 (7.85%)	179 (5.11%)	98 (2.80%)	1 (.03%)	0 (0%)
Native Hawaiian or Other Pacific Islander 28 (.79%)	20 (.6%)	8 (.23%)	0 (0%)	0 (0%)
Other, please specify 46 (1.30%)	25 (.71%)	20 (.6%)	0 (0%)	2 (.06%)
Prefer not to answer 104 (2.94%)	42 (1.20%)	13 (.37%)	1 (.03%)	49 (1.40%)
White 2654 (74.97%)	1670 (47.70%)	973 (27.79%)	7 (.20%)	7 (.20%)

Note. Out of 3,540 participants, 3,501 responses on gender were collection; 3,658 responses on race were collected as multiple options were allowed.

3.3 Data Analysis

For the purpose of the current study, we used data from 3540 teachers who completed all the survey questions. The dataset (N = 3540) was randomly split into three subsets to serve three unique types of data analysis. First, a confirmatory factor analysis (CFA) of the theoretical model was conducted using the first subset (N_1 = 1183). If the theoretical model did not exhibit an appropriate fit, the second subset (N_2 = 1169) would be investigated by exploratory factor analyses (EFAs) to determine a better-fitting latent structure of the identity constructs. Lastly, confirmatory factor analysis was conducted on the best EFA model using the last subset (N_3 = 1188).

For CFAs, the following model fit indices and cutoffs [22, 27] were selected to determine appropriate model fit: robust chi-square statistics (χ^2, non-significant χ^2 indicates good model fit), robust Comparative Fit Index (CFI, CFI < .90 indicates poor fit), robust Root Mean Square Error of Approximation (RMSEA, RMSEA > .08 indicates poor fit), and Standardized Root Mean Square Residual (SRMR, SRMR > .08 indicates poor fit). All CFA models are identified by fixing factor variances to1, and therefore, the factor loadings presented in the current study are standardized. Although no arbitrary cutoff was applied in the current study, item factor loadings larger than .70 are generally considered good for all the CFA results, which means a latent factor explains the majority (> 49%) of the observed variance of an item [27]; Loadings smaller than .30 are considered inappropriate in the study since they explain less than 9% of the observed variance of an item.

For EFAs, factor structures, explained cumulative variances, item factor loadings, and extracted communalities for items (h^2) were evaluated to determine a proper factor solution. Cumulative variances are the estimated proportion of variances that the EFA solution can explain in the data. For exploratory purposes, a standardized loading larger than .30 is considered acceptable for all EFA results in the current study [14, 27]. Items are preferable when they only have high factor loadings on one factor; otherwise, they are cross-loaded onto multiple factors and are less practical to interpret. Extracted communalities for items represent how much of the variance in the item is attributed to the target factor solution, with higher communalities being preferred.

4 RESULTS

4.1 Descriptive Statistics and Reliability

Basic descriptive statistics of all the items are presented in the following table (Table 4). Responses were mostly negatively skewed such that most responses were on the high end (“Strongly agree”, “Very confident”, etc.). Furthermore, the current sample of responses on the 22 items were not multivariately normal according to Mardia’s test [29] and Henze-Zirkler’s test [21]: Mardia’s Skewness = 20904.65, $p < .001$; Mardia’s Kurtosis =203.35, $p < .001$; HZ = 2.15, $p < .001$. Therefore, all factor analyses in later sections used either robust maximum likelihood or other alternative estimations.

Two reliability measures were estimated for the current sample: Cronbach’s alpha (α) and omega (hierarchical omega ω_h & total omega ω_t). For these 22 items, the overall Cronbach’s alpha indicates appropriate reliability (α = .90) of the 22-item scale, but subscale Cronbach’s alphas are not ideal, ranging from .64 to .86, with subscales with more items exhibiting higher Cronbach’s alphas (See Table 4). This indicates that the current theoretical subscale structures may not be the best representation of the sub-constructs and should be either modified or extended with more items for the constructs. The hierarchical omega was relatively low (ω_h = .71) compared to the total omega (ω_t = .93). This indicates that a unitary factor cannot account for all the variance among the 22 items, which

Table 4: Descriptive Statistics of the Current Sample (N = 3540)

Item	M	SD	Skew	Kurtosis	α'
Self-Identity1	4.42	0.82	-1.74	3.55	0.75
Self-Identity2	4.10	0.99	-0.95	0.22	
Self-Identity3	4.00	1.05	-0.94	0.19	
Community1	3.75	1.07	-0.57	-0.44	0.76
Community2	3.66	1.11	-0.52	-0.62	
Community3	4.15	0.85	-0.99	1.05	
Learning1	4.37	0.77	-1.43	2.65	0.7
Learning2	4.32	0.85	-1.27	1.48	
Confidence1	3.93	0.97	-0.81	0.26	0.86
Confidence2	3.80	1.01	-0.64	-0.07	
Confidence3	3.55	1.05	-0.51	-0.25	
Confidence4	3.94	0.98	-0.78	0.18	
Confidence5	3.51	1.10	-0.44	-0.47	
Confidence6	3.78	1.02	-0.64	-0.02	
Confidence7	3.79	0.99	-0.62	-0.12	
Confidence8	3.84	1.03	-0.68	-0.13	
Confidence9	3.00	1.11	0.14	-0.70	
Confidence10	4.12	0.86	-1.12	1.94	
Confidence11	4.05	0.89	-1.00	1.42	
Confidence12	3.62	1.09	-0.73	0.29	
Commitment1	4.16	0.99	-1.18	0.99	0.64
Commitment2	4.29	0.88	-1.19	1.02	

Note. Item labels correspond to the numbers and factors in Table 2; α' column reports the estimated Cronbach's α for each subscale.

partially supports the theoretical multi-factor model of teacher identity. In summary, the internal consistency measures indicate that the current 22-item scale upholds a multi-factor structure, but the theoretical factor structure may not be the best representation of the communalities among items.

4.2 Confirmatory Factor Analysis of the Theoretical Model

Due to the violation of normality assumption of the data, robust maximum likelihood estimation was used. Chi-square tests and corresponding fit statistics (CFI and RMSEA) were corrected using the Satorra-Benter correction [38]. The initial CFA was conducted on Subset 1 with N = 1183. For this five-factor model (Figure 1), $\chi^2(199) = 1318.73$, $p < .001$; robust CFI = .86; RMSEA = .08, 90% CI [.08, .09]; SRMR = .07.

The results indicate that the theoretical 5-factor structure may not be the best reflection of the sampled data and could be improved. For example, although Self-Identity, Commitment, and Learning are regarded as three different factors in the current model, their correlations with each other are extremely high (from .84 to .96). This suggests that the items designed to measure them may have more convergency than divergency, and thus it may not be necessary to decompose them as different constructs.

Another potential issue with the five-factor model is that some items have relatively low loadings on their theoretical factor. Specifically, for the confidence subscale, standardized factor loadings ranged from .30 to .71, with the lowest loading being the only reverse-coded item, Confidence9. These low loadings may be caused by (1) the inclusion of the reverse-coded item (Barnette, 2000); or (2) a potential different factor structure. In summary, the results indicate that the current theoretical 5-factor model may not best represent the factor structure and needs to be further investigated.

4.3 Exploratory Factor Analysis

Because the theoretical five-factor model did not exhibit an appropriate model fit, a series of exploratory factor analyses were conducted to investigate an alternative model based on Subset 2 (N = 1169). To avoid the potential method effect [13] from the only one negatively worded item, Confidence9 was not included in this analysis. Thus, all EFAs were based on the remaining 21 items. In all EFA analyses for the current study, weighted least square (WLS) estimation and oblimin rotation were used so that this study could account for the non-normal distributions of the items. Results of the Kaiser-Meyer-Olkin (KMO) sampling adequacy test [26] suggested that there was an adequate proportion of common variance among the selected set of 21 items. The overall measure of sampling adequacy (MSA) was .91 and item level MSAs ranged from .85 to .96.

A parallel analysis [24] suggested a 5-factor solution, but results of a 5-factor solution indicated that although the solution can account for 52% of the variance, it did not provide the five factors in line with the theoretical structure. Instead, items under the Self-identity, Commitment, and Learning subscales were loaded onto the same factor, while items under the confidence subscales were loaded onto two correlated but unique factors. Item communalities (h^2) for all items were acceptable and ranged from .39 to .67. This result supported what was observed in the initial CFA models. However, some items (Confidence2 and Community3) were cross-loaded

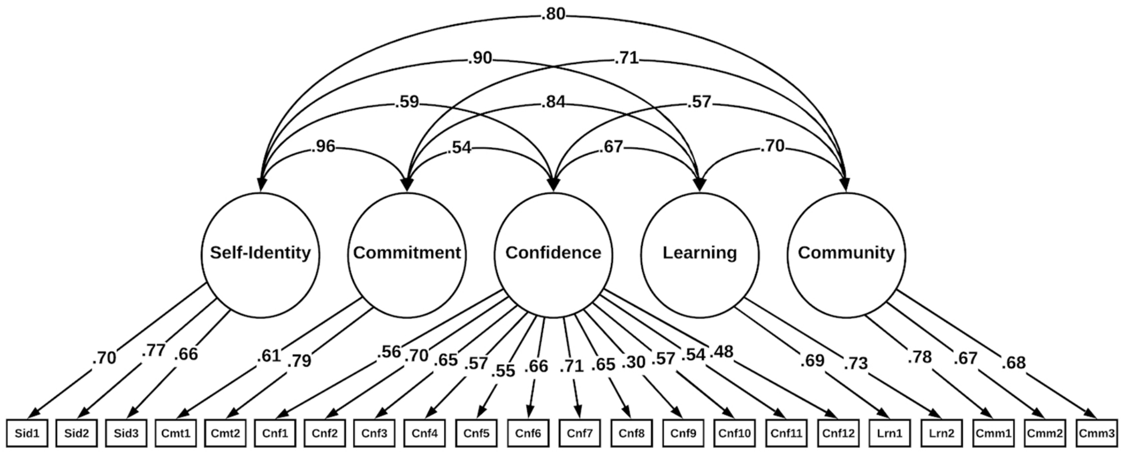

Figure 1: Theoretical 5-Factor Model of Computer Science Teacher Identity (Sid = Self-Identity; Cmm = Community; Lrn = Learning; Cmt = Commitment.)

on multiple factors and the fifth factor only had one unique item (Confidence1).

These results indicate that the 5-factor solution may not be the best representation and could be further simplified. Thus, a 4-factor and a 3-factor solution were also conducted. The 4-factor solution (Table 5) explained 50% of the total variance. Item communalities (h^2) for all items were acceptable and ranged from .37 to .68. Items from Self-Identity, Commitment, and Learning were again loaded onto the same factor as well as two cross-loaded items from the Confidence and Community subscales (Confidence1 and Community3, respectively). Table 5 presents standardized factor loadings and factor correlations of the 5-factor and the 4-factor solutions. The 3-factor solution further simplified the dimensionality of the 21 items. A total of 46% of the variance can be explained by this 3-factor oblique structure. Using a cutoff of .30 on standardized loadings, no item was cross-loaded onto multiple factors. Item communalities (h^2) ranged from .28 to .69, in which one item (Community2) had h^2 lower than .30. Again, items for Self-Identity, Commitment, and Learning loaded onto the same factor, and items for community/belonging also loaded onto this factor, which was different from the 4-factor solution. Items for confidence mostly loaded onto two separate factors (Confidence 2 to 8 loaded onto one factor while confidence 10 to 12 loaded onto the other).

Overall, the 4-factor solution and the 3-factor solution both surpassed the initial five-factor solution. The only difference between them was that the first two items for Community (Community1 and Community2) should be extracted as a unique factor or loaded together with Self-Identity, Learning, and Commitment items. Thus, both models were analyzed using confirmatory factor analysis on Subset 3.

4.4 Final Confirmatory Factor Analyses

In order to select the better alternative from the two EFA solutions, both models were analyzed using Subset 3. Items with cross-loadings were specified to load onto the factor with higher standardized loading in the solution. CFA results were mixed for the

Table 5: Factor Patterns for the 5-Factor and 4-Factor Solutions

	5-Factor					4-Factor			
Item	F1	F2	F3	F4	F5	F1	F2	F3	F4
Self-Identity1	.74					.76			
Self-Identity2	.66					.74			
Self-Identity3	.50					.54			
Community1				.62					.60
Community2				.82					.82
Community3	.39			.35		.41			.34
Learning1	.63					.66			
Learning2	.57					.54			
Confidence1					.47	.44	.30		
Confidence2		.48			.32		.58		
Confidence3		.66					.69		
Confidence4		.74					.68		
Confidence5		.74					.70		
Confidence6		.66					.74		
Confidence7		.58					.65		
Confidence8		.51					.59		
Confidence10			.75					.72	
Confidence11			.82					.82	
Confidence12			.59					.59	
Commitment1	.64					.61			
Commitment2	.73					.70			
Factor Correlation									
F1	-					-			
F2	.31	-				.37	-		
F3	.42	.46	-			.42	.50	-	
F4	.50	.25	.28	-		.50	.28	.25	
F5	.31	.20	.19	.20		-	-	-	-

Notes. Item labels correspond to the numbers and factors in Table 2; All presented loadings are standardized and item loadings smaller than .30 were omitted.

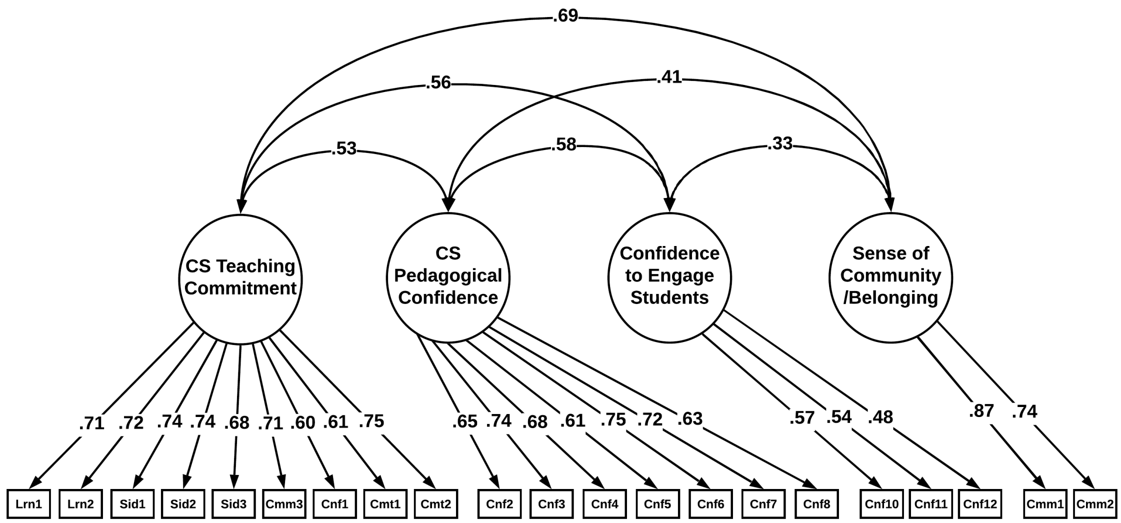

Figure 2: Updated 4-Factor Model of Computer Science Teacher Identity (Sid = Self-Identity; Cmm = Community; Lrn = Learning; Cmt = Commitment. Factor names are updated to reflect the items in each factor.)

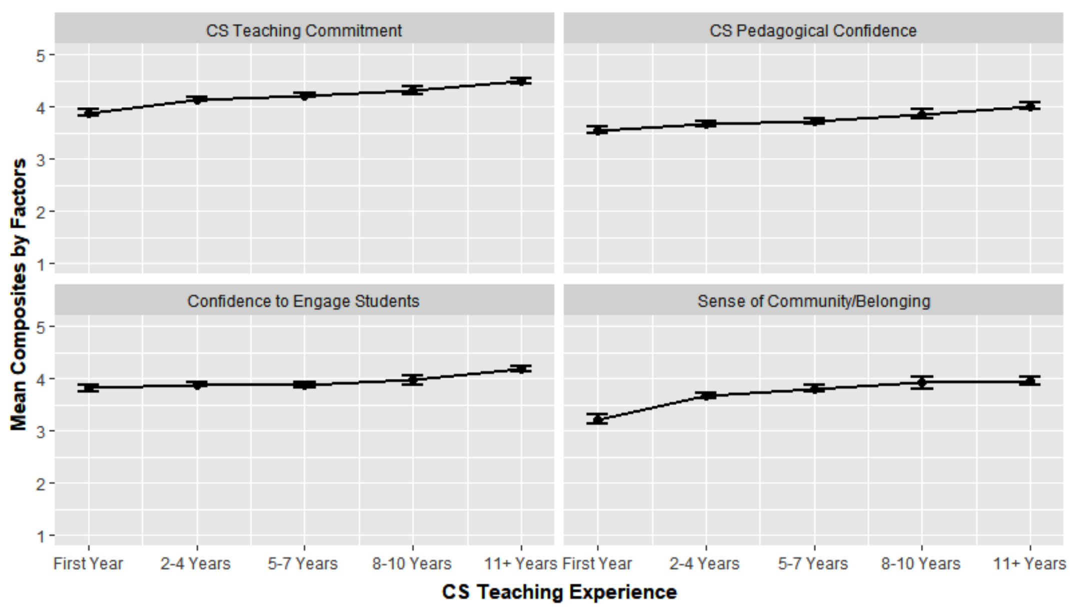

Figure 3: Means with 95%CI for Factor Scores from the Updated 4-Factor Model of Computer Science Teacher Identity by Computer Science Teaching Experience

three-factor CFA model on Subset 3: $\chi^2(186) = 1076.58$, p < .001; robust CFI = .89; RMSEA = .08, 90% CI [.07, .08]; SRMR = .06. Despite the significant χ^2 statistics, robust CFI indicated poor fit, while the remaining two (robust RMSEA and SRMR) were acceptable. On the other hand, CFA results for the four-factor CFA model suggested acceptable fit: $\chi^2(183) = 850.79$, p < .001; robust CFI = .91; RMSEA = .07, 90% CI [.06, .07]; SRMR = .05.

The model comparison using likelihood ratio test confirmed that although the three-factor model was more parsimonious, it fit the data (Subset 3) significantly worse than the four-factor model, $\Delta\chi^2(3) = 406.31$, $p < .001$. Therefore, the updated 4-factor model was selected as the final model for the Computer Science Teacher Identity Survey. Model parameters and factor structure for the final four-factor CFA model are summarized in Figure 2

Table 6: Pairwise Comparisons of Factor Scores of Computer Science Teacher Identity by Computer Science Teaching Experience

Teacher Identity Factors	CS Teaching Experience	N	Mean Factor Score	SD	Pairwise Comparison p Values			
					First Year	2-4 Years	5-7 Years	8-10 Years
CS Teaching Commitment	First Year	476	3.88	.73	-	-	-	-
	2-4 Years	1342	4.15	.63	**<.001**	-	-	-
	5-7 Years	856	4.22	.60	**<.001**	.079	-	-
	8-10 Years	274	4.31	.65	**<.001**	**.001**	.198	-
	11 or More Years	559	4.50	.55	**<.001**	**<.001**	**<.001**	**<.001**
CS Pedagogical Confidence	First Year	476	3.56	.79	-	-	-	-
	2-4 Years	1342	3.68	.75	**.036**	-	-	-
	5-7 Years	856	3.73	.69	**<.001**	.381	-	-
	8-10 Years	274	3.87	.73	**<.001**	**<.001**	.054	-
	11 or More Years	559	4.02	.71	**<.001**	**<.001**	**<.001**	**.037**
Confidence to Engage Students	First Year	476	3.81	.82	-	-	-	-
	2-4 Years	1342	3.89	.77	0.434	-	-	-
	5-7 Years	856	3.88	.76	.620	.999	-	-
	8-10 Years	274	3.97	.77	.070	.488	.427	-
	11 or More Years	559	4.18	.67	**<.001**	**<.001**	**<.001**	**.001**
Sense of Community/ Belonging	First Year	476	3.22	1.00	-	-	-	-
	2-4 Years	1342	3.66	.95	**<.001**	-	-	-
	5-7 Years	856	3.80	.91	**<.001**	**.003**	-	-
	8-10 Years	274	3.91	.97	**<.001**	**.001**	.464	-
	11 or More Years	559	3.95	.97	**<.001**	**<.001**	**.026**	.973

Notes. Pairwise comparison results with significant results are bolded in the table.

4.5 Associating the Factors with Teaching Experience

In order to explore the extent to which the four-factor model of computer science teacher identity is associated with computer science teaching experience, mean composite scores for the four subscales were estimated for all participants. The mean scores were then compared by computer science teaching experience. Computer science (CS) teaching experience was measured with one question in the survey that asks the participants to report their CS teaching experience in 5 categories: "This is my first year", "2-4 years", "5-7 years", "8-10 years", and "11 or more years". Due to the ordinal nature of the responses, for each of the 4 subscale composites, a one-way (Welch's) ANOVA was conducted to investigate the difference among the 5 CS teaching experience groups. Welch's ANOVA was applied due to the violated assumption of homogeneity of variance.

Results indicate significant differences among the 5 CS teaching experience groups for all 4 subscales. Hays' ω^2 was reported as the effect size for Welch's ANOVA. For Factor 1 "CS Teaching Commitment", $F(4, 1151.17) = 66.22$, $p < .001$, $\omega^2 = .07$; for Factor 2 "CS Pedagogical Confidence", $F(4, 1156.87) = 32.17$, $p < .001$, $\omega^2 = .03$; for Factor 3 "Confidence to Engage Students", $F(4, 1160.88) = 23.47$, $p < .001$, $\omega^2 = .02$; for Factor 4 " Sense of Community/Belonging", $F(4, 1149.96) = 44.06$, $p < .001$, $\omega^2 = .05$. Figure 3 presents the mean factor scores with 95% CI by the 5 teaching experience groups for the 4 factors. For Welch's ANOVA, ω^2 is an appropriate measure of effect size applying the following benchmarks: $\omega^2 = .01$ is considered a small effect, and $\omega^2 = .06$ and $\omega^2 = .14$ are considered medium and large effects respectively [14, 33]. Thus, CS teaching experience has the largest effect on CS teaching commitment ($\omega^2 = .07$), and a small or medium effect on the other three teacher identity factors.

Pairwise comparisons using Games-Howell test indicated that in general, teachers with more CS teaching experience had higher CS teacher identity scores on all four factors, with the notable exception of "Confidence to Engage Students". Detailed results of pairwise comparisons are presented in Table 6

5 CONCLUSION AND DISCUSSION

Results from this study indicate that computer science teacher identity may comprise the following four components: Computer Science (CS) Teaching Commitment, Computer Science (CS) Pedagogical Confidence, Confidence to Engage Students, and Sense of Community/Belonging.

- **CS Teaching Commitment**: Teachers see themselves as computer science teachers with confidence in computer science content, take actions to be good teachers, and intend to continue as computer science teachers. This component combines the three proposed constructs: Self-Identification, Learning, and Commitment, represented by the first factor in the 4-Factor Model of Computer Science Teacher Identity.
- **CS Pedagogical Confidence**: Teachers' confidence in teaching computer science with specific pedagogies to serve

Table 7: Updated Computer Science Teacher Identity Survey Items

Domain	Prompt	Item
CS Teaching Commitment	Please rate your level of agreement with the following statements:[1]	I truly enjoy teaching computer science. I see myself as a computer science teacher. I have actively looked for opportunities to teach computer science. I enjoy sharing ideas about teaching computer science. I work hard to be the best computer science teacher that I can be. I advocate for more students to take courses in computer science. I plan to continue as a computer science teacher for at least the next five years. Choosing to become a computer science teacher was a good decision.
	Please select which category best describes your confidence in the following topics:[2]	Teaching computer science content/concepts.
CS Pedagogical Confidence	Please select which category best describes your confidence in the following topics:[2]	Using inquiry-based strategies Using culturally relevant pedagogy to support student learning Teaching students from diverse backgrounds Teaching students with disabilities Using a variety of assessment strategies Adjusting lessons to the proper level for individual students Facilitating conversation around the impacts and ethics of computing
Confidence to Engage Students	Please select which category best describes your confidence in the following topics:[3]	Helping students believe they can do well in computer science Helping students value learning computer science Motivating students who show low interest in computer science
Sense of Community/Belonging	Please rate your level of agreement with the following statements:[1]	I feel part of a community of computer science teachers. I frequently talk to peers about computer science teaching.

Note. [1]Response Options = Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, Strongly Agree. [2]Response Options = 1. Not at all confident, 2. Slightly confident, 3. Somewhat confident, 4. Fairly confident, 5. Very confident. [3]Response Options = Not much, Very little, Some, Quite a bit, A great deal.

diverse groups of students. This construct is specified with seven Confidence items (Confidence2 to Confidence8).

- **Confidence to Engage Students**: Teachers' confidence in motivating and engaging students in computer science learning (Confidence10, Confidence11, and Confidence12).
- **Sense of Community/Belonging**: Teachers' sense of belonging to a community of computer science teachers (Community1 and Community2).

Ideally, survey validation studies begin with numerous items for each construct and remove ill-fitting items. One limitation of this study is that the team was limited by the number of items that could be added to the survey at the outset. The tradeoff was that we were able to collect survey data from a large national sample. Under these conditions, we analyzed five of the six original constructs, and the analysis reveals a scale with four valid constructs. Table 7 presents the updated computer science teacher identity scale, including 21 items for the four-factor model of computer science teacher identity.

We may further validate the model by asking whether it adheres to assumptions about teachers' growth in computer science teacher identity. We would expect that each of the four teacher identity constructs would increase as their computer science teaching experience increases, and we see this pattern in Figure 3. Those in their first year of teaching are not expected to possess high CS Teaching Commitment since they may not perceive that they have worthy ideas to share about teaching computer science in comparison to more experienced computer science teachers, and they may be weighing their overall commitment to teaching computer science. Likewise, they may not be confident in their knowledge of pedagogy specific to teaching computer science nor understand approaches that are best at engaging students in learning computer science. Finally, new teachers may also not possess the community support structures that more experienced teachers enjoy.

Taken together, the four-factor model along with a large national dataset invite a deeper analysis of the data and provide important benchmarks. For example, we hope to show improvements on all four constructs for teachers who are in their second to fourth years, a time in which many teachers leave the profession [25, 35]. Second, an initial analysis of first-year computer science teachers shows that experienced K-12 teachers possess a lower computer science teacher identity. One hypothesis is that having an experienced K-12 teacher teach computer science may result in an initial fragmentation of his/her identity. This indicates another area in which the computer science education community can better support teachers.

We are planning to make improvements to the computer science teacher identity survey, such as revising the computer science teacher identity constructs based on the updated four-factor model, including the untested domain (interest and value), and testing the revised scale. Currently, the project researchers are conducting narrative inquiry using interviews with a sub-group of the computer science teachers to further understand the tensions and sense of identity they bring into computer science teaching. Our preliminary results indicate that teachers can experience emotional struggles (e.g., related to teaching autonomy, job security, and exhaustion) in their computer science teaching, which informs us that emotion can be an important dimension of computer science teacher identity as well. We did not include Hanna's [19] domain 6, job satisfaction, in our original survey due to space limitations and respondent fatigue. We also felt that it may be adequately captured by the "confidence" subconstruct. Upon further reflection, we believe that job satisfaction (emotion) may measure a dimension of teacher identity beyond the four factors in our current model and that it is worth considering in further versions of the instrument. We are also interested in furthering our understanding of the roles of computer science teacher identity in teacher capacity, by examining the results from the large data set of the national Computer Science Teacher Survey.

This study provides further understanding of the meaning of computer science teacher identity. The work is also a first step towards a quantitative measurement for computer science teacher identity. We were able to test the computer science teacher identity scale through a large national sample. The instrument can be used by researchers and educators to understand and support the development of professional identity for computer science teachers. This study may also contribute to understanding computer science teachers' professional development needs and inform efforts to prepare, develop, and retain computer science teachers.

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