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Investigating dimensions of instructor trust using the words of undergraduate STEM students

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Introduction: Recent work has shown that student trust in their instructor is a key moderator of STEM student buy-in to evidence-based teaching practices (EBTs), enhancing positive student outcomes such as performance, engagement, and persistence. Although trust in instructor has been previously operationalized in related settings, a systematic classification of how undergraduate STEM students perceive trustworthiness in their instructors remains to be developed. Moreover, previous operationalizations impose a structure that often includes distinct domains, such as cognitive and affective trust, that have yet to be empirically tested in the undergraduate STEM context.

Methods: To address this gap, we engage in a multi-step qualitative approach to unify existing definitions of trust from the literature and analyze structured interviews with 57 students enrolled in undergraduate STEM classes who were asked to describe a trusted instructor. Through thematic analysis, we propose that characteristics of a trustworthy instructor can be classified into three domains. We then assess the validity of the three-domain model both qualitatively and quantitatively. First, we examine student responses to determine how traits from different domains are mentioned together. Second, we use a process-model approach to instrument design that leverages our qualitative interview codebook to develop a survey that measures student trust. We performed an exploratory factor analysis on survey responses to quantitatively test the construct validity of our proposed three-domain trust model.

Results and discussion: We identified 28 instructor traits that students perceived as trustworthy, categorized into cognitive, affective, and relational domains. Within student responses, we found that there was a high degree of interconnectedness between traits in the cognitive and relational domains. When we assessed the construct validity of the three-factor model using survey responses, we found that a three-factor model did not adequately capture the underlying latent structure. Our findings align with recent calls to both closely examine long-held assumptions of trust dimensionality and to develop context-specific trust measurements. The work presented here can inform the development of a reliable measure of student trust within undergraduate STEM student environments and ultimately improve our understanding of how instructors can best leverage the effectiveness of EBTs for positive student learning outcomes.

KEYWORDS

instructor trust, undergraduate STEM education, student-instructor relationship, trust dimensions, cognitive trust, affective trust, relational trust

1 Introduction

Two reports published 8 years apart, one in 2012 by the President's Council of Advisors on Science and Technology (PCAST) and one in 2020 by the National Science Board, both call for a modernization of STEM education to better retain students and strengthen the domestic science and technology workforce. The 2012 PCAST report found that only 40% of students who matriculate into higher education with the intent of pursuing a STEM degree persist to the end of their degree. The learning environment of introductory courses in the first 2 years of the STEM major is a critical factor in retaining these students (President's Council of Advisors on Science and Technology, 2012). Since then, national assessments have shown stagnant or declining STEM competencies among students and the general public (National Science Board, National Science Foundation, 2020; US Department of Education, 2018, 2024).

Evidence-based teaching practices (EBTs) such as student-centered active learning or discovery-based learning improve student achievement and persistence in STEM fields (Chasteen and Pollock, 2008; Gross et al., 2015; Freeman et al., 2014; Handelsman et al., 2007; Hanauer et al., 2017; Henderson and Dancy, 2009; Jensen et al., 2015; Reeves et al., 2023; Wieman, 2014). Yet, widespread adoption remains limited due to institutional barriers and student resistance (Brazeal et al., 2016; Brownell and Tanner, 2012; Finelli et al., 2018; Minhas et al., 2012; Nguyen et al., 2016; Patrick, 2020; Seidel and Tanner, 2013; Stains et al., 2018; Walker et al., 2008). Critically, instructors' experience of student resistance, which can manifest as lack of engagement or disruptive behavior, may contribute to high rates of instructors who revert to traditional lecturing after trying EBTs (Lake, 2001; Henderson et al., 2012; Seidel and Tanner, 2013; Nguyen et al., 2021). Thus, a better understanding of the social and cognitive factors underlying students' buy-in, or commitment, to the use of EBTs may improve adoption rates (Cavanagh et al., 2016; Corwin et al., 2015; Dolan, 2015; Wang et al., 2021). One factor that has emerged as an empirically significant moderator of student buy-in is trust in their instructor (Cavanagh et al., 2018; Wang et al., 2021).

Indeed, empirical studies have shown that strong personal connections between faculty and students can positively affect a variety of student outcomes (Mayhew et al., 2016), such as persistence in college (Guzzardo et al., 2021; Milem and Berger, 1997; Nora et al., 1996; Pascarella and Terenzini, 1979; Robinson et al., 2019; Schudde, 2019; Pike et al., 1997; Wilcox et al., 2005), attitudes toward learning (Christophel, 1990; McLure et al., 2022), motivation (Komarraju et al., 2010; Wentzel, 2016; Zhou et al., 2023), academic self-concept (Kim and Sax, 2014; Trinidad et al., 2024), self-efficacy (Ballen et al., 2017; Ferguson, 2021), engagement (Umbach and Wawrzynski, 2005; Snijders et al., 2020), performance (Roorda et al., 2011; Zhao and You, 2023), self-worth (Alt et al., 2022; Kuh, 1995; Trinidad et al., 2024), and interest and effort put toward a course (Fedesco et al., 2019). Students themselves report that closer relationships with faculty based on trust are critical for success in college STEM classrooms (Pedersen et al., 2022). Among these relational elements, *trust* has emerged as a key construct that not only underpins the quality of student–instructor relationships but also directly moderates student buy-in to evidence-based teaching practices (Cavanagh et al., 2018; Wang et al., 2021). Because buy-in has been identified as a critical mechanism for improving student engagement and persistence, especially in STEM, we focus our investigation on trust as a theoretically grounded and empirically supported factor within the broader construct of student–instructor connection. Despite the importance of positive student-teacher relationships for student success, how students develop a sense of trust in their instructor remains empirically understudied and may be undervalued by college STEM instructors (Beltrano et al., 2021; Christe, 2013; Felten et al., 2023; Hagenauer and Volet, 2014; Niedlich et al., 2021; Payne et al., 2022; Tierney, 2006).

The construct of trust has been widely studied across disciplines both from theoretical and empirical perspectives. For example, in an empirical study of romantic partnerships, Rempel et al. (1985) consider the development of trust as beginning with demonstrations of consistency and evolving based on shared values and goodwill. Revisiting this work, Camanto and Campbell (2025) found three key dimensions of trust in romantic relationships that reiterate Rempel et al.'s (1985) framework: predictability, dependability, and faith. Lewicki and Bunker (1996) offer an expanded theoretical framework to describe the development of trust in professional relationships. Initial calculus-based trust informed by self-interest grows into knowledge-based trust through familiarity. When two individuals identify with each other's shared values and goals, they progress to the deepest form of identification-based trust. While Lewicki and Bunker's (1996) framework describes the development of trust through different domains over time, McAllister's (1995) empirical study of workplace relationships suggests that different domains of trust, specifically cognitive and affective, develop simultaneously and independently from each other. The cognitive domain depends on a rational assessment of professional competence while the affective domain is rooted in an emotional bond. Indeed, Massey et al. (2019) argue that interpersonal trust is bidimensional in nature and consists of both affective and cognitive components, highlighting in their empirical study that affective and cognitive trust domains explain significant variance in one's perception of the quality of an interpersonal relationship. Lewis and Weigert (1985) present a theoretical description of trust as a collective social force that also considers the distinction between cognitive and emotional processes but treats trust as a generalized attitude toward an institution rather than in the context of a specific relationship. In another framing of organizational trust, Mayer et al. (1995) consider trust as unidimensional and provide a theoretical model that distinguishes between trust as an internal state of willingness of a trustor to be vulnerable to a trustee in the face of uncertainty. The decision to trust is based on the trustor's sense of the other party's trustworthiness, determined by the trustee's demonstration of ability, benevolence, and integrity. Conducting an empirical study on how trust is built in both hybrid and in-person work settings, Fischer et al. (2023) interestingly highlight the value of behavioral or relational trust, deeming authenticity and communication as trustworthy professional behaviors.

There is no one unified definition of trust, though there is some consensus in the literature that trust has at least two distinct dimensions: cognitive and affective. Despite this consensus and

exploration of these two dimensions in research on trust, there is nonetheless a shortfall in the literature in terms of a consistent and empirical distinction between cognitive and affective domains (Legood et al., 2023). In the context of higher education, there is even less consensus on the definition of trust between students and instructors (Beltrano et al., 2021; Christe, 2013; Felten et al., 2023; Hagenauer and Volet, 2014; Niedlich et al., 2021; Payne et al., 2022; Tierney, 2006). First defined in the K-12 context, Bryk and Schneider (2002) put forth a relational trust framework based on empirical research in Chicago public schools to describe the role of trust as a collective property of the school environment in improving student outcomes and organizational effectiveness. In this framework, trust is built through the quality of social exchanges (measured by benevolence, competence, integrity, and respect) between teachers, students, administrators, and parents. Building upon this framework, Tschannen-Moran and Hoy (2000) broaden the scope of Bryk and Schneider's work, adding more focus on school leadership, policies, and climate. Additionally, Tschannen-Moran and Hoy take an empirical approach to their synthesis of literature by focusing on measurable characteristics that could be used to develop a quantitative tool. Their resulting Omnibus Trust Scale measures five dimensions of trust: benevolence, reliability, competence, honesty, and openness. Using Tschannen-Moran and Hoy's framework to theoretically ground their study, Holzer and Daumiller (2025) use analyses of qualitative interviews with students and teachers in ninth-grade classes to suggest that teachers' willingness to be vulnerable and confide personal information in their students are also critical components of trust. Although developed in the context of K-12 education, Tschannen-Moran and Hoy's framework of trust has been used as a reference point for investigating trust in higher education.

Models of trust in higher education marketing have examined the relationship between students' trust and their loyalty toward their institution. Surveys of students and alumni revealed that trust in the institution included five dimensions parallel to those identified in Tschannen-Moran and Hoy's framework: expertise, integrity, congeniality, sincerity, and openness (Ghosh et al., 2001). Sampaio et al. (2012) take Ghosh et al.'s model a step further through a quantitative survey with business students, distinguishing student trust in faculty as a critical component of trust in their institution. Indeed, conceptual models of retention suggest that trust depends on the success of relational exchanges between students and faculty (Dzimińska et al., 2018; Schertzer and Schertzer, 2004). These are primarily conceptual or theoretical papers, offering models rather than new empirical data. The pedagogical impact of student-faculty trust as an important form of social capital is illustrated by Ream et al. (2014), who conducted an empirical mixed-methods study of STEM students in a research program. Using survey data and qualitative interviews, they found that STEM students who had greater trust in their mentor during a summer research program reported greater motivation and had higher career expectation. Building upon Mayer et al.'s (1995) and Tschannen-Moran and Hoy's (2000) frameworks of trust, Ream et al. (2014) estimated students' perceptions of trustworthiness through surveys measuring competence, benevolence, and integrity. Importantly, research students in this study interacted with their faculty mentor outside of a formal classroom setting. Similarly, past empirical studies of student-faculty relationships demonstrate the importance of informal interactions with faculty outside of class for student satisfaction, engagement, and retention (Mattanah et al., 2024; Wong and Chapman, 2023; Pascarella and Terenzini, 2005; Tinto, 2015; Wilcox et al., 2005).

Whether students choose to interact with faculty outside of class is based on perceptions of approachability and support, informed by behavioral cues during class (Lamport, 1993; Wilson et al., 1974). Based on surveys and classroom observation, Lamport (1993) found that rather than age, gender, academic rank, or research accolades, students are more likely to engage in informal interactions with faculty based on their instructors' interpersonal sociopsychological characteristics, such as friendliness, understanding, and authenticity. Similarly, student surveys collected by Schussler et al. (2021) found that student ratings of instructor support were influenced by student perceptions of care and approachability as well as the instructor's personality. Moreover, an empirical survey study (Denzine and Pulos, 2000) found that in-class behaviors demonstrating care and concern for the student (such as asking personal questions) explained significantly more variance in measures of approachability compared to behaviors that demonstrated conscientiousness (such as starting class on time). Empirical evidence gathered from surveys shows that students who report greater trust in the instructor are more likely to engage in out-of-classroom contact with their instructors (Faranda, 2015; Jaasma and Koper, 1999), thus faculty approachability based on demonstrations of care may be a significant factor contributing to student trust. Relatedly, other empirical studies have found that when instructors bring personal elements into their instruction, such as showing vulnerability through acts of self-disclosure (Johnson and LaBelle, 2017; LaBelle et al., 2023) or teacher immediacy (Andersen, 1979; Liu, 2021), students report higher relational satisfaction (Johnson and LaBelle, 2017; LaBelle et al., 2023), increased motivation, and more positive attitudes toward learning (Christophel, 1990; Frymier, 1994; Frymier et al., 2019). While these studies do not explicitly reference the development of trust, the broader literature suggests that trust develops over the course of repeated interactions between individuals. Thus, the factors that lead students to have a positive view of their interactions with faculty both inside and out-of-class likely play a significant role in the development of trust. In a reflective, qualitative study that did explicitly explore the development of trust, Meinking and Hall (2024) describe how students emphasized the importance of relational trust and the willingness of both students and instructors to be vulnerable with one another as key factors for building a trusting learning environment.

The treatment of the teacher-student relationship as an interpersonal one with significant relational and emotional components has been widely adopted in the instructional communication literature (Hess and Mazer, 2017). In 2018, Cavanagh et al. adapted and validated the use of Clark and Lemay's (2010) close interpersonal relationship framework to define student trust in their STEM instructor. Clark and Lemay's work highlights the positive impact of mutual responsiveness and communal norms, where individuals act for each other's benefit without

contingency, for long-term, intimate relationships. Cavanagh et al. (2018) adapt this theory to model students' responsiveness to their instructor's use of EBTs, arising from trust that their instructor is acting for their benefit. The decision to trust is based on the extent to which students believe their instructor understands, accepts, and cares about them. This operationalization of trust was further validated in Wang et al.'s (2021) study of the relationship between student trust and buy-in in 14 large-enrollment STEM courses. However, a critique of the instructional communication literature has been that too much focus has been placed on the interpersonal aspects of the student-teacher relationship without consideration for cognitive factors (Hess and Mazer, 2017). Indeed, when students in an online learning environment were surveyed about instructor trustworthiness, high-trusting students cited the instructor's professional credibility and expertise in addition to interpersonal traits related to care, acceptance, and understanding (Hai-Jew, 2007). Similarly, a conceptual model for student trust developed through interviews with college faculty included a domain related to cognitive factors, such as instructors' knowledge, skill, and competence, in addition to affective, identity, and value-based domains (Felten et al., 2023). These studies suggest that both students and faculty believe that trust in instructor encompasses both affective and cognitive domains and that the conceptualization of student-instructor trust solely through the lens of a close personal relationship is insufficient.

However, the distinction between different dimensions of trustworthiness has also been debated. McEvily and Tortoriello's (2011) and Whipple et al.'s (2013) reviews of the measurement of trustworthiness argue there is weak evidence to support the construct validity of separate dimensions. A literature review conducted by Niedlich et al. (2021) similarly highlights the lack of conceptual clarity and inconsistent application of existing theoretical frameworks to define trust and its dimensionality across studies specifically within education contexts. Moreover, Niedlich et al. (2021) note that while existing research often depends on the use of multidimensional trust scales, the relationships between dimensions is rarely examined. Concerns about the construct validity of trust dimensions have also been raised in other domains. For instance, Bradford et al. (2022), in a mixed-methods study of trust in police among immigrant communities in Australia, emphasize the contextual and interpretive variability in how trustworthiness is perceived and measured—raising similar questions about the transferability of pre-defined trust constructs. Likewise, Nielsen and Nielsen (2023), working from an ethnomethodological and micro-sociological perspective, argue that trustworthiness emerges in the details of social interaction, challenging the assumption that it can be cleanly isolated and captured through conventional self-report measures. Together, these studies align with our argument that trust, as perceived by undergraduate STEM students, may not be fully captured by dimensions derived from other top-down theoretical models.

To empirically test the construct validity of trust in higher education, Di Battista et al. (2020, 2021) sought to determine if students could themselves consistently differentiate between instructor characteristics related to two dimensions of trust often used in education contexts: competence and benevolence. In a quantitative study, Di Battista et al. (2021) found that manipulating students' perceptions of an instructor's competence significantly affected their subsequent judgment of benevolence, and vice versa. In a qualitative study, they further found that when students were asked to list characteristics associated with a benevolent or competent instructor, students frequently used the same words to describe both dimensions and used words that were not aligned with theoretical definitions (Di Battista et al., 2020). These findings affirm the argument that theorized sub-constructs of trust and the relationships between them may be highly dependent on institutional context or overlap entirely when empirically tested (PytlikZillig and Kimbrough, 2016). The lack of empirical studies of trust-dimensionality in higher STEM education calls for a more thorough examination of how well theorized trust dimensions drawn from organizational, social, and educational psychology frameworks or from K-12 contexts represent student perceptions in this specific context.

In the current study, we therefore seek to address the following research question: are college STEM students' perceptions of instructor trustworthiness accurately captured by previously theorized sub-constructs of trust? Based on research evidence discussed above, we hypothesize that a simple two- or three-domain model may not capture the rich dimensionality of student descriptions of trustworthiness. To test this hypothesis, we first employ a multi-step qualitative approach that gives students the opportunity to describe trusted instructors in their own words. To the best of our knowledge, such a "bottom-up" approach has yet to be applied in empirical studies of American college STEM students' trust in their instructors (Di Battista et al., 2020). Di Battista et al.'s qualitative study (2020) was conducted with a group of 125 psychology students in a single course at an Italian institution. Previous studies of American STEM undergraduate student trust have been limited to research faculty mentorship (Ream et al., 2014), faculty perceptions (Felten et al., 2023; Bayraktar et al., 2025), small classroom settings (Meinking and Hall, 2024) or to a close personal relationship framing of the student-instructor relationship (Cavanagh et al., 2018; Wang et al., 2021). Therefore, deepening our understanding of trust from the perspective of students themselves is a key step toward advancing student experiences in STEM classrooms.

To prioritize empirical model testing, we chose to follow a defined "process model" approach that leverages qualitative data for instrument design (Chatterji, 2003). First, we reviewed literature across education, psychology, and management to identify existing trust constructs. We then conducted structured interviews with 57 STEM undergraduates, asking them to describe a trusted instructor. Using *a priori* codes from the literature and inductively generating new ones, we developed a codebook that categorized traits into conceptual groupings. These categories were then used to draft survey items and test dimensionality. The purpose of the qualitative work was therefore twofold: (1) to propose a preliminary model of instructor trustworthiness grounded in student descriptions and (2) to draft an instrument for empirical testing.

In this manuscript, we distinguish between *trust* and *trustworthiness*. Drawing on Mayer et al. (1995), *trust* refers to the psychological state of the trustor based on a decision to be vulnerable to the actions of the trustee. *Trustworthiness*, by contrast, refers to the characteristics or behaviors of the trustee, such as

competence, care, or fairness, that lead the trustor to view them as deserving of trust. Our study centers on students' descriptions of instructor *trustworthiness* and uses these perceptions as a window into how trust develops. Although we use the term "trust" at times for brevity, our analyses focus on the observable antecedents to trust as experienced and articulated by students.

Our qualitative analysis revealed that trustworthy instructor traits clustered into cognitive, affective, and relational domains, with notable overlap between cognitive and relational elements. We piloted a survey based on the codebook in a large-enrollment STEM course. A forced three-factor exploratory factor analysis (EFA) yielded poor-to-acceptable model fit while higher-order models performed better. Moreover, items did not load cleanly into the predefined domains, indicating that student conceptions of trustworthiness may not align neatly with previously theorized models. These findings suggest a more nuanced understanding of trust is needed to improve student buy-in to evidence-based practices and, ultimately, support retention in STEM fields (Cavanagh et al., 2018; Graham et al., 2013; Wang et al., 2021).

2 Materials and methods

2.1 Process model approach to instrument design

In this study, we apply an iterative process model for instrument design to develop a codebook of trustworthy instructor characteristics (Chatterji, 2003; Chatterji et al., 2002; Graham et al., 2009). The process has four phases, depicted in Figure 1. In phase 1, we began by defining the assessment context, including the constructs and population that will be targeted for measurement. In this case, the domain of interest was defined as the constructs underlying trust for undergraduate STEM students. In phase 2, we specified the domain in terms of action-oriented and observable indicators to facilitate instrument construction in phase 3. To do so, we conducted a literature review and held structured interviews with current undergraduate STEM students. The work of phase 3 then focused on converting the specified behaviors and characteristics into rating items for a survey. Finally, in phase 4, we conducted iterative rounds of validation and revision, including content validation of the items and a pilot test of the instrument. The process model approach used here is based on recommendations for test development grounded in psychometric modeling described in the *Standards for Educational and Psychological Testing* (American Educational Research Association, 1999). Instruments developed using this model typically achieve desired reliability and a concise factor structure within fewer rounds of empirical testing (Chatterji et al., 2002; Graham et al., 2009). We apply all four phases of the process model in this work, focusing primarily on domain specification to clarify and validate the constructs underlying student trust in their instructor. Importantly, while we present findings from a pilot study, this paper does not address phase 4 in full. In the process model, phase 4 typically includes exploratory and confirmatory studies with large independent data sets. Overall, this study followed a sequential exploratory mixed methods design, in which qualitative data collection and analysis preceded and directly informed the quantitative phase. The qualitative phase involved structured interviews to identify traits students associate with instructor trustworthiness. These traits were used to develop a survey instrument, which was then pilot tested using exploratory factor analysis to examine the dimensional structure of trust.

2.2 Process model phase 1

We defined the domain of interest as the constructs underlying the latent variable "trust" and the assessment context was defined as undergraduate STEM classrooms in the United States.

2.3 Process model phase 2

2.3.1 Literature review

To identify actions, characteristics, and other related variables underlying descriptions of trusted individuals, the research team conducted an exploratory literature search to identify key dimensions previously used to operationalize the latent variable, "trust," across multiple disciplinary contexts. We began our search by first expanding upon theoretical frameworks used to measure trust in schools. These included the close personal relationship framework adapted by Cavanagh et al. (2018) and the five dimensions of trust highlighted by Tschannen-Moran and Hoy (2000). The research team identified potential new sources via keyword searches of the following online databases: JSTOR, ProQuest, EBSCOHost, and Google Scholar. Example keywords used in the search included: "trust in schools," "trust in organizations," "trust between superior and subordinates," "trust among colleagues," "trust in leaders," and "trust in teachers." Searches were conducted between Spring 2021 and 2022 and yielded about 100 research articles published between 1967 and 2022, spanning psychology, education, and organizational studies. Articles were included based on whether the authors provided a clear operational definition or framework of trust with specific domains, or clear descriptions of behaviors and characteristics associated with trustworthy individuals. Articles that did not involve the study of human behavior or that did not provide a working definition of trust were excluded.

In reviewing each article, research team members recorded the dimensions and individual characteristics used to operationalize and describe trustworthiness. Each dimension or characteristic was recorded within a preliminary codebook and accompanied by any available definitions, behaviors, or sample items included in the original article. Definitions and examples of dimensions or characteristics not explicitly tied to education settings were contextualized to the student-instructor relationship based on definitions provided in the original source material. Our focus was to clarify existing trust dimensions with descriptive language that placed actions and characteristics into the specified domain context. The literature review concluded once the research team agreed that saturation had been achieved, or that few new terms appeared in each successive article. The full literature review codebook is presented in Supplementary Table 1.

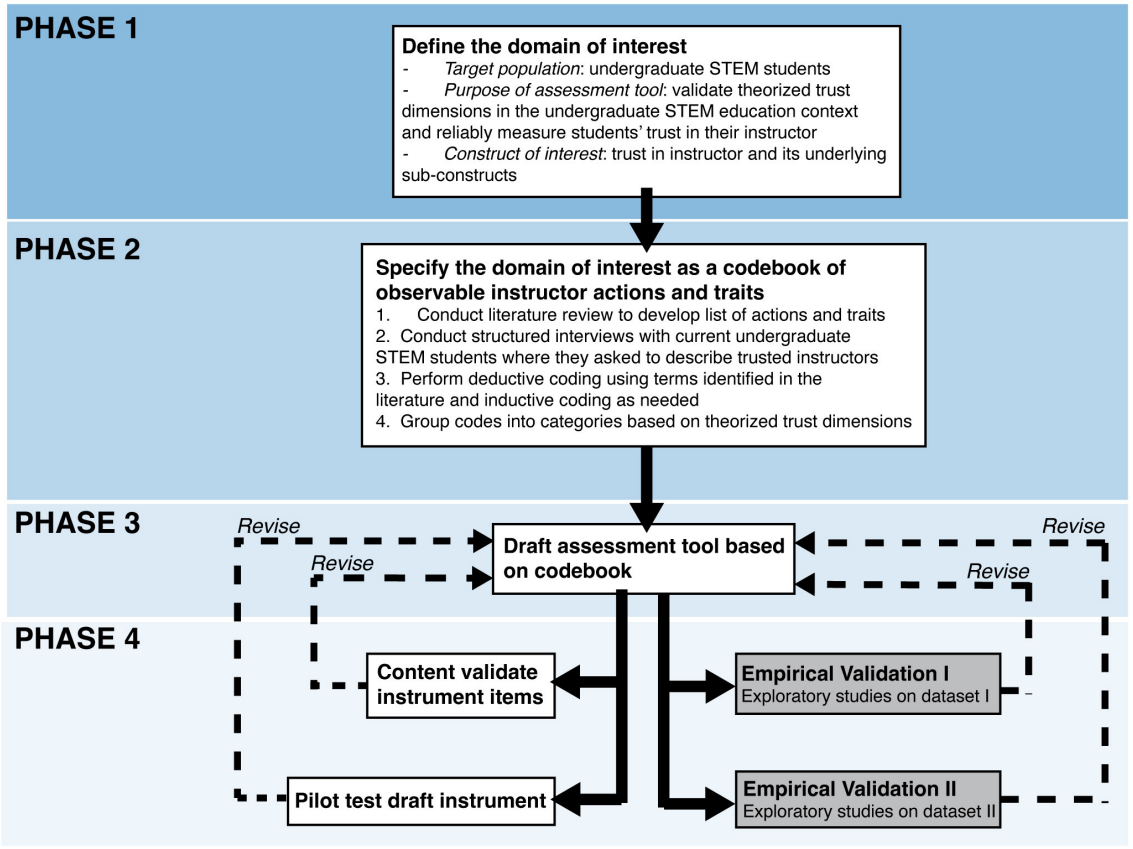

FIGURE 1
Phases in the development of a codebook of instructor behaviors and characteristics that contribute to the development of student trust and validation of trust measurement instrument derived from the codebook. Dashed lines depict revisions made to the instrument following rounds of validation. Boxes in gray ("Empirical Validation I" and "Empirical Validation II") represent steps of the process model approach not addressed in this paper.

2.3.2 Interview participants and procedures

Next, we sought to obtain the perspectives of students as key stakeholders in the study of instructor trust. To do so, we recruited undergraduate students enrolled in STEM classes (N = 57) from one large public research university, one mid-size private research university, and one mid-size public teaching college to participate in a study about their relationships with college instructors. Students were first recruited via convenience sampling by undergraduate assistants on the research team. Recruitment was then formalized through posters, web posts, and emails to students with the incentive of $10 compensation.

Thirty participants identified as students of color (52.6%). Of those 30, 12 identified as Black (21%), 10 identified as Hispanic or Latino (17.5%), three as more than one group (5.3%), and five did not identify their race/ethnicity (8.8%). Thirty-eight participants identified as women (67.7%) and 19 identified as men (33.3%). Most students were in their first and second years (56.2%) while the remainder were in their third and fourth year (43.8%) of college. Most students majored in STEM fields (68.4%) with some from the social sciences (21.1%), humanities (7%), and other fields (3.5%). Seventeen students (29.8%) were first-generation college students. See Table 1 for all interview participant demographic characteristics.

Upon volunteering to participate in the study, students were invited to a 15-min Zoom interview with a member of the research team. The interview followed a two-part structure. In the first, priming task, participants were asked to reflect on a past college instructor they trusted and to generate words describing the instructor's traits. Using Google Slides, participants were asked to place each trait on a bullseye graphic based on how important they believed each trait was to their perception of trustworthiness (e.g. if a student believed that an instructor's "punctuality" was the foremost reason for trust, the student would place "punctuality" in the center of the bullseye; see Figure 2 for an example). In the second part of the task, participants were asked to explain *why* the characteristics they chose were perceived as being trustworthy and *how those characteristics were demonstrated by the instructor*. Participants were encouraged to provide anecdotal examples of how their instructor had displayed the traits they had chosen. The purpose of the priming task was to prime the participant to reflect on a past trusted instructor in preparation for discussing their experiences in depth during the "free response task" (see Figure 2 for a schematic overview of the interview procedure). In the current study, we focus our analysis on responses during the free response task. A second manuscript in progress (Chen et al., *in review*) provides an analysis of the responses to the

TABLE 1 Demographic characteristics of student interview participants ($N = 57$).

	Number of participants	Percent
Self-identified gender		
Male	19	33.3%
Female	38	67.7%
School year		
First-year	5	8.8%
Second-year	27	47.4%
Third-year	17	29.8%
Fourth-year	8	14.0%
Race/ethnicity		
White or Asian or Pacific Islander	27	47.4%
Black or African American	12	21.0%
Hispanic or Latino	10	17.5%
Multiple Ethnicities	3	5.3%
Prefer not to answer	5	8.8%
First-generation student status		
Yes	17	29.8%
No	8	14.0%
Unsure/prefer not to answer	32	56.2%
Major		
STEM	39	68.4%
Social Sciences	12	21.1%
Humanities	4	7.0%
Other	2	3.5%

Percent is rounded to nearest decimal place.

priming task. Interviewers (consisting of two full-time researchers and three undergraduate research assistants) only asked follow-up questions if participants' responses were unclear. Each interview was securely recorded on Zoom. This project was granted exempt status from each institution's Institutional Review Board Human Subjects Committee, as it examined standard educational practices.

2.3.3 Thematic coding of interview free responses

We adhered to the established qualitative methodology of thematic analysis to identify emergent themes in students' free-response interview data (Braun and Clarke, 2006). First, three members of the research team (one full-time researcher and two undergraduate research assistants) familiarized themselves with the data by reading through all student responses and generating an initial list of themes. Next, we engaged in a directed content analysis approach (Hsieh and Shannon, 2005), integrating both deductive and inductive coding, to systematically code individual student responses. All interview responses were uploaded to NVivo, which enabled us to electronically code and manage data and ideas (Hilal and Alabri, 2013). Research team members systematically identified all traits associated with the trusted instructor by considering student responses sentence by sentence, contextualizing each sentence within the greater paragraph. Using deductive coding, constructs from the literature review and initial list of themes were used as an *a priori* list of codes to label students' responses. When student responses did not readily align with existing codes, we used inductive coding to generate new codes that more accurately captured emerging constructs. This iterative process ensured that our coding scheme remained grounded in prior research while allowing flexibility to accommodate novel insights from the data.

While our methodological approach incorporated both deductive and inductive elements, we did not adopt a fully inductive Grounded Theory method (Glaser and Strauss, 2017). Instead, we followed an abductive approach informed by Chatterji's (2003) process model, using existing frameworks to guide initial coding while allowing new codes to emerge from student responses. We recognize that this hybrid strategy limits the possibility of generating an entirely novel theory of instructor trust. However, it was intentionally chosen to balance theoretical grounding with openness to context-specific constructs, as our goal was to develop a preliminary instrument aligned with both empirical data and existing conceptualizations of trust.

Once an initial codebook was generated, two members of the research used the codebook to code all student responses independently. Once the two raters coded all responses, they met to discuss their independent analyses. To ensure consistency and validity, three rounds of intercoder reliability checks were conducted. When coding disagreements arose between the two coders, the coders and a senior investigator would discuss them and assign a final code after consensus was reached. The kappa value of the first intercoder reliability check was 0.64. The kappa value increased to 0.80 and finally to 0.85 after disagreements were resolved during the second and third rounds of intercoder reliability checks. The final kappa value indicates strong agreement between coders based on the codebook. Once agreement was reached on the codebook structure, two coders continued to complete the coding of all student interview free responses. At the completion of coding, NVivo's Coding Query functionality was used to calculate code frequencies. Even if a construct was mentioned more than once by a participant, we coded it a maximum of one time per response.

Finally, we searched for themes in the data by grouping codes into categories based on existing theoretical frameworks of trust identified during the literature review. Specifically, we had identified a consensus in the literature that trust broadly encompasses at least two domains: affective and cognitive. Additionally, previous research of undergraduate STEM students defined trust using a close personal relationship framework. Thus, we included a third, relational trust domain. Members of the research team first grouped codes into these broad domains. These themes were then iteratively refined through discussion among the research team. Where necessary, major themes were divided into sub-categories to ensure that the richness of our interview data was accurately represented. The final codebook contains 28 individual codes grouped into three major themes: affective, cognitive, and relational trust. The cognitive domain comprises six sub-categories,

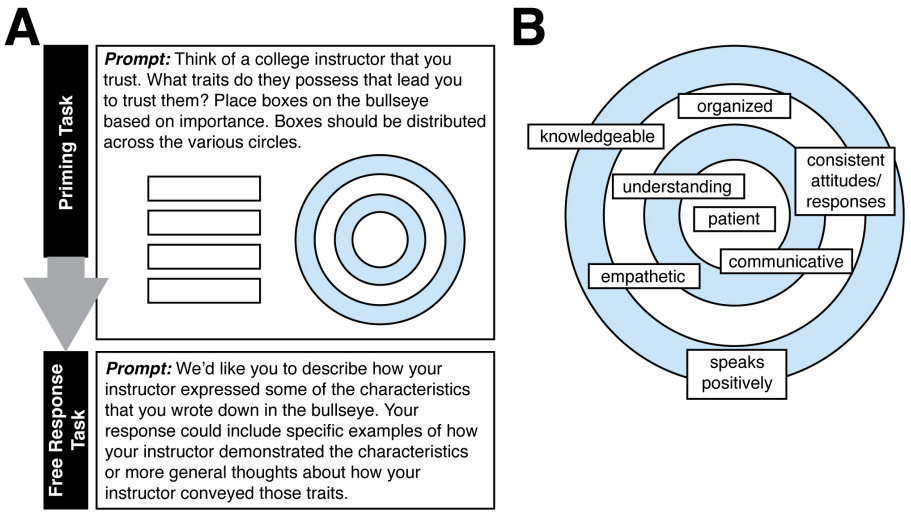

FIGURE 2
(A) Schematic overview of the two-part student interview procedure. In the first priming task, students were prompted to recall a past trusted instructor, identify characteristics of that instructor they perceived as being trustworthy and put them in boxes. Students then placed traits in order of perceived importance by moving boxes onto a "bullseye" image. In the second free response task, students were asked to expand upon the characteristics they listed in the priming task. **(B)** Example of a bullseye completed by a student participant in the priming task.

the relational domain comprises five sub-categories, and it was not necessary to split the affective domain into smaller sub-categories.

2.3.4 Network analysis of code frequencies

To examine patterns in how students associated different instructor traits with trust, we constructed a co-occurrence network diagram based on qualitative interview responses. Each node in the network represents a unique interview code (trait) mentioned by students, and edges represent instances where two traits were co-mentioned in the same interview. The weight of each edge reflects the frequency of co-occurrence across all participants. To further analyze network structure, for each node, we calculated degree centrality (the number of connections a trait had) and betweenness centrality (how often a trait acted as a bridge between others). At the domain level, we computed the average node degree and average betweenness centrality, as well as the intra-domain edge density, defined as the ratio of actual to possible connections among traits within the same domain. Finally, we quantified inter-domain edge frequencies to assess the extent to which traits from different trust domains co-occurred. These analyses allowed us to identify not only which traits were most central to students' conceptualizations of trust, but also how traits within and across trust domains were structurally interconnected.

2.4 Process model phase 3

2.4.1 Survey item writing and content validation

According to the process model approach to instrument design, the interview codebook was used to draft items for an assessment tool measuring students' trust in their instructor. Each survey item was derived from each unique code. To draft survey items, three senior members of the research team independently wrote items for all codes. In some cases, multiple items were written for the same code to ensure an accurate representation of the behaviors or traits encompassed within the code. Once completed, the researchers convened to discuss the drafted items. When items written for the same code differed from each other, the researchers reviewed the contextual definitions of the code, consulted with senior investigators, and edited the items until consensus was reached. To content validate survey items, three currently enrolled undergraduate STEM students were asked to provide feedback on each item. Each student provided an interpretation of what each item was asking for, highlighted items that were unclear or ambiguous, and provided feedback on how well the items aligned with their experiences as STEM students. Items were revised according to their feedback. The final survey contained 38 items and is provided on the first page of the Supplementary material.

2.5 Process model phase 4

2.5.1 Survey participants and procedures

As a pilot study, the survey was distributed in one STEM classroom at a large public research university. Students received an e-mail from their instructor inviting them to participate in an online survey administered with Qualtrics survey software. Of the 252 students who received the survey, 210, or 83%, completed the survey in its entirety. Of the participants, 58.6% identified as female, 14.8% identified as male, 0.5% identified as non-binary and 26.2% declined to provide their gender identity. Most students were in their second year (54.3%), with 41.4% of students in their third and fourth years and only 0.9% of students in their first year. Most participants self-identified as: White (58.6%), followed by Asian or Pacific Islander (15.7%), Hispanic or Latino (8.1%), multiple ethnicities (6.7%), and Black or African American (6.2%). 4.3% of

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TABLE 2 Demographic characteristics of survey participants ($N = 210$).

	Number of participants	Percent
Self-identified gender		
Male	31	14.8%
Female	123	58.6%
Non-binary	1	0.5%
Prefer not to answer	55	26.2%
School year		
First-year	2	1%
Second-year	114	54.3%
Third-year	66	31.4%
Fourth-year	21	10.0%
Other	7	3.3%
Race/Ethnicity		
White	125	58.6%
Asian or Pacific Islander	34	15.7%
Black or African American	13	6.2%
Hispanic or Latino	19	8.1%
Multiple Ethnicities	15	6.7%
Prefer not to answer	9	4.3%
Other	1	0.5%
First-generation student status		
Yes	59	28.1%
No	148	70.5%
Unsure/prefer not to answer	3	1.4%
Major		
STEM	202	96.2%
Social Sciences	5	2.4%
Undecided	3	1.4%

Percent is rounded to nearest decimal place.

participants declined to provide information regarding their race or ethnicity. 28.1% of participants were first-generation college students. Almost all students (96.2%) majored in STEM fields. 2.4% of students majored in Social Sciences and 1.4% were undeclared. See Table 2 for all survey participant demographic characteristics. This project was granted exempt status from each institution's Institutional Review Board Human Subjects Committee, as it examined standard educational practices.

2.5.2 Psychometric analysis of survey

Statistical analyses for the pilot study were conducted to investigate the psychometric properties of the survey derived from the interview codebook. Based on thematic analysis of the codebook, we hypothesized that a three-factor solution would define the dimensions of the survey (affective, cognitive, and relational trust). To evaluate this hypothesis, we conducted a maximum-likelihood factor analysis with promax rotation. Sampling adequacy was evaluated using a Kaiser-Meyer-Olkin analysis and suitability for factor analysis was evaluated using Bartlett's test. We evaluated model fit with the chi-square test of model fit, comparative fit index (CFI; Bentler, 1990), Tucker-Lewis Index (TLI; Tucker and Lewis, 1973), normed-fit index (NFI; Bentler and Bonett, 1980) and root mean square error of approximation (RMSEA). Finally, we computed a factor correlation matrix and examined internal consistency using Cronbach's α for all survey items and for each component factor.

3 Results

To understand how students conceptualize trust in instructors in their own words, we conducted structured interviews with 57 currently enrolled undergraduate STEM students at 3 institutions. They were asked to describe characteristics of a past trusted instructor, including examples of how the instructor had demonstrated these characteristics (see Section 2 for details). We first performed qualitative analyses to determine the dimensional organization of traits students used to describe trusted instructors, resulting in an interview codebook that proposes a three-dimensional structure to the development of trust. Next, we used qualitative and quantitative methods to understand the relationships between proposed dimensions of trust. We first sought to determine whether the proposed dimensions of trust were highly interrelated or if they remained distinct by examining co-occurrences of trait mentions in student responses. Finally, we developed a survey based on the qualitative interview codebook and used it to empirically test the construct validity of the proposed dimensions of trust.

3.1 Emergent dimensions of trust based on student interviews

Through content analysis of open-ended interview responses, our findings reveal 28 individual codes representing instructor characteristics perceived by students as demonstrating trustworthiness (see Section 2 for details). Because students were asked to provide examples of how instructors demonstrated these characteristics, we extracted observable contextual definitions for each code and included them in our codebook. Through thematic analysis, we organized individual codes into three major dimensions: affective, cognitive, and relational trust (Figure 3; see Section 2 for details). The major coding categories were then further divided into subcategories that grouped together similar individual codes as needed. In our qualitative codebook of trust, readers can find the three major coding categories, subcategories, individual code definitions, and accompanying student examples for each code (Table 3).

As described in "Section 2," our coding and thematic analysis were informed by a broad literature review, which yielded 50 distinct characteristics that have been previously used to operationalize the latent variable "trust" or have been found to be statistically strongly associated with trust. Our search included

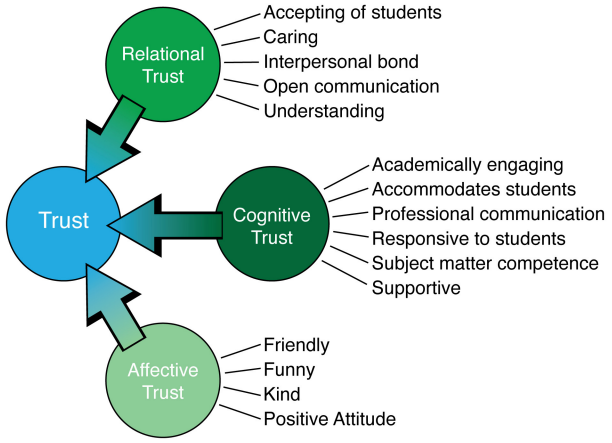

FIGURE 3
Schematic of major code categories and their subcategories, representing the three dimensions of trust captured by qualitative analysis of student interview responses.

more than 100 review articles, experimental studies, and qualitative analyses across a wide array of fields (see Supplementary Table 1 for the full literature review codebook). While our review was comparatively limited in scope relative to the entire body of literature on "trust," we found that many operational definitions of trust included two sub-constructs: cognitive and affective trust. Thus, we sought to categorize interview codes into these two domains, using the existing literature to guide our categorization of traits related either to an instructor's professional capabilities or an instructor's ability to elicit positive emotions from their students, respectively. Additionally, in previous studies of undergraduate STEM student trust, trust was operationally defined using a close personal relationship framework encompassing care, acceptance, and understanding as sub-constructs (Clark and Lemay, 2010; Cavanagh et al., 2018; Wang et al., 2021). We therefore opted to include a third, relational trust domain to capture instructor traits related to these and other constructs that could be associated with developing and maintaining a close personal relationship with students. In the following, we describe each of the three domains—cognitive, relational, and affective trust—in more detail, providing contextual information about each domain and a rationale for the inclusion of individual codes within specific domains.

3.1.1 Cognitive trust

In our literature review, we found that cognitive trust is causally driven and based on a knowledge-based evaluation of a trustee's ability to fulfill an obligation (Dowell et al., 2015; Johnson and Grayson, 2005; Lewis and Weigert, 1985; Rempel et al., 1985). In this framing of trust, the trustor holds certain expectations of the trustee, based on a promise the trustee made to the trustor. Traits that were often found to be associated with the cognitive domain in a review of the literature included "competence," "reliability," "consistency," "fairness," "professionalism," "responsiveness," "flexibility," and "timeliness" (Butler and Cantrell, 1984; Cook and Wall, 1980; Friedland, 1990; Ghosh et al., 2001; Lindskold and Bennett, 1973; McAllister, 1995; Moorman et al., 1993; Rousseau et al., 1998; Tschannen-Moran and Hoy, 2000; others, see Supplementary Table 1), among others.

In the higher education context, the trustor is the student making a cognitive decision about whether the trustee, their instructor, can meet their expectations of what an instructor should do in the classroom. This decision may be driven by evaluations of the instructor's competence and reliability, or other behaviors that seek to facilitate an effective working relationship between the student and instructor. Thus, interview codes related to the professional responsibilities typical of an undergraduate STEM instructor, such as demonstrating subject matter competence and providing adequate support for students' academic success, were subsequently grouped into the cognitive dimension (Table 3). In previous work, student trust in the higher education context was assessed using Tschannen-Moran and Hoy's framework of trust developed in the K-12 setting, which included "reliability" and "competence" as key domains of trust (McClain and Cokley, 2017). These elements were also captured in our analysis, represented in the cognitive domain of trust.

Overall, we found that cognitive trust was an important dimension for student perceptions of trustworthiness. Cognitive trust was the second most coded theme with 54 out of 57 students (94.7%) referencing at least one instructor characteristic associated with building cognitive trust (Table 4). Containing 14 codes, the project team divided cognitive trust into six subcategories: academically engaging, accommodating students, professional communication, responsive to students, competent in subject matter, and supportive. The most cited singular codes within the cognitive domain were "supportive," referenced by 33 out of 57 of students (57.9%) and "flexible," referenced by 19 out of 57 students (33.4%; Table 4).

In interviews, students described instructor behaviors and traits that demonstrated the instructor's ability to fulfill their professional obligations in creating an effective learning environment. For example, instructor flexibility was described as an instructor's willingness to accommodate extenuating circumstances, such as illness or family emergencies, that prevented students from turning in assignments on time:

> "[My instructor] was willing to work with me when it came to catching up on class notes. He set up informal office hours with me so I could catch up on materials and this was an action that not many of my professors were willing to do when I was sick. His ability to be flexible, understanding, and attentive to my needs as a student truly meant a lot to me."

While this action could be interpreted as kindness, the context in which students described this trait had strong implications for the student's course performance. Similarly, instructor support was not described as being emotionally supportive but rather, operationalized as the instructor's role as a resource for academic success. For example, behaviors described as supportive included providing the necessary resources for students to complete assignments and motivating students to engage deeply with the course material. One student explained the importance of instructor support as: "I considered this period in my academic career my most productive because I knew there was always

TABLE 3 Qualitative codebook emerging from student interviews.

Trust dimension	Code category	Code	Definition	Student example
Affective trust		Friendly/personable	The instructor demonstrates personal kindness to students. Statements indicate that the instructor is pleasant, likable, and/or agreeable	"He was always friendly and greeted everyone when he got into class"
		Funny	The instructor displays a sense of humor	"I was considerably more likely to attend and enjoy class taught by professors that…could make jokes to keep us interested"
		Kind	The instructor demonstrates benevolence. [Sentence must mention the word "kind"]	"One of the biggest things a professor can do that can increase my likelihood of trusting them is to simply be kind…"
		Positive attitude	The instructor displays a positive demeanor	"They did their best to lighten the mood and keep everyone smiling"
Cognitive trust		Academically engaging	The instructor cultivates a positive academic/classroom environment through involvement with students and course material	"They were also very engaging and did not read off of their slides but rather made sure that they engaged with us"
	Accommodates students	Available	The instructor is accessible to students and makes time to meet	"He took a genuine interest in individual students and would be willing to spend a long time in office hours with every student who was struggling"
		Fair	The instructor demonstrates reasonable judgments, such as when grading assignments	"She was always fair in her grading and willing to work with her students to understand and achieve"
		Flexible	The instructor breaks existing norms or patterns of behavior to accommodate students.	"When classes switched to 'online-mode' she was super flexible when it came to the new difficulties and challenges we were facing"
		Patient	The instructor tolerates delays, confusion, or other unanticipated confusion	"The instructor showed patience by taking the time to listen to others who had questions"
	Professional communication	Ongoing communication	The instructor communicates with students over time and, perhaps, after the course ends	"He has consistently checked in with me throughout the semester since that exam and even reached out to me before the next exam offering some last-minute help"
		Transparent communication	The instructor sets out goals for the class that are understandable	"Our class only had ten people, so she was able to connect with us and clearly communicate everything that was going on with the course"
	Responsive to students	Good listener	The instructor demonstrates their capacity to hear students' questions/concerns and the instructor thoughtfully considers students words and values their opinions/feedback	"He always listened to all of his students' concerns- and made it obvious that he was really listening and really cared"
		Provides feedback	The instructor actively and constructively reacts to students' assignments including providing feedback	"I built trust with this professor because of his ability to provide active feedback to all of my work for his class"
	Subject matter competence	Communicates concepts clearly	The instructor is adept at relaying academic concepts in class. The instructor answers student questions well	"The teacher was dependable in the sense that you as the student could count on the professor to teach difficult topics really well and efficiently"
		Knowledgeable	The instructor is well-versed in their subject area	"Having a breadth of knowledge also played a role because this professor would include small details about why this topic was important and how it could be used in the bigger picture made me actually want to learn it"
		Organized, prepared, and responsible in class	The instructor is adept at effectively structuring and planning their course	"Finally, he was very organized and responsible, as all of the class material was organized very neatly and in an easy-to-access manner"
		Passionate about subject and work	The instructor has a strong interest, commitment and desire for their work.	"This professor has a huge depth of knowledge in this class and just wants to share their passion with us every time we meet"

(Continued)

TABLE 3 (Continued)

Trust dimension	Code category	Code	Definition	Student example
		Supportive	The instructor indicates they are a resource for academic assignments, projects, materials, etc. The instructor also supports and motivates students to interact with course material	"He was very supportive and would not belittle students for their failures or difficulties…"
Relational trust		Accepting of students	The instructor is cognizant of and supportive of a diversity of learners (This requires patience and flexibility). The instructor ensures all students are given access to opportunities and made to feel welcomed and involved (e.g. no matter ability, background, etc.). The instructor comprehends and shows consideration for other points of view/ideas, creating a safe environment	"He was always sure to engage all of the students no matter their age or willingness to raise their hand"
		Caring	The instructor shows interest and investment in student achievement within the scope of their class/in the academic sphere. Instructor may motivate/inspire students to care about course materials. When a sentence mentions a teaching approach/strategy (e.g., patience, teaching competence: communicating concepts), do not use this code. Only code as "caring for students' success" if no strategy is mentioned and only the instructor's intention(s) are mentioned	"My instructor demonstrated that they cared about students' by making it a point to learn each and every student's name"
	Interpersonal bond	Connects with students	The instructor seeks to cultivate a personal relationship with students	"While we were in class, she would make it a point to laugh with her students and truly connect"
		Expresses Interest in students' lives	The instructor actively displays interest in students beyond the classroom (e.g., asking questions about their past)	"The instructor that I trusted really wanted to get to know me and my background"
		Relatable	The student perceives that the instructor is more like them than not	"In our one-to-one meeting, my professor made sure to take my worries/doubts about declaring the major seriously and made me feel as though she had once experienced them herself and that she could relate to my experience"
		Vulnerable	The instructor takes risks by disclosing personal information or emotions	"They established this relationship by getting personal and sharing information about themself so I could then open up"
		Open communication	The instructor communicates in a way that is perceived as open, or a mode wherein multiple subjects (e.g. academic subjects, personal subjects, etc.) can be broached The sentence should indicate that there was a "two-way communication" which fosters an engaging, communicative relationship	"My instructor would always have time to meet with me either to talk about course material or just what was going on in my life"
	Understanding	Empathetic	The instructor is able to share students' feelings and experiences	"My professor is a very empathetic person who would always make sure his students were doing well in and outside of class"
		Humanizes students	The instructor comprehends and shows consideration for the fact that students are human beings, not just students. Therefore, the instructor may show that they really know the student (e.g., knowing students' names). They may also respect the student and display politeness	"He understood that we are human beings and not just robots that should always complete our work right on time and always know the answer"
		Understanding	The instructor comprehends and shows consideration for students' situational non-academic responsibilities, personal circumstance, the difficulties of the pandemic, or being sick during school, and other things more generally.	"A professor who understands that life happens and that their students have other responsibilities besides school and reaches out to their students when they notice something might be wrong is greatly appreciated"

TABLE 4 Frequency of unique code mentions by students (out of 57 students) and codes most frequently co-occurring with it.

Trust dimension	Code category	Code	Number of mentions (out of 57 students)	Most frequently co-occurring codes (number of co-occurrences across all interviews)
Affective trust			**19**	
		Friendly/personable	5	Humanizes Students (5) Supportive (4)
		Funny	6	Caring (4) Supportive (3) Relatable (3) Empathetic (3) Understanding (3)
		Kind	6	Supportive (4) Available (3) Good Listener (3) Humanizes Students (3)
		Positive attitude	7	Caring (5) Supportive (4) Understanding (3)
Cognitive trust			**54**	
		Academically engaging	10	Communicates Concepts Clearly (5) Passionate (5) Caring (5) Supportive (4) Accepting (4)
	Accommodates students	Available	13	Caring (10) Supportive (9) Flexible (5) Communicates Concepts Clearly (5)
		Fair	9	Caring (6) Communicates Concepts Clearly (5) Understanding (5)
		Flexible	19	Caring (13) Supportive (10) Understanding (9)
		Patient	8	Accepting (6) Communicates Concepts Clearly (5) Supportive (5)
	Professional communication	Ongoing communication	6	Supportive (6) Caring (5) Understanding (4)
		Transparent communication	3	Caring (3) Communicates Concepts Clearly (2)
	Responsive to students	Good listener	12	Supportive (7) Caring (6) Humanizes Students (5) Understanding (5)
		Provides feedback	4	Caring (4) Supportive (3)
	Subject matter competence	Communicates concepts clearly	14	Caring (9) Passionate (8) Supportive (7)
		Knowledgeable	11	Supportive (7) Passionate (6) Caring (6)
		Organized, prepared, and responsible in class	5	Caring (4) Supportive (3)
		Passionate about subject and work	13	Caring (9) Supportive (6) Accepting (5) Understanding (5)

(Continued)

TABLE 4 (Continued)

Trust dimension	Code category	Code	Number of mentions (out of 57 students)	Most frequently co-occurring codes (number of co-occurrences across all interviews)
		Supportive	33	Caring (26) Open Communication (11) Understanding (11)
Relational trust			**55**	
		Accepting of students	16	Caring (8) Open Communication (6) Humanizes Students (4)
		Caring	40	Understanding (19) Open Communcation (12) Humanizes Students (9)
	Interpersonal bond	Connects with students	5	Understanding (3)
		Expresses interest in students' lives	8	Vulnerable (4) Humanizes Students (4) Understanding (4)
		Relatable	8	Humanizes Students (5) Understanding (5) Empathetic (4)
		Vulnerable	9	Understanding (5) Open Communication (4) Humanizes Students (4)
		Open communication	18	Understanding (7) Humanizes Students (4)
	Understanding	Empathetic	11	Understanding (7) Humanizes Students (4)
		Humanizes students	15	Understanding (7)
		Understanding	23	Caring (19) Supportive (11) Flexible (9)

someone who supported my learning and would answer any of my questions, no matter what."

3.1.2 Relational trust

In contrast to cognitive trust, which captures instructor characteristics aimed at building an effective working relationship, relational trust captures characteristics that reflect the cultivation of a strong personal relationship. This is not meant to connote an inappropriate relationship but rather refers to the ways in which an instructor may get to know a student and treat a student as a whole person. These actions may not have direct implications for students' classroom performance or academic achievement, but may have indirect effects through impact on students' self-efficacy, engagement, academic self-concept, motivation, and persistence (Ballen et al., 2017; Eimers, 2001; Komarraju et al., 2010; Kuh and Hu, 2001; Micari and Pazos, 2012; Umbach and Wawrzynski, 2005; Vogt et al., 2007).

Previous studies of trust in the higher education STEM context defined trust through elements of care, understanding, and acceptance (Cavanagh et al., 2018; Wang et al., 2021; Supplementary Table 1). Thus, we included emergent interview codes that reiterated these three elements in the relational trust domain (Table 3). Further, we considered some of the key elements that have been associated with positive personal student-teacher relationship in other studies, including openness, benevolence, care, connectedness, vulnerability, and respect (Anderson and Carta-Falsa, 2002; Jacklin and Le Riche, 2009; Komarraju et al., 2010; Meinking and Hall, 2024; McClain and Cokley, 2017; Micari and Pazos, 2012; Tschannen-Moran and Hoy, 2000; Umbach and Wawrzynski, 2005). Willing vulnerability and the disclosure of personal information by teachers have also been emphasized as key components of a trust student-teacher relationship in the K-12 context (Holzer and Daumiller, 2025). Interview codes showing instructor behaviors intended to build and maintain strong interpersonal relationships were therefore also grouped into the relational trust dimension (Table 3).

The relational trust category contained 10 unique codes, divided into five subcategories: accepting of students, caring, interpersonal bond, open communication, and understanding. After "caring," traits associated with an instructor's understanding were the most mentioned during student interviews and were referenced by 34 out of 57 students (59.6%; Table 4). Our analysis found that relational trust was the most coded theme with 55 out of 57 students (96.5%) referencing at least one instructor characteristic associated with building relational trust (Table 4). Across all student

interviews, instructor characteristics from the relational domain were among the most cited traits informing students' overall perception of their instructor's trustworthiness. Indeed, the single most often cited instructor characteristic perceived by students as indicating trustworthiness was "caring," mentioned by 40 out of 57 students (70.2%; Table 4).

In student interviews, traits associated with building relational trust were often described within the context of the instructor's efforts to recognize students' identities beyond their role as students and to share aspects of their own identity beyond that of an instructor. For example, one student explained that the trust they had in their instructor came from how:

"[t]he instructor [] really wanted to get to know me and my background. Usually, instructors just see you as just another person in a class, but this instructor really wanted to understand what [was] going on in my other classes and would check in to make sure that I wasn't being too hard on myself. They established this relationship by getting personal and sharing information about themself so I could then open up. This instructor's willingness and desire to get to know me past the identity of a student is why I trust them."

Across disciplines, trust is often described as a "willingness to be vulnerable" to the actions of a trustee (Mayer et al., 1995). In the context of the student experiences described here, instructors who were also willing to be vulnerable through acts of self-disclosure or who made strides to accept and understand their students' vulnerability appeared to succeed in building not only relational trust, but overall trust with their students.

3.1.3 Affective trust

Affective trust is the emotional component of trust based upon an initial interpersonal connection between two individuals that can lead to feelings of closeness, care, concern, or friendship. In turn, these positive emotions can deepen the development of trust, even in the absence of other causal attributes (Dowell et al., 2015; Johnson and Grayson, 2005; Lewis and Weigert, 1985; Rempel et al., 1985). It is important to distinguish between the relational and affective domains of trust. For example, "benevolence," or acting out of kindness, is often cited as a component of trust in the broader literature as part of an affective dimension (Erdem and Ozen, 2003; Hoy and Tschannen-Moran, 1999; Jarvenpaa and Leidner, 1998; Kramer and Cook, 2004; Lindskold and Bennett, 1973; Mayer et al., 1995; McAllister, 1995; Morgan and Hunt, 1994; Renn and Levine, 1991; Rousseau et al., 1998; others, see Supplementary Table 1). However, taking students' contextualized meaning into account in our qualitative analysis, we deemed that certain interview codes that could be related to "benevolence" went beyond simple acts of professional courtesy or kindness and instead represented truly individualized acts of care. Such codes were subsequently categorized within the relational trust domain.

Interview codes included in the affective domain were instead related to students developing positive feelings toward their instructor that initially built trust or encouraged students' openness to the possibility of pursuing a personal relationship with their instructor (Table 3). In other words, codes included within the affective domain are related to students' first impressions of their instructor's affect and approachability, which then informed their decision to interact further with their instructor. Indeed, our review of the literature found that instructor approachability and frequency of positive interactions with instructors were important affective components of trustworthiness (Boyas and Sharpe, 2010; Denzine and Pulos, 2000; Edmondson et al., 2004; Jaasma and Koper, 1999; Kramer and Cook, 2004; Lamport, 1993; Robinson, 1996; Tschannen-Moran and Hoy, 1998; others, see Supplementary Table 1). Of the three dimensions of trust that emerged from student interviews, affective trust was the least commonly coded theme, with only 19 out of 57 students (33.3%) referencing at least one of the associated characteristics in their interviews (Table 4). The affective trust code category was encompassed by four singular codes (friendly/personable, funny, kind, and positive attitude), with no additional categorization of codes needed (Table 3).

When students referenced the affective domain of trust during interviews, they referred to instructor characteristics that made them feel more positive about the classroom environment and attending class or office hours. For example, one student discussed the importance of instructor kindness in building trust and motivating attendance: "One of the biggest things a professor can do that can increase my likelihood of trusting them is to simply be kind and empathetic. I am much less likely to go to a professor's office hours if they are cold and callous during class but am much more likely to approach a professor when they are kind."

3.2 Relationships between dimensions of trust in students' words

Once we qualitatively categorized interview codes into three dimensions, we next sought to understand how different dimensions of trust interacted within students' open-ended responses. In doing so, we aimed to assess whether students tended to systematically distinguish between different dimensions of trust in their descriptions or if there was a pattern in how traits were mentioned in relation to each other. First, we tabulated the number of codes mentioned by each student in their free responses (Table 4). Of the 57 students we interviewed, 37 students mentioned traits from at least two dimensions, 17 students mentioned traits from all three dimensions, and three students mentioned traits from only one dimension. The three students who mentioned traits from only one dimension all used traits belonging to the relational domain. On average, students used between five and six traits to describe an instructor and 2–3 of those traits tended to fall within the cognitive and relational domains, respectively.

Next, we determined the frequency of codes co-occurring together within a student's response. Across all interviews, we found that "supportive" from the cognitive domain and "caring" from the relational domain were most frequently mentioned together, co-occurring 26 times. Following behind, "caring" and "understanding" from the relational domain co-occurred 19 times while "flexible" from the cognitive domain and "caring" from the relational domain were mentioned together 13 times. "Supportive" from the cognitive domain also frequently co-occurred with "open communication" from the cognitive domain (12 co-occurrences)

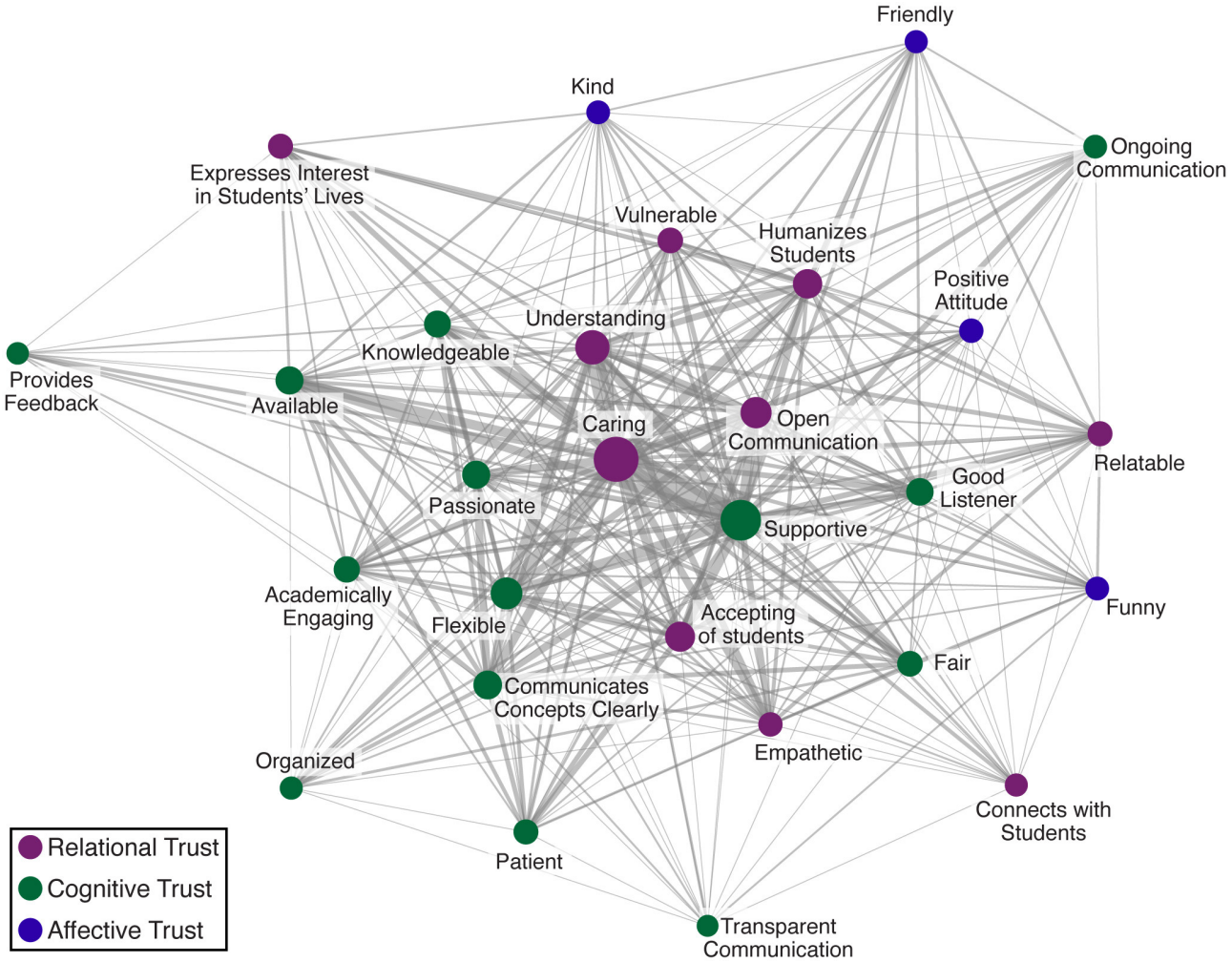

FIGURE 4
Co-occurrence network graph of interview codes. Each code is represented by a node, whose size reflects the number of times it was mentioned across all student interviews and whose color denotes the thematic domain, or trust dimension, to which it belongs. Edges connect codes that were mentioned by the same student and thickness of the edges represents how frequently pairs co-occurred.

and "understanding" from the relational domain (11 co-occurrences). The rightmost column of Table 4 lists the traits that were most frequently mentioned in conjunction with each individual code.

The complete network diagram is shown in Figure 4, where each individual code is represented by a node and edges connect nodes that co-occurred in student responses. The size of the node reflects the number of times a code was mentioned across all students, and thickness of the edges represents how frequently two codes were mentioned together. Nodes are additionally color-coded by trust domain. As seen in the co-occurrence network, traits associated with the relational and cognitive domains occupy central positions in the network and exhibit a high degree of co-occurrence. These nodes are not only frequently mentioned, based on their size, but also highly interconnected. The high degree of interdependence suggests that students may perceive traits falling within these domains as closely linked and reinforcing when evaluating trust in their instructors. On the other hand, traits falling within the affective domain are not as consistently interconnected with other traits in the network, suggesting they may play a more peripheral role in student evaluations of trust.

To further characterize the network structure, we calculated node-level and domain-level descriptive statistics. Traits in the relational and cognitive domains exhibited higher average degrees (22.8 and 21.21, respectively) than those in the affective domain (18.25), indicating that they co-occurred more frequently with other traits. Similarly, betweenness centrality scores were higher for relational (3.4) and cognitive (2.77) traits compared to affective traits (1.56), suggesting that nodes within these domains function as more central bridges within the network. Intra-domain edge density was also higher among relational (0.93) and cognitive traits (0.82), compared to affective traits (0.67), reinforcing that these domains are more densely interconnected. Lastly, we found that the number of inter-domain edges was highest between relational and cognitive traits (113 edges between relational and cognitive domains compared to 31 edges between relational and affective domains and 34 edges between cognitive and affective domains), further supporting their overlapping nature in students' descriptions of trustworthy instructors.

Finally, we examined students' open-ended responses to qualitatively understand how students, in their own words, used traits from different domains in relation to each other when describing trusted instructors. In a notable example of the relationship between relational and cognitive dimensions, one student describes their instructor:

"He viewed the task of building students' understanding as *his* responsibility as a professor rather than the student's responsibility. When students went to see him for office hours, he always asked about them even though it was technically extraneous information—what a student's major was, what their interests were, etc. And he would not only remember this information, but he would also use it to help explain ideas better. He would introduce students to each other if they were in office hours at the same time. Essentially, he humanized and dignified the students who would come to see him, which was particularly helpful during times of struggling with the material."

From their response, it is apparent that the instructor first took the time to get to know their students personally and build a bond based on acceptance and understanding. Once the student began to build relational trust and felt humanized, they felt more comfortable asking for help with course material. Moreover, because the instructor had taken the time to get to know students personally, they were able to provide personalized examples and analogies when explaining difficult course concepts. By making the content more individually meaningful, the instructor was better able to provide academic support for their students. Thus, the instructor built cognitive trust by leveraging the personal information they learned about the student in the process of building relational trust. Based on students' descriptions of their instructors, traits within the relational and cognitive dimensions appear to be highly interrelated, frequently overlapping and interacting within students' perceptions rather than functioning as distinct or independent categories.

3.3 Construct validity of trust dimensionality

Following our assessment of trust dimensionality using students' open-ended responses, we then sought to quantitatively test the construct validity of the three dimensions. Because we had constructed the interview codebook as part of a process model approach to instrument design (see Section 2 for a detailed description), we could readily derive survey items from individual interview codes. The resulting survey could then be used to determine whether the dimensionality we had proposed in the interview codebook similarly emerged from a factor analysis of student responses.

Student descriptions of trusted instructors gave observable contextual operationalizations of instructor traits, which were incorporated into the interview codebook. Based on these descriptions, we wrote example items that could be used in an instrument to assess the extent to which instructors demonstrated these traits and thus ultimately assess students' perceptions of trust in their instructor. For example, based on students' use of the trait, "humanizes students" in their open-ended responses, the contextual definition of the code was determined to be: "the instructor comprehends and shows consideration for the fact that students are human beings, not just students. Therefore, the instructor may show that they really know the student (e.g., knowing students' names). They may also respect the student and "display politeness" (Table 3). Example items to assess this trait could therefore be: "My instructor treats students with respect" or "My instructor makes me feel like more than a student" (Table 4).

Three senior members of the research team independently wrote draft items matched to each interview code and description. Once consensus was reached on all drafted items, three currently enrolled undergraduate STEM students were asked to provide feedback on the items for the purpose of content validation (see Section 2 for details). After items were revised according to their feedback, the final survey contained 38 items. Table 5 presents all finalized items that were included in the survey, matched to interview codes. In addition to newly drafted items, we also chose to include previously validated items from the trust survey used by Cavanagh et al. (2018) due to the similarity of constructs that emerged in our qualitative data and that were used to operationalize trust in their study. The full survey is provided in Supplementary material. We distributed the survey to one STEM classroom at a large public research university and received responses from 210 students (see Section 2 for details).

Based on thematic analysis of the codebook from which the survey items were derived, we hypothesized that a three-factor solution would define the dimensions of survey responses (affective, cognitive, and relational trust). To evaluate this hypothesis, we conducted a maximum-likelihood factor analysis with promax rotation (to accommodate nonorthogonal relationships) with a forced three-factor solution. Sampling adequacy was evaluated using a Kaiser–Meyer–Olkin (KMO) analysis; the KMO value of 0.953 supports a suitable sample size for factor analysis. Bartlett's test additionally indicated that the data were suitable for a factor analysis [c^2 (703) = 7,621.74, $p < 0.0001$].

The three extracted factors accounted for 54.4% of the total variance. Table 6 presents the factor pattern matrix and cross-loadings with other factors. The first factor accounted for 21.1% of the variance, the second factor accounted 18.6% of the variance, and the third factor accounted for 14.7% of the variance. Using a factor correlation matrix, we found that the three factors were sufficiently distinct from each other as all factor correlations fell below the recommend 0.84 threshold (Brown, 2015; Kline, 2016) (Supplementary Table 2). When all survey items were included, we observed a high degree of internal consistency (Cronbach's $\alpha = 0.971$). Internal consistency was also evaluated for each of the factors independently and was high for each factor (Cronbach's $\alpha = 0.957$, 0.950, and 0.934, respectively). To evaluate model fit for the three-factor solution, we utilized the following fit indices: TLI, CFI, NFI, RMSEA, and chi-square goodness of fit. We found that the close-fit indices for the three-factor solution approximate, but do not all reach recommended levels (RMSEA ≤ 0.8; NFI, TLI, and CFI ≈ 0.95) for an appropriate outcome [c^2 (592) = 1,593.55, $p < 0.000$ TLI = 0.84, NFI = 0.80, CFI = 0.866, RMSEA = 0.09] (Bentler and Bonett, 1980; Hu and Bentler, 1999; Tucker and Lewis, 1973). Specifically, while RMSEA and

TABLE 5 Survey items derived from unique interview codes.

Trust dimension	Code category	Code	Survey item(s)
Affective trust		Friendly/personable	My instructor is friendly
		Funny	My instructor has a sense of humor
		Kind	My instructor is kind
		Positive attitude	My instructor is a positive person
Cognitive trust		Academically engaging	My instructor makes class activities interesting
	Accommodates students	Available	My instructor makes themselves available
		Fair	My instructor treats students fairly
		Flexible	My instructor is flexible
		Patient	My instructor is patient
	Professional Communication	Ongoing Communication	My instructor consistently communicates with students outside of class
		Transparent Communication	My instructor clearly communicates class expectations
	Responsive to students	Good listener	My instructor listens to student feedback My instructor does not dismiss my concerns My instructor listens very carefully to me
		Provides feedback	My instructor provides feedback on my work
	Subject matter competence	Communicates concepts clearly	My instructor communicates course concepts well
		Knowledgeable	My instructor is knowledgeable about their subject area
		Organized, prepared, and responsible in class	My instructor is prepared for class
		Passionate about subject and work	My instructor is passionate about their subject area
		Supportive	My instructor helps students be academically successful My instructor helps me overcome personal challenges My instructor helps me achieve my professional goals
Relational trust		Accepting of students	My instructor is accepting of students' differences My instructor "gets" me My instructor accepts me for who I am
		Caring	My instructor cares about students' educational success My instructor cares about students' wellbeing My instructor truly cares about my educational welfare My instructor cares about my education
	Interpersonal bond	Connects with students	My instructor can connect with students.
		Expresses interest in students' lives	My instructor expresses interest in students' lives outside of school
		Relatable	My instructor is easy to relate to
		Vulnerable	My instructor shares personal stories with us
		Open communication	I can talk openly with my instructor
	Understanding	Empathetic	My instructor is empathetic to students' personal circumstances
		Humanizes students	My instructor treats students with respect My instructor makes me feel like more than a student
		Understanding	My instructor understands students have other academic responsibilities It's important to my instructor to understand what my educational goals are

chi-square fitness for the three-factor solution are in the acceptable fit range, NFI, CFI, and TLI are below acceptable fit levels. When we evaluated model fit indices for other factor solutions for the survey, we found that four- and five-factor solutions more closely approached recommended levels (Supplementary Table 3). Taken together, psychometric properties of the survey suggest

TABLE 6 Factor pattern matrix and cross-loadings for individual items in the survey.

Survey item	Factor 1 (α = 0.957)	Factor 2 (α = 0.950)	Factor 3 (α = 0.934)
My instructor understands students have other academic responsibilities	**0.976**	−0.240	0.026
My instructor helps students be academically successful	**0.871**	−0.012	−0.001
My instructor listens to student feedback	**0.787**	$-4.13e^{-5}$	0.019
My instructor communicates course concepts well	**0.761**	0.111	0.017
My instructor can connect with students	**0.654**	0.063	0.168
My instructor expresses interest in students' lives outside of school	**0.651**	−0.201	0.269
My instructor makes class activities interesting	**0.650**	0.036	0.015
My instructor cares about students' educational success	**0.634**	0.271	−0.003
My instructor consistently communicates with students outside of class	**0.626**	−0.129	0.223
My instructor shares personal stories with us	**0.607**	−0.111	0.125
My instructor clearly communicates class expectations	**0.553**	0.270	0.003
My instructor is flexible	**0.550**	0.174	0.024
My instructor makes themselves available	**0.505**	0.225	0.097
My instructor treats students fairly	**0.478**	0.371	−0.033
My instructor cares about students' wellbeing	**0.449**	0.340	0.017
My instructor is easy to relate to	**0.427**	0.372	−0.044
My instructor has a sense of humor	**0.426**	0.308	−0.007
My instructor is patient	**0.419**	0.417	0.029
My instructor is kind	−0.231	**1.065**	0.077
My instructor is a positive person	−0.234	**1.064**	0.048
My instructor is friendly	−0.222	**1.055**	0.102
My instructor is passionate about their subject area	0.038	**0.721**	−0.042
My instructor is prepared for class	0.167	**0.703**	−0.094
My instructor is knowledgeable about their subject area	0.167	**0.647**	−0.161
My instructor is empathetic to students' personal circumstances	0.336	**0.609**	−0.034
My instructor treats students with respect	0.344	**0.517**	0.021
My instructor is accepting of students' differences	0.360	**0.498**	−0.012
My instructor helps me achieve my professional goals	0.156	−0.213	**0.802**
My instructor accepts me for who I am	−0.303	0.336	**0.792**
My instructor makes me feel like more than a student	0.022	−0.037	**0.789**
My instructor "gets" me	−0.028	−0.041	**0.787**
My instructor listens very carefully to me	−0.035	0.097	**0.773**
My instructor helps me overcome personal challenges	0.094	−0.160	**0.703**
It's important to my instructor to understand what my educational goals are	0.045	0.003	**0.695**
I can talk openly with my instructor	0.010	0.191	**0.662**
My instructor does not dismiss my concerns	0.151	0.091	**0.622**
My instructor truly cares about my educational welfare	0.153	0.178	**0.516**
My instructor cares about my education	0.308	0.158	**0.410**

Bolded values specify the survey items considered to be members of a specified factors. Reliability coefficients (Cronbach's α) for each factor are provided in column headings.

that while the instrument has discriminant validity and high internal consistency, our hypothesized three-factor solution may not adequately capture the underlying structure.

Moreover, as can be seen in Table 6 and presented schematically in Figure 5, items derived from codes that were qualitatively categorized into cognitive, relational, and affective dimensions did not factor into similar units. Factor 1 included 18 items primarily from the cognitive and relational dimensions, and 1 from the affective domain. Factor 2 included 10 items spanning all three trust dimensions, while Factor 3 included 11 items from the cognitive and relational dimensions. Across all factors, several items exhibited moderate or strong cross-loadings above the 0.32 threshold (Table 6; Tabachnick and Fidell, 2001). Given

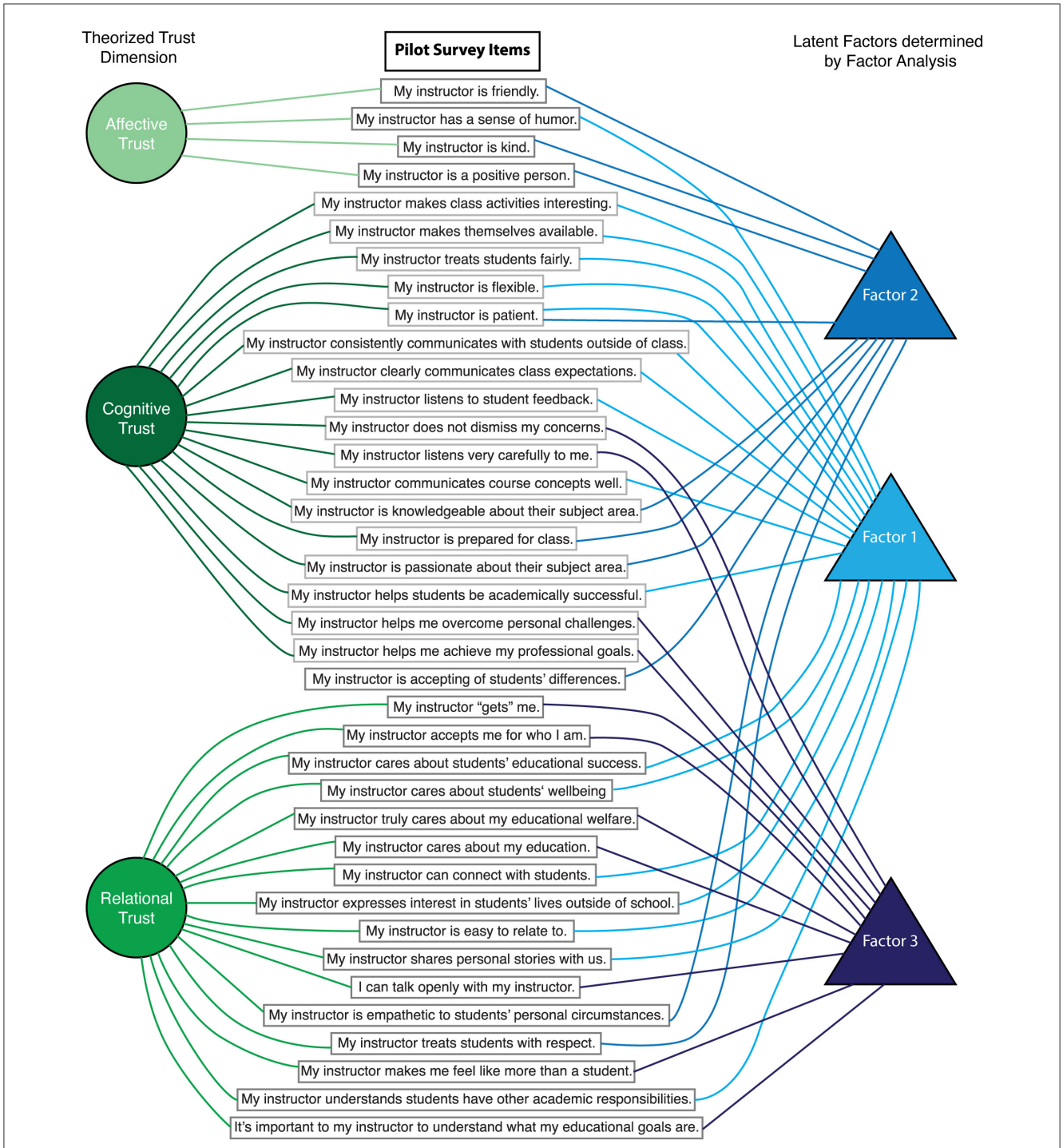

FIGURE 5
Schematic representing survey items (boxes) and their corresponding trust domain from the qualitative interview codebook (circles) and extracted factors from a forced three-factor solution (triangles).

the high degree of cross-loading and distribution of items across the three factors, our analysis suggests that the hypothesized three-dimensional structure of trust may not be representative of the complex interactions between domains that inform student perceptions of trust. Further, items from relational and cognitive domains tended to factor together consistently. This affirms findings from our co-occurrence network analysis, suggesting that traits from these two dimensions are highly interrelated.

4 Discussion

With this study we sought to broaden our understanding of STEM students' perceptions of trust in their instructor by performing a qualitative analysis of structured interviews where students were asked to share characteristics of a trusted college instructor. Further, we sought to test whether the dimensionality of the latent trust construct proposed in previous research could

be recapitulated in the higher education STEM context. Our findings build upon previous work that defined student trust in their instructor using a close-personal relationship framework that highlighted the instructor's care, understanding, and acceptance (Cavanagh et al., 2018; Clark and Lemay, 2010; Wang et al., 2021) and previous work in related fields defining trust between relevant organizational stakeholders using different domains, such as cognitive or affective trust (Ghosh et al., 2001; Lewicki and Bunker, 1996; Lewis and Weigert, 1985; Mayer et al., 1995; McAllister, 1995; Tschannen-Moran and Hoy, 2000). Our qualitative analysis suggested trust dimensions similar to existing frameworks, but student responses revealed substantial overlap between traits theoretically categorized as distinct, particularly between relational and cognitive domains. This interdependence was reinforced by a factor analysis, which failed to empirically validate the proposed dimensional structure derived from student-identified traits.

4.1 Proposed three-domain model of instructor trust

We found that the characteristics students used to describe trusted instructors fell into three broad domains: "relational trust" included characteristics related to how an instructor intentionally cultivated a personal relationship with their students, "cognitive trust" encompassed characteristics related to students' evaluation of their instructors' professional competence, and "affective trust" contained characteristics that led to a positive first impression of the instructor (Figure 3). The relational trust domain was most comparable to subconstructs previously used to define student trust through the close-personal relationship framework. In previous work, the subconstructs of "care," "acceptance," and "understanding" were empirically validated to underlie trust and found to be strongly positively associated with other positive student learning outcomes (Cavanagh et al., 2018; Wang et al., 2021). Another study similarly found that students participating in small classrooms using EBTs such as co-creating and un-grading, reported that relational trust with their peers and instructors, centered on reciprocated vulnerability, was critical for their engagement (Meinking and Hall, 2024). The importance of reciprocated vulnerability for building trust has been echoed in K-12 education settings as well (Holzer and Daumiller, 2025). Our findings confirm the validity of using a relational framework in the college STEM context given that more than 96% of interviewed students referenced instructor characteristics related to relationship-building (Table 4). Indeed, all three subconstructs of the close-personal relationship framework (care, understanding, and acceptance) were among both the most cited traits and the most highly interconnected traits in a co-occurrence network analysis (Figure 4).

The cognitive trust domain of our codebook parallels the use of competence to operationalize trust in instructors in the K-12 context and in broader literature, with many of the traits identified by students in our study previously associated with cognitive trust in other contexts (Butler and Cantrell, 1984; Cook and Wall, 1980; Friedland, 1990; Ghosh et al., 2001; Lindskold and Bennett, 1973; McAllister, 1995; Moorman et al., 1993; Rousseau et al., 1998; Tschannen-Moran and Hoy, 2000; others, see Supplementary Table 1). Characteristics such as "organized," "knowledgeable," and "professional communication" were salient among college STEM students, with more than 94% of students mentioning instructor traits that demonstrated their ability to perform their professional duties (Table 4). Additionally, we found that an important aspect of cognitive trust for students was that their instructor be "academically engaging." While this trait is not widely cited in the broader literature, it bears similarity to descriptions that emerged in Di Battista et al.'s (2020) qualitative study investigating Italian student perceptions of instructor trustworthiness. In their study, students referenced the instructor's ability to manage the classroom, engage student participation, and demonstrate passion for the subject as important aspects of trustworthiness. Here, we similarly found that "academically engaging" instructors were skilled in cultivating an active classroom environment where students were compelled to pay close attention and engage with course material. From the broader literature, this definition is most closely paralleled by Gabarro's (1978) description of "interpersonal competence" in the context of organizational management and trust, which references managers' ability to build effective social relationships and competently engage in social interactions.

The affective domain is perhaps most closely related to the subconstruct of benevolence previously used to define trust in the K-12 setting and in broader literature; the term is used to describe trustees who act with the best interest of the trustor in mind (Baier, 1986; Butler and Cantrell, 1984; Cummings and Bromiley, 1996; Mayer et al., 1995; Morgan and Hunt, 1994; Renn and Levine, 1991; Schindler and Thomas, 1993; Tschannen-Moran and Hoy, 2000; Zand, 1972; others, see Supplementary Table 1). We found that characteristics in this domain were least often mentioned by participants, with only a third of the students we interviewed referencing "friendly," "funny," "kind," and "positive attitude" (Table 4). These traits may form the basis for students' first impressions, which previous research suggests can be formed in <6 s (Ambady and Rosenthal, 1993; Tom et al., 2010; Begrich et al., 2020). A favorable impression of approachability can lead to increased interactions with the instructor both formally within the classroom or informally out-of-class (Cox et al., 2010; Denzine and Pulos, 2000; Lamport, 1993; Schussler et al., 2021; Valenzuela, 2025; Wilson et al., 1974). These interactions have been shown to be critical for students' social integration and subsequent trust in institutions of higher education (Milem and Berger, 1997; Nora et al., 1996; Pascarella and Terenzini, 1979; Tinto, 2015; Pike et al., 1997; Wilcox et al., 2005; Kim et al., 2023; Reindl et al., 2022; Paquin et al., 2025). The fact that these traits were not among the most frequently cited by interviewed students may suggest that, over time, the importance of traits informing their first impression was superseded by the strength of the personal relationship that developed afterward.

Our codebook shares a great deal of overlap with frameworks in the existing literature on trust across many contexts. However, no one existing framework of trust sufficiently captures the complexity of college STEM students' perceptions of trust in their instructor that was uncovered through our qualitative interviews. We acknowledge that many of the characteristics students associated with trust, such as "good listener," "flexibility,"

or "support," may also be interpreted as dimensions of related constructs such as helpfulness or general teaching effectiveness. This overlap reflects a broader challenge in trust research: trust often co-occurs with other relational or affective constructs, making clean conceptual boundaries difficult to maintain (McEvily and Tortoriello, 2011). Rather than asserting that these traits are unique to trust, our approach sought to identify which traits *students themselves* associated with trustworthiness. In doing so, we recognize that students' definitions of trust are likely embedded in broader relational judgments and shaped by contextual cues. This underscores the importance of bottom-up approaches for operationalizing trust in context-specific ways. Based on our literature review, existing work on trust in higher education is relatively limited in its inclusion of direct student responses (Di Battista et al., 2020). Our codebook centers students' perspective on what makes an instructor trustworthy, including specific examples of actions instructors took to gain their trust. Future work may use the codebook as a tool to generate actionable strategies for building trust in college STEM classrooms.

4.2 Validity of three-domain model

As a latent variable, trust has long been made observable through operationalization using sub-constructs or domains.

The construct validity of trust dimensionality itself, though, has been challenged. When existing conceptualizations and measures of trust were used across disciplines, Whipple et al. (2013) found that content validity and replicability were significantly below adequate standards. A lack of replicability for existing trust measures was similarly critiqued by McEvily and Tortoriello (2011). In their review of 171 publications that included 129 distinct measures of trust, only 24 had been successfully replicated and of those, only 13 were replicated by an independent research group. Finally, in a series of confirmatory factor analyses exploring the construct validity of models of trust across several institutional contexts, PytlikZillig and Kimbrough (2016) found that there was highly variable discriminant validity depending on the test sample and context. In the education context specifically, Niedlich et al. (2021) systematically identify the inconsistency with which trust has been operationalized in existing research and note that theorized trust dimensions often overlap or are conflated. The conclusions of these reviews are also supported by recent empirical study (Di Battista et al., 2020, 2021).

Our work recapitulates these findings. When we qualitatively examined student responses, we found that traits from different domains frequently co-occurred and that students described traits from different dimensions as reinforcing rather than distinct (Figure 4). Using an instrument derived from our qualitative interview codebook, we found that items from different theorized dimensions factored into the same latent sub-construct and the model fit of a three-factor solution was inadequate (Figure 5). We found that a four- or five-factor solution may exhibit better model fit (Supplementary Table 2), aligning with previous findings that higher-order factors may provide a better fit than attempting to collapse sub-constructs into fewer factors (PytlikZillig and Kimbrough, 2016). Although our quantitative evidence suggests that there are indeed distinct factors underlying trust, the actual dimensions do not necessarily align with those that we and others have previously proposed. For example, the five-factor solution distinguishes between an instructor's treatment of the class as a whole (e.g. "My instructor is accepting of students' differences" and "My instructor cares about students' wellbeing) vs. developing a personal relationship with individual students (e.g. "My instructor listens very carefully to me" and "My instructor accepts me for who I am"). Moreover, two of the factors also exemplified a distinction between competent instructional communication (e.g. "My instructor communicates course concepts clearly" and "My instructor makes class activities interesting") and interpersonal communication (e.g. "My instructor expresses interests in students' lives" and "My instructor consistently communicates with students outside of class"). These findings reinforce previous calls for careful consideration of the influence of context when attempting to define and measure trust (Di Battista et al., 2020, 2021; McEvily and Tortoriello, 2011; Niedlich et al., 2021; PytlikZillig and Kimbrough, 2016; Whipple et al., 2013). Our codebook and resulting instrument can therefore form the basis for a contextualized re-examination of student trust specifically within STEM higher education. Future work, however, is needed to empirically test the instrument with multiple different samples to assess whether a higher-order factor structure consistently emerges.

4.3 Implications and future directions

The strength of the student-instructor relationship has long been shown to have benefits for student social and learning outcomes. Students who interact more frequently with their instructors increased social and cultural capital in academic research environments (Ahmad et al., 2017; Cooper et al., 2018, 2021; Gillespie, 2005; Ream et al., 2014; Thompson et al., 2016; Wilson and Davis, 2020). As student-centered teaching transforms the college STEM education landscape, interactions between students and their instructors are steadily increasing (Esparza et al., 2020; Freeman et al., 2014; Handelsman et al., 2007; Henderson and Dancy, 2009). Given the effectiveness of EBTs and early undergraduate research experiences for increased student performance and retention, there is a need to better understand how students form perceptions of trust in their instructors and consequently develop strong relationships with them (Freeman et al., 2014; Graham et al., 2013; Hanauer et al., 2017; Theobald et al., 2020; Wang and Degol, 2013).

Indeed, previous work has shown that trust in instructor is strongly positively associated with student buy-in to an instructor's use of EBTs, student engagement, intent to persist, and course performance (Wang et al., 2021). In this study, researchers also tested the relationship between student's growth mindset and the same outcomes and found that trust had more than twice as strong an association with outcomes than growth mindset (Wang et al., 2021). This finding is particularly striking because growth mindset is an *internal* view of intelligence, while trust is a perception of someone *external* to the student. Given that changing students' internal beliefs about their intelligence can be difficult (Dweck, 2008), it is an encouraging possibility that instructors might be able to improve learning outcomes by investing time toward gaining trust.

We followed a "process model" approach to develop the interview codebook in order to facilitate the construction of an instrument that could be used for empirical testing (Chatterji, 2003). By drafting items from a codebook supported by student interview data (Table 5), this approach essentially allows students themselves to write the instrument items.

After an empirical pilot study of the instrument constructed from our codebook, we found that the instrument demonstrated both discriminant validity and high internal consistency, but its internal structure was not adequately modeled by a hypothesized three-factor solution (Table 6; Supplementary Table 2). Our study was limited to a relatively small sample: a single high-enrollment college STEM classroom. Therefore, future work is needed to empirically validate the drafted instrument items with a larger and more diverse sample to determine the underlying factor structure. Such an instrument can be used not only to inform future lines of research, but also as a tool for practitioner use in the classroom and in instructor training and evaluation.

While our study specifically focused on undergraduate STEM students given previous research demonstrating the importance of trust for student buy-in to EBTs, it is possible that our findings may be relevant for students and instructors in other disciplines. Large-enrollment classrooms are common among introductory courses for many disciplines, such as the arts, humanities, and social sciences, and the characteristics that help STEM instructors build trust with their students in large courses may be generalizable to other large courses. Future empirical testing of the drafted instrument may be done in a variety of contexts, including other disciplines, to test this possibility.

5 Limitations

There are several important limitations to consider when interpreting the results of our study. First, due to the qualitative nature of the data, all analyses are inherently subject to researcher biases. Our primary research team was composed of people who belong to majority groups in STEM and higher education, situated at an affluent private research university. Data were analyzed individually by members of the research team and our prior knowledge and experiences naturally color our interpretation of student responses. We chose a qualitative approach to capture more detailed insights than a survey might.

Additionally, every student we interviewed may interpret the word "trust" differently based on their prior experiences and assumptions. This limitation may be addressed in the future by providing participants with a definition of "trust." We opted not to do so in the current study because our work was exploratory in nature, and we wanted to capture students' most unbiased interpretation of the concept of trust. Due to the in-depth nature of the interview process, we were limited to the number of students and contexts we could sample from. Specifically, student interviews were conducted during the COVID-19 pandemic which severely impacted college learning experiences. Thus, without an investigation of a larger and more diverse sample, we do not intend to generalize the results for students in other contexts. Students were also specifically asked to recall a single past instructor. The characteristics that emerged therefore may not fully capture the developmental process of building trust over time or may be influenced by the amount of time that had elapsed and the changing perceptions of students at different points in their college careers. Future work may take a longitudinal approach to better understand how trusting relationships are built and sustained.

6 Conclusion

In this study, we engaged in a "bottom-up" qualitative approach that allowed students to define trustworthy instructors in their own words. We found that students used many traits spanning previously theorized sub-constructs of trust—including cognitive, affective, and relational domains—in interrelated ways and latent factor analysis challenged the construct validity of a simple three-domain model. This work informs future investigation of the impact of student trust in their instructors on desired long-term student outcomes, such as persistence in STEM education and STEM-related careers, by providing a contextualized and broadened framework of trust and an accompanying assessment tool for the undergraduate STEM student population.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Yale University Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The author(s) declare that no Gen AI was used in the creation of this manuscript.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2025.1617067/full#supplementary-material

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