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# Developing Resilient K-12 STEM Teachers

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**Abstract**

**The Problem.**

The US is currently experiencing a shortage of K-12 science, technology, engineering, and mathematics (STEM) teachers, especially in high-poverty communities. The shortage can be explained by both low teacher recruitment and high teacher turnover; however, the reasons why teachers leave the profession are complex.

**The Solution.**

We argue that teacher professional development programs are often focused on how teachers can meet the needs of their students but ignore how teachers can build their own professional resilience. We draw from research in both teacher self-efficacy and ecological adaptive capacity to propose a revised Teacher-Centered Systemic Reform Model that identifies adaptive capacity as an outcome goal for individuals and school systems. School environments are dynamic (e.g., new policies, student needs, and changing administrators), and as a result, teachers need skills to adapt, enabling them to be resilient while still meeting students' needs.

**The Stakeholders.**

Professional development, teacher educators, human resource development (HRD) practitioners, K-12 STEM teachers.

**Keywords**

STEM teachers, teacher turnover, professional resilience, adaptive capacity

The foundation of American success is the guarantee of access to K-12 educational opportunities. Schools across the country are experiencing what's been termed a teacher shortage crisis, heavily influenced by both a reduction in teachers entering the

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workforce as well as startlingly high rates of teacher attrition. According to the National Center for Education Statistics, within the first 5 years of teaching in K-12 classrooms, there is a 17% attrition rate of teachers (Kaigher, 2011), although other models predict that the attrition rate is closer to 30% (Darling-Hammond, 2010; Ingersoll, 2001). High quality teachers are in short-supply and are particularly difficult to retain in urban regions (Jacob, 2007) and rural communities (Ingersoll, 2003). Furthermore, for high-poverty schools, the teacher attrition problem is exacerbated (Hanushek, Kain, & Rivkin, 1999; Ingersoll, 2001; Ingersoll & May, 2011) and these schools have a notably hard time recruiting and retaining staff (Borman & Dowling, 2008).

For Science, Technology, Engineering, and Mathematics (STEM) teachers, shortages are even more pronounced. Vacancies in STEM classrooms are more prevalent than any other discipline (Cowan, Goldhaber, Hayes, & Theobald, 2016). In a meta-analysis, Borman and Dowling (2008) found that teacher attrition is more prevalent for those who teach mathematics and science, and because these subjects are required for graduation in all states, this is a national issue. Therefore, recruiting and retaining STEM teachers prepared to teach across educational contexts (i.e., geographic, economic, cultural) is a significant and timely concern. Challenges with recruiting across educational contexts are exacerbated by the fact that teachers typically intend to teach in communities that are most like those in which they were raised (Boyd, Lankford, Loeb, & Wyckoff, 2005).

Some of the greatest teacher shortages are in high-poverty schools that often are in urban and rural communities (Ingersoll & May, 2011), and Abel and Sewell's (1999) research found that poor working conditions and classroom management can contribute to high levels of teacher stress and burnout. Some solutions to the issues of staffing schools across communities with STEM teachers focus on the recruitment and preparation of teachers for diverse school settings during their teacher education programs. Some headway has been made, for example, with recruiting. Other proposed solutions include professional development and structures of support for in-service teachers to help them increase their capacities to respond to workplace demands and disruptions (e.g., Gist, 2018).

There are implications for districts, schools, classrooms, and students when there is a teacher shortage. Teacher turnover costs school districts over US$2.2 billion per year (Haynes, 2014). In addition, there are challenges of developing and maintaining long-term professional relationships between teachers and the communities they serve (Darling-Hammond, 2010). These challenges disproportionately affect high-poverty schools, which struggle with lower per-pupil budgets on top of having an average of 50% more teacher turnover each school year than affluent schools (Darling-Hammond, 2010). Varied student needs (e.g., English language acquisition, special education, and access to sufficient nutrition) place additional demands on teachers, who may not have had sufficient formal training to support these student needs (Lee, Maerten-Rivera, Penfield, LeRoy, & Secada, 2008; McLeskey & Billingsley, 2008).

## Reasons for Teacher Attrition

While a decrease in enrollment of students into teacher education programs contributes to the teacher shortage (Hutchison, 2012), attrition is of utmost concern. Teachers

leave schools or leave teaching altogether because of challenges they face in the classrooms and the systems within which they work (Borman & Dowling, 2008; Darling-Hammond, 2010; Gist, 2018). Proportionally, very little of the attrition is due to retirement (Henke, Chen, & Geis, 2000). Instead, Darling-Hammond (2010) identified three major reasons for high teacher turnover: poor working conditions, lack of preparation, and lack of mentoring and support. Teachers in their early years of teaching have not accumulated enough knowledge and expertise of the profession and, therefore, have less to lose compared to those who have stayed in the profession longer (Guarino, Santibanez, & Daley, 2006; Kirby & Grissmer, 1991; Tait, 2008). Experienced teachers, who have spent many years within a career with a potentially high-impact but with a myriad of barriers to success, may burn out of the profession, much like employees in other, similar sectors, such as health care (e.g., Kilroy, Flood, Bosak, & Chênevert, 2017). The challenges facing teachers in general can be extrapolated to STEM teachers specifically. Although statistics are not specified for STEM content areas, the Learning Policy Institute recently reported shortages of science and mathematics in most states (Sutcher, Darling-Hammond, & Carver-Thomas, 2016).

Many demands (e.g., including meeting the needs of diverse students, adhering to new academic standards, demonstrating student growth on standardized assessments) are placed on teachers (Darling-Hammond & Bransford, 2007; Pitot, 2014; Woodbury & Gess-Newsome, 2002), especially for novice teachers, who are expected to perform the same roles as experienced teachers (Borman & Dowling, 2008). Of the teachers who remain in the profession, there is a marked "shuffling" of job location from high-poverty schools to wealthier ones (Achinstein, Ogawa, Sexton, & Freitas, 2010; Showalter, Klein, Johnson, & Hartman, 2015). In fact, teachers in high-poverty schools leave at a rate double that of those in low-poverty schools (Darling-Hammond, 1997).

Little attention is paid to the professional struggles of individual teachers and how these experiences might influence professional resilience, which we define as having the capacity to respond to occupational turbulence in ways that allow them to remain in the profession. Some teacher advocates argue that teachers need financial incentives to remain in the profession. A higher salary, although, may not be enough of an incentive to retain the numbers of teachers needed to meet U.S. workforce demands (Ingersoll, 2002). Other teacher concerns include job satisfaction regarding administrative support, student motivation, and student discipline (Darling-Hammond, 2010; Ingersoll, Sirinides, & Dougherty, 2018). At an organizational level, schools and districts could move toward structures and policies that promote a number of high-involvement work practices (HIWP), which have been shown to improve employee well-being (Boxall & Macky, 2009; Kilroy et al., 2017). However, these changes take time to enact and may not always be possible. Therefore, teachers need resources and support through ongoing professional development from teacher educators and human resource development (HRD) practitioners who are responsive to where teachers' discontentment lies (Southerland, Sowell, Blanchard, & Granger, 2011; Wilson, 2013). In doing so, we ensure that teachers have skills needed to be resilient members of their school organizations and professional communities as they continue to support and influence students' career decisions.

## Teachers Influence Students' STEM Aspirations

Teacher quality is the most important school-related factor in student achievement (RAND Corporation, 2012), and teachers can play an influential role in developing student interests and career aspirations (Sjaastad, 2012). This influence is especially apparent in STEM fields (Maltese & Tai, 2011). Quality STEM teachers have the potential to advance efforts to increase diversity of those entering STEM studies and help address the national shortfall of STEM workers. Students' decisions to pursue STEM careers are influenced by early school experiences (Fouad & Smith, 1996; Fouad, Smith, & Zao, 2002). Although there are other aspects of the STEM landscape that influence students' decisions to pursue STEM professions, the role that K-12 teachers play is important. In the absence of highly qualified STEM teachers who remain in the profession long term, STEM career pathways lose an important link in the development of K-12 students into STEM professionals.

The STEM workforce has a significant impact on a nation's competitiveness, economic growth, and overall standard of living (Langdon, McKittrick, Beede, Khan, & Doms, 2011). The calls for meeting demands for STEM workers require a 34% increase of STEM graduates per year (Xue & Larson, 2015). However, there are not enough students pursuing degrees or training in STEM to fill the jobs created over the next decade, and projections estimate a gap of approximately 1 million STEM professionals (Olson & Riordan, 2012). In response, within the STEM education community, there is a focused effort on broadening participation of those who traditionally pursue STEM studies (Hill, Corbett, & St. Rose, 2010; Ladson-Billings, 2000). Thus, within the culture of teacher attrition amid high professional standards, another expectation is now thrust upon teachers—increasing students' interests in pursuing STEM studies and careers.

## Supporting STEM Teachers

Apart from or in addition to large-scale or systemic change (e.g., HIWP), many programs exist to support teachers. To date, most STEM teacher educators have focused on recruiting, preparing, and retaining STEM teachers. Current reform efforts have centered on changing teacher attitudes and practices around inclusivity and social justice (Ladson-Billings, 2000) to provide equitable access to learning for all students in STEM content. In this paper, we argue that simply focusing on inclusivity and social justice for students may not be sufficient. Resilient individuals continue to work and to restore their confidence, even in the face of adversity in the workplace (Luthans, Youssef, & Avolio, 2007). Therefore, teachers need professional development to support their personal skills to be adaptive in a dynamic educational landscape to build resilience to persist and thrive long-term in the education profession.

We present a theoretical and practical discussion about the application of research-based change models as they relate to the development of holistic teacher preparation programs. We ground our ideas in the well-examined Teacher-Centered Systemic Reform (TCSR) Model, a helpful framework for teacher educators to support teachers

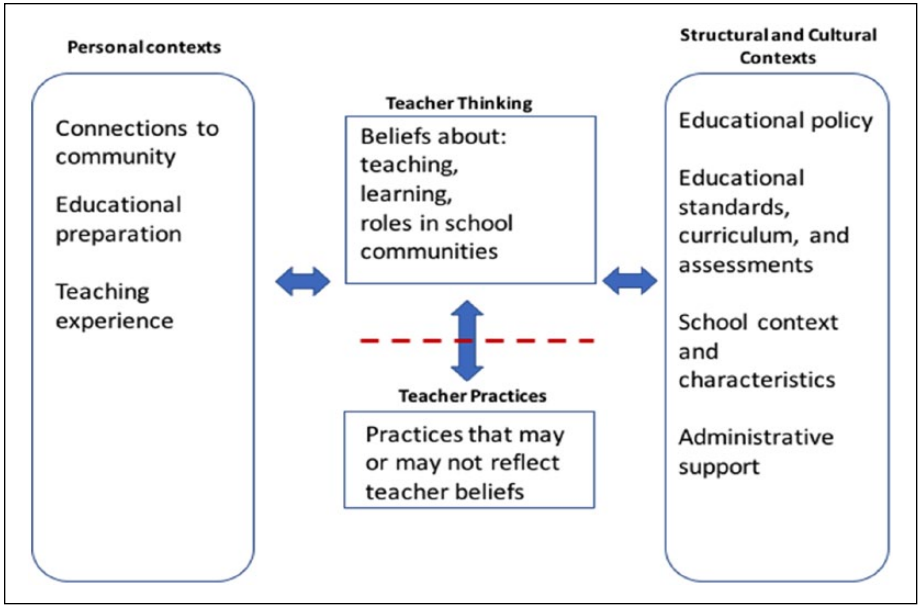


**Figure 1.** Teacher-Centered Systemic Reform is a framework to understand how teachers' beliefs are shaped and may influence individual professional behaviors.
*Note.* Although beliefs can sometimes explain behaviors, other times teachers are unable to enact what they believe due to intrinsic or extrinsic reasons. Framework adapted from Woodbury & Gess-Newsome, 2002.

in reflecting on, modifying, and implementing professional practices (Clapp, 2017; Gibbons, Villafañe, Stains, Murphy, & Raker, 2018; Graves, Hughes, & Balgopal, 2016; Southerland et al., 2011; Woodbury & Gess-Newsome, 2002; Figure 1).

The TCSR model emerged from the self-efficacy literature (Bandura, 1997; Gibson, 2004) and explains that both personal and environmental (structural and cultural) contexts influence beliefs about teaching (Woodbury & Gess-Newsome, 2002). Subsequently, some of these beliefs influence behavior (professional practices), which may be in part due to the dynamic nature of the structural and cultural contexts of schools. Despite the TCSR model's recognition of the importance of school and personal contexts (Alsup, 2006; Borman & Dowling, 2008; Darling-Hammond, 2010), it fails to account for changing professional landscapes. If teachers are unprepared to adapt to unpredictable and dynamic climates, they may leave the profession.

We argue that integrating dynamic professional environments with the TCSR model informs teacher PD leaders on how to meaningfully support novice and experienced teachers alike and increase their capacity to adapt to changing job demands. One example of the changing context is the recent adoption of national academic standards (e.g., Next Generation Science Standards (NGSS Lead States, 2013), Common Core State Standards (National Governors Association Center, Council of Chief State

School Officers, 2010)) that teachers are expected to use to design instructional plans and assessments. Another example is new teacher evaluation policies (e.g., value-added models) to which teachers must respond to be promoted (Pitot, 2014).

As teacher educators and PD leaders, we have a specific interest in preparing teachers to respond to dynamic professional landscapes. We draw on literature from environmental conservation, human resource development, and teacher education to propose a creative modification of the TCSR model to account for the dynamic nature of structural and cultural contexts. We posit that this modified "TCSR to increase adaptive capacity" model, which we are currently testing, will inform the teacher PD community on how best to support STEM teachers to reduce attrition and increase job satisfaction.

## Professional Resilience

As novice teachers enter the workforce and tenured teachers shift schools, they must learn to navigate new landscapes and unfamiliar contexts. Through social exchanges with staff, students, and community members, teachers construct meaning of and learn about the cultural values of this novel environment (Alsup, 2006; Lave & Wenger, 1991). This phenomenon is relevant for all teachers, but because STEM teacher attrition has been identified as a national problem, in particular it allows experts to examine which STEM teachers persist in the profession and under what conditions. One way to examine teacher behaviors within the education system, including how they respond to dynamic school environments, is through a social ecological system (SES) lens. SESs are typically described as the integration of different systems (e.g., social and biophysical) and are composed of numerous actors, who interact across temporal and spatial scales. SESs are complex and adaptive, contain individual parts linked through feedback mechanisms, and each part displays resilience (Berkes, Colding, & Folke, 2008; Berkes, Folke, & Colding, 1998). Emergent properties of such systems cannot easily be anticipated, and because social networks are inherent to SESs, they account for local knowledge.

The concept of resilience is well-grounded and oft-studied in the field of environmental science and is described as having the capacity to buffer change, learn, and develop through adaptive behaviors (Folke et al., 2002; Folke et al., 2010). System dynamics, from an ecological perspective, can be examined using the adaptive cycle and its distinct phases: growth (r), maintenance (K), disturbance ($\Omega$), and reorganization ($\alpha$) (Chapin, Folke, & Kofinas, 2009; Figure 2). This model is helpful to understand how systems respond to changes as well as predict subsequent responses to disturbances ($\Omega$) as indicated by the behaviors of individual parts of the system. Some systems quickly enter reorganization phases and move into a growth phase using adaptive responses. Other systems may push toward transformation over reorganization thereby pushing them in a new direction. Systems that enter growth phases typically maintain their adaptations through a period of conservation, until they experience subsequent disturbances ($\Omega$). In this model, disturbances ($\Omega$) need not be negative events; they are simply changes that require the system to respond.

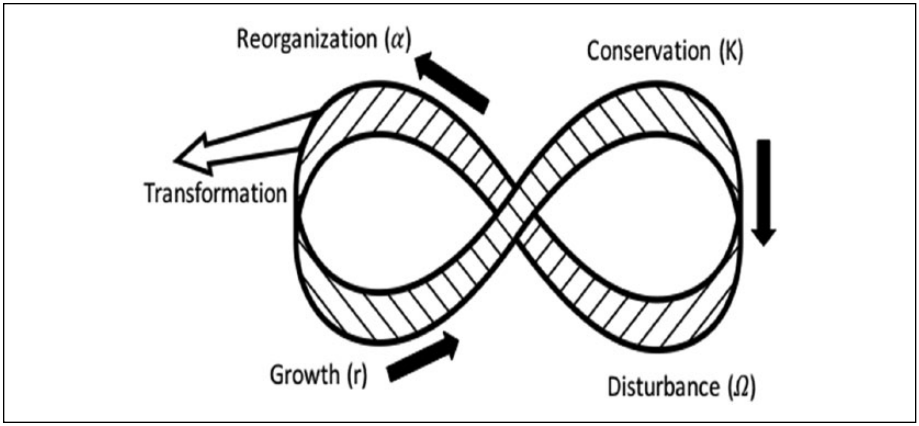


**Figure 2.** Adaptive cycle model (recreated from Holling & Gunderson, 2002).
*Note.* Systems comprising individual parts experience different stages of response to disruption (disturbance, reorganization, growth, and conservation). Systems that remain relatively stable are considered to be resilience, whereas, systems that experience dramatic change may be transformed.

We believe that the SES model is informative to teacher educators and HRD practitioners because it allows us to recognize that, although education systems regularly experience disturbances, individual schools may not all respond in the same way or at the same time because of the actions of individual actors (e.g., faculty, staff, administrators, parents, students) within the system. As Bhamra, Dani, and Burnard (2011) explained, resilience encompasses both organizations and individuals and how they react to turbulence. Teachers' capacities to be responsive to change should be developed to enhance both organizational and individual resilience, as the collective resilience of individuals will support the resilience of the organization itself (Lengnick-Hall, Beck, & Lengnick-Hall, 2011). By identifying the adaptive cycle phases, interventions and supports can be designed for teachers that are meaningful and promote adaptive practices that support and maintain system and professional resilience.

Professional resilience is likely related to personal or psychological resilience (Luthans, Vogelgesang, & Lester, 2006). Professional and human resource development that centers on building the strengths of individuals, increasing their self-efficacy, and attending to their performance capacities can, therefore, result in the psychological dimension of resilience (Gibson, 2004). For example, resilient individuals demonstrate emotional stability, a willingness to adapt, and an openness to change (Luthans et al., 2006). At the system (or organizational) level, resilience is indicated by diversity, efficiency, adaptability, and cohesion (Fiksel, 2003). Both organizations and the individuals that make up the organization must have attributes that allow them to "weather the storm," whether they transform or return to the previous state.

Taking an ecosystem-based approach allows experts to study whether the multiple components within schools and their communities work in tandem (Falk & Dierking, 2018). Resilient school ecosystems are those in which mutually beneficial relationships

develop to support shared goals and can withstand perturbations (such as political or economic changes). In their descriptive case study of an elementary school in a low-resourced community in Portland, Oregon, Falk and Dierking (2018) identified how shifts to promote science education occurred over time. They found that leveraging informal science education partners in the community, while fostering support from school administrators and other leaders, was essential in enhancing the science learning infrastructure of the school. Moreover, they discovered that a community coordinator was an important link for students, connecting in-school and out-of-school learning and helping maintain students' interests in STEM. We take a similar view of school ecosystems as being complex in nature and that allow synergistic relationships to form, yet we believe that understanding the role of the individual actors (i.e., teachers) is necessary if teacher educators and HRD experts are to support schools experiencing major changes. Falk and Dierking (2018) focused on how school ecosystems affected individual students, and likewise, we present an approach that seeks to understand the needs of individual teaching professionals.

## *Case Study of Professional Resilience*

Our model is relevant to school environments and the issue of STEM teacher shortages. To illustrate how the adaptive cycle model can be helpful in describing school systems based on teacher actions, we present a case study of one elementary school that underwent all four phases of the adaptive cycle. Springwood Elementary School (a pseudonym for a public school in northern Colorado) experienced a disturbance ($\Omega$) 10 years ago when student numbers began to decrease, resulting in the redirection of monetary resources to other schools. In this district, parents can select which public school they want their children to attend, and district funds follow student enrollment. For Springwood Elementary to survive within the district, a reorganization ($\alpha$) plan was necessary (Balgopal & Cornwall, 2010). The school improvement team determined that becoming a STEM-centric school was the best adaptive option. At this point, some teachers chose to leave the school because changing their teaching practices to fit a STEM model was inconsistent with their pedagogical beliefs and/or they were overwhelmed with the perceived effort involved (Southerland et al., 2011). Others chose to remain and participated in a period of system growth (r). Throughout the growth period, teachers learned ways to adapt their teaching to support STEM. They drew on resources in the community (e.g., PD leaders, local engineers and scientists, teacher educators, and STEM support educators) as well as their own collective understanding of STEM instruction and assessment.

Over time, teachers increased their collective capacity to integrate STEM into their daily routine, adapting their own beliefs and behaviors about teaching and learning to support system growth and maintenance at Springwood Elementary. After a few years, the principal left, resulting in another system disturbance ($\Omega$). As a plan was enacted to reorganize ($\alpha$) under new leadership, the school embarked once again on the phases of the adaptive cycle, but the teachers maintained a collective resilience mind-set to persist in an ever-changing educational landscape. In time, the STEM education

professional identity of individual teachers was well-established at Springwood, which was illustrated when they moved to have their school name officially changed to Springwood STEM Elementary. The teachers who remained have demonstrated their personal adaptive capacity in the changing, transformed landscape of structural and cultural contexts that affected their school system. We believe that the organizational resilience that Springwood teachers and staff, as a collective, exhibited was because individuals were secure in both their personal and professional identities (Alsup, 2006). This may be because all the faculty/staff experienced the disruption at the same time and were able to strengthen their membership in the community. Beijaard, Verloop, and Vermunt (2000) found when teachers have perceptions of their professional roles that are shared by others at their school, they may feel more secure with their professional identities. Because Springwood STEM Elementary School adopted a new curricular, instructional, and administrative approach, they demonstrated adaptive capacity (Bhamra et al., 2011), yet the teachers, who chose to remain at the school and employed new practices, demonstrated professional resilience although they altered their teaching practices (Gu & Day, 2013).

Adaptive capacity is the key to resilience leading to growth (Berkes et al., 2008). Likewise, systems in place for developing the next generation of K-12 STEM educators demonstrate the same characteristics of complexity, feedback, and resilience. As preservice teachers transform into novice and, eventually, master teachers, they experience multiple iterations of adaptation and growth. At an organizational level, Springwood STEM Elementary School, moved through multiple iterations of the adaptive cycle as it transformed its current STEM culture. All systems exist and function on multiple scales of space, time, and social organization as do the individuals that comprise the system. Hence, we believe that what is missing from the typical STEM teacher preparation program is a critical examination of helping novice teachers build adaptive capacity skills to cope with dynamic school landscapes and changing education systems.

## *Building Professional Skills for Resilience in STEM Teachers*

Although many teacher education programs are attuned to current reform efforts and prepare novice teachers to meet such demands including those in STEM content areas, they do not necessarily help their graduates consider how they can respond to unexpected changes in their professional environment. All teachers need support. Our proposal to use an SES resilience lens can help teacher educators and HRD experts to contextualize the needs of all practicing teachers, albeit our interests focus specifically on STEM teachers. We seek to positively influence STEM teachers' abilities to build resilience and to remain in the profession. Our desired ultimate end is for these teachers to encourage their students to pursue higher education degrees in STEM fields, and perhaps become classroom teachers themselves. Our revised TCSR model demonstrates the essential role that beliefs about personal adaptive capacity and a mind-set about professional resilience supports the adaptive capacity of the school system leading to increased system (organizational) resilience as a salient outcome toward which PD leaders can design support (Figure 3) for individuals and for the system.

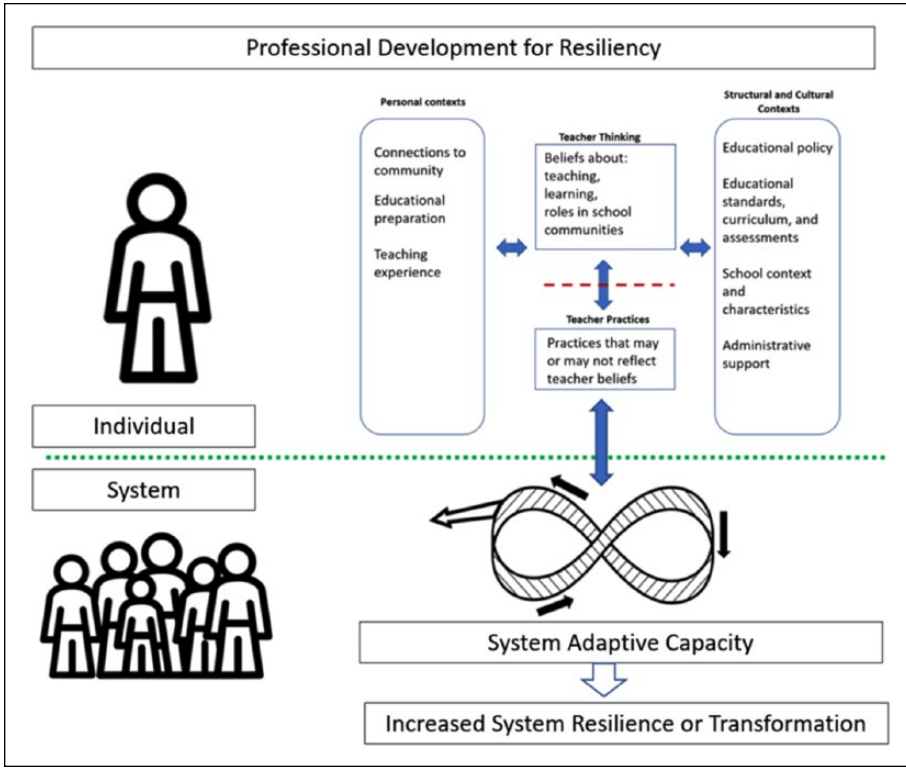


**Figure 3.** Revised Teacher-centered systemic reform-for resilience (TCSR-R) model.
*Note.* The revised model explains that both personal and structural/cultural contexts influence teachers' beliefs about adaptability. When individuals' beliefs are able to adapt to a changing educational landscape, teachers' behaviors are also able to adapt to influence resilience or transformation of the school system.

Adaptive STEM teachers are flexible and can design multiple pathways to meet teaching goals in dynamic professional landscapes. Adaptation is fundamental to long term persistence in any profession and should be viewed as the way the professional is engineered to be in harmony with the work environment (Gu & Day, 2007; Little, 1995). As in the original TCSR model (Figure 1), for which we noted that not all beliefs are enacted into practices, we recognize that simply being metacognitive about adaptive capacity and resilience is not sufficient for demonstrating professional resilience. Teachers not only need the skills to be adaptive, but they must also weigh the pros and cons of expending energy to become adaptive (Alsup, 2006). In other words, the ability to adapt to stressors in the education environment is not a simple matter of negative feedbacks. It requires constant adjustment to system parts and even some changes in classroom structure in response to perturbations (Moran & Brondizio, 2013). Adaptation influences resilience and focuses on reducing vulnerabilities to specific threats, so teachers can remain in their profession and be good at their jobs.

Drawing on resilience frameworks used to examine SESs, we suggest that schools can be viewed as local systems for study with school districts and state education systems scaling up to national systems. Within the system there are numerous interconnected stakeholders competing for limited resources. Resilience supports persistence through change for both systems and individuals within it. It is measured in distance to potential thresholds for transformation (Nelson, 2011). In a continually changing education environment, individual teachers are constantly adapting and therefore, dynamically moving toward or away from transformational thresholds. Teachers who are aware of their personal thresholds can direct their adaptations to either maintain resilience in the current system or move toward positive (or sometimes negative) transformations. Without this awareness, thresholds may be crossed resulting in unintended transformation and the potential to exit the teaching profession. Teacher quality and teaching quality are distinct characteristics "since it is not only who teachers are that counts, but also what they do in the classroom" (Gu & Day, 2013, p. xvii).

These outcomes have a measurable effect on developing a STEM workforce. In many states, licensed public school teachers of mathematics and science must have formal education in these disciplines, pass discipline-specific knowledge exams, and receive a license from the state department of education acknowledging their preparation. Subsequently, to keep their license active, teachers seek continuing education credits in either pedagogy or content. These requirements ensure that practicing teachers are engaged in continuous learning, so they can be prepared to best address the needs of their students and the changing landscape of education. By designing and offering meaningful PD to practicing teachers, teacher educators can help increase the resilience of STEM teachers.

A "resilience mind-set," or psychological capacity for resilience, requires being aware that aspects of both personal as well as educational, structural, and cultural contexts are dynamic (Luthans et al., 2006). This individual mind-set precedes being adaptive to changing educational landscapes; however, some teachers may be more, or less aware of how their beliefs explain their practices. From our collective experiences, it is apparent that teachers seek PD opportunities for different reasons: some are fulfilling continuing education requirements, while others actively pursue options that challenge their current practices. According to Holling and Gunderson (2002), individuals with less adaptive capacity have a higher vulnerability to leaving the system once the system experiences a disturbance ($\Omega$). In the professional context of teachers, this disturbance ($\Omega$) can include new educational policy, standards, contexts, or administrators. Therefore, we posit that teachers who exhibit professional resilience must first develop their adaptive capacities. Richardson (2002) proposed that this first requires that the following are identified: resilient qualities of individuals and systems, processes of coping with stressors, and motivational forces to respond to stressors. We argue, therefore, understanding how teachers' institutional and personal contexts influence their beliefs can inform teacher educators, who hope to support the development of both personal and professional resilience.

## Designing Meaningful Professional Development for STEM Teachers

STEM teachers need support and education in (a) meeting the diverse needs of their students, whose backgrounds vary linguistically, economically, socially, and culturally; (b) increasing content knowledge to meet the continually updated academic standards; (c) implementing culturally sustaining pedagogy and social justice to value inclusion (Paris, 2012; Thomas, Tran, & Dawson, 2010) and understand their role in encouraging and empowering youth to pursue STEM studies; and (d) becoming a part of local communities, so they can feel connected to the place where they live and work. In other words, all teachers need the skills and knowledge to accomplish their immediate goals as a teacher (needs a-c), but also the skills of becoming grounded in their community (need d). We believe this strongly applies to STEM teachers because of the recruitment and attrition problems specific to these content areas.

We are in the process of testing the revised TCSR model (Figure 3) with preservice STEM teachers at Colorado State University who are committed to teaching in high-needs secondary schools. Through a series of PD workshops, students explore STEM content presented by university professors and engage in discussion related to social justice and high leverage teaching practices presented through vignettes. Experienced STEM teachers serving as mentors participate alongside preservice STEM teachers to provide guidance in navigating potential tensions between personal and institutional contexts. The aim of the workshops is to develop the individual adaptive capacity of preservice teachers to recognize their needs once they are employed, so they are prepared to build professional resilience within a school system. A secondary goal of the workshops is to support preservice teachers as they begin to join communities of practice, both personal and professional, in their new school context. The "communities of practice" literature explains that professionals, including STEM teachers, often belong to multiple communities of practice (professional, personal, and social), which can provide them with support and guidance as they navigate challenges at work (Balgopal, 2014; Lave & Wenger, 1991). Furthermore, feeling supported by colleagues is strengthened by membership in either formal or informal communities of practice (Alsup, 2006; Lave & Wenger, 1991).

Because many teacher education programs do not focus on potentially disruptive professional environments, teachers may feel unprepared for the realities of the profession. However, belonging to a community in which teachers can identify the skills they need to respond to policy, administrative, or cultural shifts in their schools is essential. Teacher PD leaders should be aware of this. Teachers need adaptive strategies and skills to become members of different communities of practice. By encouraging novice teachers to connect with their peers through professional communities and with their students, families, and local environment through social communities, we posit that they will feel more grounded in their schools and jobs. STEM teachers may feel like outsiders in communities in which they did not grow up or with which they identify. Skaalvik and Skaalvik (2011) found, in their study of over 2,500 teachers in Norway, that teachers who left their jobs were either emotionally exhausted or felt a

lack of belonging. Because communities of practice can offer support to teachers, including those who feel exhausted or unsupported, PD guidance on how to identify and become parts of communities (both professional and personal) can be valuable for STEM teachers. To meet this outcome, we argue that the adaptive capacity framework from environmental conservation can inform the types of PD that we believe must be developed.

Not only are resilient STEM teachers more likely stay in the profession and contribute to the resilience of their organizations, they are more likely to grow as quality teachers who can engage and encourage students from diverse backgrounds to consider STEM studies and professions through positive interactions with students. Resilient teachers must be able to demonstrate a deep understanding of culturally sustaining pedagogies (Paris, 2012) that will enable them to respond to the languages, literacies, and cultural practices of students, parents, and colleagues. These knowledge and skills must be fostered in all novice STEM teachers. Resilient teachers not only know how to teach students to be science knowledge consumers and science knowledge producers, they teach students about the community of scientists. By doing so, they help their students value how science communities function (NGSS Lead States, 2013), which is necessary for students to build their own adaptive strategies and resilience if they choose to pursue science studies. This research can inform teacher PD and HRD experts on skills teachers need to help them stay in the profession.

Resilient STEM teachers adapt to the education environment by connecting with local community members as well (Goodpaster, Adedokun, & Weaver, 2012). When teachers become part of communities, they increase their local content knowledge as well as their physical and financial resources to support their teaching. These teachers demonstrate abilities to both create community and become a part of community. By modeling for their students the importance of working with others to identify problems and design solutions, teachers can encourage their students to develop critical thinking skills, while feeling grounded in relevant, local issues. Moreover, when teachers reach out to community members, the benefits are felt by many: local citizens are more aware of the schools in their communities, students have improved educational experiences and discover potential local career options, and teachers feel connected to/valued by those outside of the school walls. When teachers are part of a community that includes non-teachers, they can share their successes, wonderings, and challenges with a broader circle allowing their needs to be known and legitimized.

Finally, resilient teachers are aware of their own limitations and seek PD, enabling continued personal growth. To encourage more novice teachers to be metacognitive, teacher educators must help them understand that seeking help is not a sign of weakness; rather, it is modeling for their own K-12 students the importance of lifelong learning. To develop these competencies, novice teachers need mentors, whether these are formal mentors assigned to them or informal mentors who teachers find on their own. Mentors, who are often more experienced educators, can help new teachers recognize that their sustained role in the school community can benefit students by encouraging them to persist in STEM studies, and potentially enter STEM professions (Hutchison, 2012). Because teachers' identities are reinforced or redefined at different

levels, mentors who recognize this complexity in their own identity formation are likely in a better position to support novice teachers.

## Conclusion

Teacher shortages have both short- and long-term implications. Although there is concern around recruitment of STEM teachers, our focus is on increasing STEM teacher retention—especially those in their first five years of teaching. Unfortunately, once novice teachers are overwhelmed and feel unprepared to juggle the needs of students, their families, administration, policy demands, and the content that they were hired to teach, they exit the profession. Those who stay must respond to dynamic classroom and school environments. Teacher PD programs for both preservice and in-service teachers must reflect that dynamic nature. To develop teachers who are well-equipped to be classroom leaders, holistic methodologies, including those that build resilience, should be employed (Brendel & Bennett, 2016). Hence, increasing teachers' adaptive capacity to build resilience and persist in the teaching profession through the development of community building capacities is vital if the United States is truly committed to preparing and supporting a diverse STEM workforce. By investing in PD of all teachers generally and STEM teachers specifically, we will discover the emerging property of functioning and productive STEM communities beginning in K-12 schools. Functional, productive groups are innovative. Individuals within these groups recognize the importance of each group member and their inputs, and the group demonstrates organizational self-efficacy (Gibson, 2004). We implore HRD practitioners and teacher educators who develop professional development programs for STEM teachers to design their programs so teachers have the opportunity to the think about their own needs in changing professional landscapes, as they develop competencies to help diverse students thrive in school. If HRD practitioners discuss changing school landscapes explicitly with teachers, they can reinforce the fact that they are a part of a system, an organization dependent on interconnected actors.

A first step to ensuring that the United States maintains a wide and diverse source of STEM professionals that help advance U.S. innovation and global competitiveness is enabling and encouraging equitable access to premium STEM education in K-12 schools (Hill et al., 2010). This begins with recruiting, training, and retaining highly qualified STEM teachers. When people feel supported by a community, they tend to want to remain in that community. Likewise, once diverse communities of Americans are recruited into STEM professions, it is important for them to have the capacity to stay, if they choose. If the U.S. is to address the demand for more diverse STEM professionals, though, it must start in the K-12 setting, an institution that almost all Americans pass through before joining the workforce, with highly qualified STEM teachers for all students. Here, we call on our colleagues to go beyond traditional PD for STEM teachers that solely focuses on student success, and include interpersonal skills by guiding teachers as they identify and use available resources (e.g., communities of practice, curriculum, and PD) to build adaptive capacity leading to professional resilience.

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