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# Broadening Conceptions of STEM Learning: "STEM Smart Skills" and School-Based Multilingual Family Engagement

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**ABSTRACT**

STEM education researchers are well aware of the need for increased access and inclusivity in Science, Technology, Engineering, and Mathematics (STEM) education for students from culturally and linguistically diverse (CLD) backgrounds. One of the many barriers for students from underserved cultural and linguistic groups is the difficulty of connecting families to school models of STEM education. This is one reason we advocate for improvement in culturally relevant STEM curriculum and content instruction. This commentary does not focus on STEM content instruction, although we certainly believe children from CLD communities deserve high expectations and high quality, culturally sustaining, STEM pedagogy. In this article we discuss non-curricular skills that are vital to success in STEM – and the advantages of sharing with family members the importance of particular essential life skills that support STEM learning. Communicating these essential "STEM Smart skills" showcases the power and influence that families have in kids' STEM learning. In this commentary we describe a school-based family STEM night that included a demonstration that success in a STEM task is not based primarily on content knowledge but on "STEM Smart skills." Many family members found success in the activity, regardless of parents' educational level or background in STEM. Family members' rich life experiences, critical thinking skills, and cultural knowledge include these "STEM Smart skills." We argue that teachers and schools should communicate to families about these life skills. This focus can benefit students by highlighting family members' power and role in teaching and modeling, essential skills for students' STEM success. This focus also can benefit educators by challenging common stereotypes about families from underrepresented cultural and linguistic backgrounds. In this way, acknowledgement of "STEM Smart" life skills could play a small part in dismantling structural racism and inequitable power relations between schools and communities.

*Keywords:* STEM education, STEM Smart skills, family engagement, culturally and linguistically diverse (CLD) families, culturally relevant pedagogy

## Introduction

Science, technology, engineering, and mathematics (STEM) education research identifies STEM education and STEM career paths must become more accessible and inclusive for students from *culturally and linguistically diverse* (CLD) backgrounds (Jong et al., 2020). Previous research has documented a number of structural barriers in education and society toward STEM achievement among students from underrepresented groups (Buck et al., 2020; McGee, 2020). This article focuses on one specific aspect of increasing equity in STEM education – strengthening the alliance between schools and families in culturally relevant and culturally sustaining ways. One way to increase CLD students' interest in pursuing advanced STEM education is through communicating and showcasing STEM strengths and connections that already exist within cultural communities (Johnson et al., 2014; Magee et al., 2020). We suggest one approach to family engagement in STEM that focuses not only on STEM-specific topics, but also on non-STEM-specific (and oftentimes non-academic) life skills that are essential for success in STEM education. Communicating these essential "STEM Smart skills" showcases the power and influence that families have in kids' STEM learning.

In this commentary we describe a school-based family STEM night that demonstrated success in a STEM task that is not based primarily on content knowledge but on "STEM Smart skills." We found many family members had success in the activity, regardless of parents' educational level or background in STEM (Hoffman et al., 2021b). Parents' and guardians' rich life experiences, critical thinking skills, and cultural knowledge include critical "STEM Smart skills." We argue that teachers and schools should consider these "STEM Smart skills" and communicate about them to families. This focus benefits families by highlighting parents' and guardians' power and role in teaching and modeling essential skills for students' STEM success. This focus also benefits educators by challenging common stereotypes about families from underrepresented cultural and linguistic backgrounds. In this way, acknowledgement of "STEM Smart skills" plays a small part in dismantling structural racism and inequitable power relations between schools and communities.

## Culturally Sustaining Pedagogy: A Conceptual Framework

We propose a model of STEM family engagement based in culturally sustaining pedagogy (Paris, 2012; Paris & Alim, 2017). This asset-based pedagogy builds from heritage and contemporary practices of communities of color while critically examining assumptions about the (lack of) value of community practices versus dominant cultural practices. Like other asset-based pedagogies, culturally sustaining pedagogy views communities of color as important sources of language/literacy practices and cultural ways of being that support students' academic achievement. Simultaneously, culturally sustaining pedagogy seeks to *sustain* "linguistic, literate, and cultural pluralism as part of the demogractic project of schooling" (Paris & Alim, 2014, p. 88). Scholars have applied culturally sustaining practices in mathematics (Leonard, 2018) and science (Oatman, 2015) learning contexts. In particular, we argue that family engagement activities can amplify and increase the visibility of the ways in which communities' rich cultural knowledge and life experiences are relevant to STEM learning.

## STEM Education and Family Engagement

Research over the last decade consistently shows a variety of barriers to STEM education and career accessibility for students from underrepresented cultural and linguistic groups. These barriers include educational quality in many non-White and low-income communities, access to opportunities to apply STEM skills, lack of role models and mentorship in STEM careers, lack of culturally relevant pedagogy in K-12 classrooms, school and work environments that stereotype or devalue students' identities, and marginalization in the workplace (Jong et al., 2020; McGee & Robinson, 2020). We believe a majority of educators want to connect with families as allies and advocates for their children's educational achievement. Yet many educators – most of whom are from the White, monolingual English-speaking background dominant in U.S. schooling – are only comfortable engaging parents and STEM content through the dominant STEM curricula that reflect a White, Eurocentric cultural framework (Mensah & Jackson, 2018; Leonard et al., 2010). Likewise, it can be difficult for families to connect to their children's schooling if they do not feel connected to the school due to cultural or linguistic differences or if they do not have much formal education themselves (Thomas et al., 2020).

We believe that all parents need to know that success in STEM comes not only from disciplinary or content-based knowledge but also from particular essential life skills that support STEM learning. Communicating these essential "STEM Smart skills" to CLD families can be especially significant in acknowledging the influence and importance of families' cultural heritage, funds of knowledge, and professional skills (Gonzalez et al., 2006; McKenna & Millen, 2013). Understanding how caregivers can support children's mindset, tenacity, and critical thinking skill development helps them realize the power and influence that they have over their students' STEM learning. Showcasing families' "STEM Smart skills" also is instructive to educators and administrators who may be accustomed to viewing their students' families through a too-common deficit-based lens (Hoffman et al., 2021b).

We want to emphasize that we are not focusing on family engagement initiatives because of incorrect perceptions of families of students as a barrier or impediment to students' STEM learning. On the contrary, we agree with current family engagement research that challenges such traditional top-down (and often deficit-based) "parent outreach" initiatives (Albrecht, 2020; Goodall & Montgomery, 2014). Instead we aim for a cooperative asset-based approach that focuses on families' funds of knowledge and STEM-related life skills. In this vein, we approach our role in school-based family engagement activities not as the visiting experts, but as facilitators with the opportunity to point out to both parents and school staff the connections between parents' prior knowledge, families' cultural heritage, and the skills students need for success in STEM fields. In this commentary, we describe a school-based event for families where we demonstrate that success in a STEM task is not always based on content knowledge.

We argue that teachers and schools should consider explicitly addressing "STEM Smart skills" both with students and with families. These "STEM Smart skills" are life skills that caregivers can support at home. When parents and guardians realize their own power and role in teaching "STEM Smart skills," they recognize how essential they are in students' STEM success. We urge STEM educators to consider the usefulness of communicating the importance of these "STEM Smart skills" to families. We encourage STEM education researchers to consider further research into the role of these "STEM Smart skills," both in STEM learning and in STEM family engagement.

## The Need for STEM Smart Skills

Educators and families alike are nurturing young STEM thinkers who will solve the problems of today and develop new tools to resolve future problems not yet encountered. The upcoming generation must be prepared to address: (1) societal needs for new technological and scientific advances; (2) economic needs for national security; and (3) personal needs to become fulfilled, productive, knowledgeable citizens (Zollman, 2012). From an equity-oriented approach, the need for increased skills relates to overlooked needs of learners from marginalized communities and the overdue need for social justice in STEM education (Barton, 2003; Leonard et al., 2010). Robert Berry III, Past President of the National Council of Teachers of Mathematics, along with his co-authors (2020) state that teaching mathematics for social justice is critical for four reasons: building an informed society; connecting mathematics with students' cultural and community histories;

empowering student to confront and solve real-world challenges they face, and helping students learn to use mathematics as a tool for social change (Berry et al.).

As we said before, preparation for STEM innovation requires more than just content knowledge or exposure to STEM content. Families can buy all the STEM-marketed kits and toys they want, but these predesigned, partially assembled kits will not prepare young "STEM Smart" citizens for meeting upcoming challenges. An intellectual risk taker's mindset, an innovator's tenacity, and a skeptic's critical thinking skills are must-have attributes all children will need to solve the problems of the future. Children need to develop perseverance and critical thinking to analyze multiple arguments, to innovate possible solutions, and to advocate for causes they support.

## Identifying Five "STEM Smart Skills"

When engaging with families, we stress five "STEM Smart skills" for students. With families we use the acronym **SMART** as a mnemonic device to help us communicate these essential life skills for STEM learning: **S** for productive **s**truggle, **M** for usefulness of **m**istakes, **A** for STEM's relevance for **a**ll people, **R** for intellectual **r**isk taking, and **T** for critical and divergent **t**hinking.

*1. "Struggle can be productive" (S):* We feel that the importance of working through challenges is important to "STEM Smart" thinking. When we talk about "struggle" in terms of learning, we're specifically talking about persistence through tackling tough problems. A student with a "STEM Smart" mindset is willing to tackle tough concepts and problems that do not have instant, easy answers. Key components to this type of learning are persistence and reflection about what works and what does not work. In "productive struggle" (NCTM, 2014), it is vital that a student's efforts are *productive* so as to reinforce a student's self confidence and willingness to persist doing challenging tasks.

We discuss with families the importance of giving students time and opportunity to manage their struggles through adversity and failure by not stepping in too soon or helping too much. When adults step in too quickly to solve a problem for students, they take the intellectual work away from the learners (Warshauer, 2015). Hiebert and Wearn (1993) and Borasi (1996) found that this practice repeated over time can contribute to students viewing struggles with learning mathematics negatively instead of viewing struggle as an opportunity to learn. In our experience, parents and guardians appreciate hearing about this relevant research.

*2. "Mistakes are how we learn" (M):* STEM skill development cannot flourish without acceptance of mistakes as natural, even welcome, parts of the learning process. Being wrong makes us uncomfortable, but students cannot develop and discover without mistakes. Human ingenuity and invention is inextricably connected with making mistakes. Asking parents what notable "mistakes" we value in our culture may yield answers from champagne to Coca-Cola, from popsicles to penicillin, from sticky notes to Silly Putty, and from rubber to Velcro.

Many students feel that their work needs to be perfect to be worthwhile. Perfectionism can be dangerous, as it has been linked to anxiety disorders and other forms of psychological distress. Even in small doses, this rigid unwillingness and fear of making mistakes prevents children from accessing a powerful tool for learning. Research on math anxiety, and now STEM anxiety, for the past 45 years has shown that math anxiety is a *taught* negative mental and physical response. Researcher Sheila Tobias (1993) said math anxiety is a mental phobia that affects children's motivation, self-confidence, attitudes, beliefs, and thus achievement. In our experience, parents and guardians are interested in concrete suggestions to address students' math anxiety; this relates to other areas of STEM as well in a broader discussion on the important role of making mistakes.

*3. "STEM is for all people in all places" (A):* Dominant popular culture and school curriculum alike reflect a history of not recognizing or valuing certain groups of people and certain types of knowledge in STEM. Since adults grow up surrounded by dominant cultural values, we often do not realize the messages children are receiving.

Students need to know that everybody has a STEM heritage. Many students (of all racial, cultural, and linguistic backgrounds) are unaware that people throughout time and across the world have made discoveries and developed technologies not taught in U.S. schools. Often school experiences focus on European and North American inventions – particularly those inventions made by White males for application in profitable industries. As one example, most Americans were taught that Greeks were pioneers of science and mathematics, when actually the Aztec, Incan, Nubian, Malian, Congolese, South African, Kenyan, Egyptian, Indian, and Chinese civilizations all utilized mathematics and astronomy in their cultures much earlier (Prescod-Weinstein, 2015).

It is critical for students to understand that STEM is for everyone for at least three reasons. First, students need to break the cycle of stereotyping their peers' STEM potential based on racial and gender stereotypes (Jong et al., 2020). Second, STEM professional and educational spaces need to become more welcoming to students from underrepresented groups (Leonard et al., 2010). Third, we want to combat the too-common imposter concerns among CLD students that perhaps STEM fields are not for them (Boaler & Greeno, 2000; McGee, 2020). Actively modeling a broader cultural and racial view of STEM – as well as dispelling stereotypes surrounding computer geeks and lab coats – provides our kids with an equitable vision for STEM and thus a stronger "STEM Smart" foundation.

***4. "Reward intellectual risk taking" (R)*:** Children's intellectual risk taking is based on their natural sense of wonder and curiosity about the world and the way things work. Children who are willing to take risks develop a tendency to be open-minded, to generate multiple options, to explore alternative views, and to have an alertness to narrow thinking (Grotzer, 1997). Children's disposition toward wondering, problem finding, and investigating relates positively to an adventurous mindset.

As educators we need to foster an environment that allows children to go beyond their comfort zone. "STEM Smart" kids need to be bold. Whether it is learning a new skill, creating a business, or searching for a cure to a pandemic, having the bravery to take risks is an essential "STEM Smart skill."

***5. "Think before you trust" (T):*** Some technical skills taught in today's STEM courses will be obsolete by the time our students are adults. But "STEM Smart skills" are never obsolete. They are the habits of mind that give our children the agility to apply their existing knowledge and skills to new contexts. This final skill in our acronym alerts parents and guardians to the importance of critical thinking – itself a set of skills that is becoming increasingly important in the age of digital literacy and social media.

We explain critical thinking as a combination of several intellectual processes. Critical thinking involves deciding what knowledge is relevant to a situation, evaluating information for quality, and applying the relevant knowledge to make informed decisions. "STEM Smart" critical thinking also includes questioning others' thinking, recognizing contradictions and biases, and admitting flaws in our own thinking.

In the current U.S. cultural climate, many people voice concern about finding and evaluating trustworthy sources of information (Ortutay & Klepper, 2020). Teachers at every level from elementary to graduate school have voiced concerns about young people's information literacy and media literacy skills. The ability to evaluate information, to make judgments, and to think critically, is key to a successful STEM mindset.

Lack of skill and judgment in this key area of STEM thinking has a wide-reaching influence on our society in areas ranging from ill-considered government policies to significant numbers of Americans refusing to believe highly qualified scientific experts (Hayhoe & Schwartz, 2017). The Pew Research Center reported most Americans believe that science has benefited society, but fewer than one-third of Americans trust medical research scientists to give fair and accurate information (Funk et al., 2020). Consumers of media of all kinds, print and digital, need basic skills in questioning reported trends, interpreting statistics, identifying bias, and recognizing the validity and reliability of data.

Current K-12 students often view a friend's reposted quote on social media as equally or more valid than an article published in a research journal. We want kids to question: the sources of their information, the possible bias of the sources, the resources these sources use for the information, and the analysis that was conducted on the information.

**Considerations for STEM Family Engagement Activities**

Current literature supports many possible forms of family engagement (Baker et al., 2016; Mahmood, 2013). As one example, we have done several "STEM Family Night" events hosted by elementary schools with large numbers of Spanish-speaking Latinx families. We advocate approaching such STEM family engagement activities with five key considerations:

- Center the Event in Existing Community Relationships (Albrecht, 2020);
- Connect with Community Knowledge, Heritage, and Values (Magee et al., 2020);
- Choose a High-Interest, Integrated STEM Exploration Activity (Suh et al., 2020);
- Make the Activity Hands-On and Challenging (NCTM, 2014); and
- Focus on STEM as Inquiry for *All* Participants (Hoffman et al., 2021b).

First, in terms of *existing community relations*, research identifies relationships with students as keys to learning families' "funds of knowledge" and finding natural community partners (Gonzalez et al., 2006; Moll et al., 1992; Rios-Aguilar et al., 2011). These funds of knowledge may be outside of commonly "aspirational" STEM fields such as engineering or medicine. Most jobs and learned skills require some level of expertise that can be related to "STEM Smart skills."

Second, both culturally relevant STEM pedagogy and current family engagement research emphasize the importance of *connecting with community knowledge, heritage, and values* (Magee et al., 2020; Thomas et al., 2020). Choose a focus and activity that centers the experiences and identities of the families who will be attending (Kayumova et al., 2015). Recognition of the knowledge and resources families possess and bring into the school is at the heart of culturally sustaining pedagogy (Paris, 2012).

Third, effective STEM exploration activities for family engagement are *open-ended activities* that encourage *hands-on problem-solving*. As family engagement events usually occur outside of the regular academic day, it is easier to do an integrated approach to STEM than in a traditional school curriculum. Further, open-ended activities lessen the impulse to "find correct answers" or "teach parents" some STEM content.

Fourth, the activity for the event should be *novel, challenging, and interactive*. It should require physical activity yet be accessible to multiple ages and abilities. Examples could include a competitive challenge of building the tallest freestanding tower out of dried spaghetti noodles, masking tape, string, and marshmallows. Another small-group challenge is building a "ringlet" arch using only Pringles potato chips.

Fifth, we want *all family members to view themselves as learners*. Our activities demonstrate that fluency in English or possessing specific content knowledge is not necessary to STEM learning. At the end of the activity, we ask participants to join in a reflection to discuss what STEM is and what STEM is not. STEM skills are not content knowledge, but STEM success does not require the ability to use knowledge in solving problems. We want parents to encourage their children to become intellectual risk takers with the tenacity to tackle tough problems and the critical thinking skills to separate scientific information from opinions.

## One Example of a STEM Family Engagement Event

One successful event we have done at elementary schools is "STEM Family Night." These events center around an interactive activity. We conducted two such events on weeknights at two different elementary schools in the same school district. At one school, the event was designed for families with children receiving services as English language learners. Parents and guardians were invited via email, and flyers printed in both Spanish and English were sent home in children's backpacks. At the other school, where a large percentage of students come from bilingual families, the entire student body was invited to the event via bilingual flyers sent home in backpacks as well as weekly email newsletters. (Spanish was the most common language spoken by English learners at both schools, by far, although other languages were also represented.) Invitations for events at both schools welcomed entire families, including siblings.

At both schools, administrators, including the principal, and teachers attended the event and the school provided dinner to all participants. Once families had time to eat and socialize, we welcomed everyone and invited them to move into groups to participate in a marshmallow tower-building group challenge activity.

In hands-on challenges like these, we ask participants to move into working groups having parents sit with other parents, kids sit with other kids of various ages, teachers sit with teachers, and school administrators sit with other administrators. We prefer this grouping strategy because we have found that some parents defer to teachers or school administrators if all adults are grouped together. When parents or teachers are grouped with children, the adults tend to direct the children. When parents are placed at a table with other parents, however, they feel less self-conscious about making mistakes and more likely to take risks and enjoy their errors. (As an aside, we have also noticed that the children relish competing with adults.) When participants represent several language backgrounds, we deliberately mix participants from different languages to show that learning can be accomplished with limited verbal communication.

In our experiences, we observe that parent groups are much more reserved, often needing a lot of encouragement to try divergent ideas. In contrast, the groups of children are eager to experiment with various strategies to tackle the challenge, regardless of whether adults think such strategies might work. At one event, one group of children taped dried spaghetti noodles end-to-end before putting their marshmallow on top. Of course their tower would not stand; it bent over in an arc instead. But that did not bother the kids. They realized that they could make another arc at a right angle to support the first one. The two intersecting arcs supported the marshmallow. That group's initial mistake produced a better result.

Experiences like these demonstrate the importance of "STEM Smart Skills" and provide openings for conversations about the value of each of the five STEM Smart skills. Participants in the STEM challenge had to be willing to persist through struggle ("S"), make mistakes ("M"), consider the ideas of all group members ("A"), take risks ("R"), and think critically about possible solutions ("T").

As a physical "takeaway," we give a bilingual handout with advice for reducing STEM anxiety and supporting a positive mathematical mindset in adults learning with their children (Boaler, 2015; Suh et al., 2021). In our event evaluations, parents described STEM education as more hands-on, enjoyable, and problem-based than expected. They saw the value of communicating in a team, allowing mistakes, and persevering as important aspects of learning "STEM Smart skills" (Zollman et al., 2020).

## Findings from STEM Family Engagement Activities

As this is a commentary and not a research report, this article focuses on connecting multilingual family engagement with "STEM Smart skills" rather than sharing empirical results.

However, we do believe that we have learned six important lessons from our work on family engagement:

1. A STEM activity does not need to focus on academic content;
2. The STEM activity focus should begin with families' funds of knowledge;
3. Activities can focus explicitly on "STEM Smart skills;"
4. School teachers and administrators need to take part, but not lead, in the activities to have the opportunity to adjust and expand their views of students' families as partners in education;
5. Family members are excited to be asked to join in STEM education; and
6. Family members appreciate concrete examples of "STEM Smart" concepts and skills.

## Implications for Future Research

Based on our experiences facilitating STEM family engagement events, we suggest three main areas for future research. These include the effects of family engagement programming, the effects of highlighting cultural connections, and the effects of "STEM Smart skills" on academic learning.

### Effect of Engagement Efforts on Students, Families/Communities, and Educators

First, we encourage researchers to explore the efficacy of STEM family engagement events in developing STEM content knowledge, skills, and motivation. Researchers can also explore the impact of STEM family engagement events on school administrators and teachers – how witnessing family-based informal and collaborative STEM exploration might reduce educators' deficit perspectives of families' interest in STEM, or their ability to support children's STEM learning. Here are some additional questions researchers may want to explore:

- Do families/communities change their view of STEM from being a product to being a process through family engagement activities?
- Do families/communities see students' STEM abilities as fixed or open to growth?
- Do family engagement efforts affect families' perception of their role in teaching "STEM Smart skills" such as perseverance, intellectual risk-taking, acceptance of mistakes, appreciation of STEM in all fields, and critical thinking?
- How do family/community engagement activities increase educators' ability to make meaningful and authentic connections between STEM content and students' lived experiences?

### Connections Between Student Cultures, STEM Heritage, and "STEM Smart skills"

STEM education researchers can draw on STEM equity literature and family engagement literature to connect the STEM heritage and funds of knowledge of CLD families with STEM curriculum and instruction in schools. Such research is needed to explore how family engagement can support current scholarly efforts to "decolonize" STEM curricula (Anthony-Stevens & Matsaw, 2019; Howard & Kern, 2019; Kimbrough, 2017; Kimmerer, 2013; Nhemachena et al., 2020; Prescod-Weinstein, 2015). Again, here are possible questions to study:

- Do culturally relevant STEM activities deepen students' and families' understanding of STEM as part of their own heritage, instead of "belonging to" the dominant culture of U.S. education?
- How does family/community engagement support efforts to relocate STEM knowledge outside of traditional narratives of Western scientific discovery?

- How does the use of cultural connections in family engagement activities affect families' view of STEM learning and their children's potential future in STEM careers?
- What effect does highlighting cultural connections in family engagement activities have upon educators' views of their students, their students' communities, and of the intercultural connections possible in STEM teaching?
- What effect do efforts to decolonize STEM curriculum and pedagogy have upon teachers' attitudes and student achievement?

**Effect of "STEM Smart skills" on Academic Achievement in STEM**

Research also can examine the connection between students' STEM learning and the skills and knowledge we call "STEM Smart skills." Possible research questions here could include:

- What effect does each of the five "STEM Smart skills" have on student achievement in STEM academic areas?
- What are effective ways schools and teachers can increase students' "STEM Smart skills"?
- What are effective ways educators can communicate to families their critical role in nurturing students' "STEM Smart skills" development?

In closing, we wish to emphasize the importance of basing future research efforts in authentic school-family partnerships (or school-family-university partnerships), which centralize the family's role and knowledge in supporting students' STEM learning. Like Moll et al. (1992), we view these "strategic connections" to families as essential to centering our understanding of funds of knowledge around the family's values and ways of knowing rather than the researchers' values and ways of knowing (p. 132).

We view the families' role in nurturing "STEM Smart skill" development as essential to support students' STEM education. Like Moll et al. (1992), we urge an approach to research that values parents' funds of knowledge rather than a traditional approach that centers around our preconceived values and assumptions. A research agenda that integrates the views and values of CLD families aligns with culturally relevant and sustaining teaching practices (Ladson-Billings, 1995; Paris & Alim, 2014, 2017).

The field of STEM education is evolving. As part of this evolution, we strive to be more culturally responsive STEM educators and researchers. The purpose of this commentary is to encourage further discussion about research in connecting the three growing areas of STEM Smart skill development, culturally relevant STEM instruction, and family engagement. Such a focus can benefit students by highlighting family members' powers and roles in teaching and modeling essential skills for students' STEM success. This focus also can benefit educators by challenging common stereotypes about families from underrepresented cultural and linguistic backgrounds.

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