RESEARCH-ARTICLE

Exploring the Role of Culture and Bilingualism in Programming Activities: Lessons from African Educators

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Exploring the Role of Culture and Bilingualism in Programming Activities: Lessons from African Educators

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Abstract

The delivery of culturally relevant content in K-12 computing education is widely recognized as essential for engaging students and fostering meaningful learning experiences. However, in many African contexts, K-12 computing teachers feel unprepared to address this need. Course materials often fail to reflect the cultural and linguistic diversity of the students they serve. In this study, we conducted participatory design sessions with education stakeholders, including primary and secondary school teachers, to develop culturally relevant programming activities for a national programming outreach initiative in Botswana. Our findings emphasize the importance of relatable examples and a balanced approach to integrating cultural elements into learning materials. Challenges, such as diverse dialects and difficulties with direct translation, led stakeholders to adopt a bilingual approach to the initiative. This research contributes insights into the complexities of integrating culturally relevant programming languages and course materials and highlights the need for flexibility and adaptability. The implications of this study include the need for cross-regional research collaborations, teacher training and guidelines, and empowering teachers to effectively integrate cultural elements, promoting inclusivity and cultural responsiveness in programming education.

CCS Concepts

• **Applied computing** → *Language translation*; • **Social and professional topics** → **K-12 education**; **Computer science education**; • **Human-centered computing** → Participatory design; Contextual design.

Keywords

Bilingualism, Contextualization, Cultural Relevance, K-12, Teachers

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1 Introduction

Broadening computing education internationally requires integrating cultural relevance [8, 27]. Culturally relevant pedagogy (CRP) aims to make computing, which encompasses programming, more inclusive and accessible to students from culturally and linguistically diverse backgrounds [24]. Scholars emphasize the importance of merging computational thinking [17] with cultural practices to improve the relevance of computing for ethnically underrepresented groups, thus empowering and improving their academic success and social development [12]. Although CRP has gained traction in computing education communities, particularly in the global North [13, 14, 31], there has been limited exploration of these efforts within sub-Saharan Africa, which has been relatively understudied in computer science (CS). Meeting the demand for computing skills is necessary for Africa to become a leading hub of technological growth and innovation [29].

This study explores how a group of teacher stakeholders perceive the integration of culturally relevant programming content in Senior Secondary School programming education in Botswana. We examine how the roles of culture, context, and language in programming can enhance the learning experiences of these students. Our research is guided by these two questions:

(1) *How do teachers balance standardization and contextualization of cultural elements when designing programming activities?*
(2) *In what ways do teachers co-design programming activities to integrate national language while navigating cultural and linguistic challenges?*

2 Background

2.1 Global Disparities in Culturally Responsive Research

While existing literature has investigated how to make CS more equitable for underrepresented learners in the global North [31], research on culturally relevant CS [27] in the global South remains limited. Existing studies in the global South focus primarily on aspects of inequality rather than exploring specific learning experience design. For example, Karetai et al.'s [22] case study in New Zealand argues the need to decolonize computing education to improve outcomes for the Indigenous Maori population. Another study of 46 educators from Latin America, South Asia, the Middle East, Africa, and Australia revealed potential dissonance between local practices, values, and impacts of technology in the Global South compared to the predominant approaches commonly advocated by global North organizations [42]. Global South countries

often replicate existing global North curricula, demonstrating little adaptation to the unique needs and contexts of local learners [28]. Further research is needed to understand how computing education can be made more equitable for countries in the Global South.

To date, previous work focusing on Africa has highlighted the struggles faced by African countries due to their lower capacity compared to higher-income countries [39]. The findings from a study involving 16 Senior Secondary Schools delivering a national programming intervention in Botswana found that students who engaged in bilingual programming experienced a significantly higher increase in programming comfort than those who coded only in English [38]. Most recently, work has highlighted the need for contextualization in computing activities in sub-Saharan Africa to solve local problems and draw on language customs [18].

2.2 Theoretical Framework

This paper draws on the work of academic scholars in the US who sought to increase equity for students from underrepresented groups in education. CRP [24] and culturally responsive teaching (CRT) [15] have been applied to computing education to develop curricula that integrate students' culture, experiences, community, and interests into learning material [31]. However, although the language is well recognized as an essential part of cultural capital [3], less is known about how national languages contribute to cultural relevance in computing.

In programming education research, two contrasting approaches suggest ways to modify programming environments and tools to make them more culturally relevant. One approach is to design everything in the student's national language [36], while the other is to opt for a more intricate multilingual design [45]. An investigation into the translation of robotics terminology into national languages for learners in South Africa underscores the complexity of this work. Due to the specialized nature of the concepts, the authors concluded that no universal strategy existed for developing robotics terminology applicable across all contexts [26]. Further research is needed to explore the impact of translation on language, as students who program in their mother tongue may achieve better results than those who do not [33]. This research aims to fill this gap by investigating how text-based programming environments can be adapted to be more culturally relevant, with a particular focus on the use of Setswana.

2.3 Implementing Culturally Relevant Activities

Teachers require a variety of competencies and skills to employ CRT practices effectively. These include developing a comprehensive understanding of cultural diversity, integrating cultural content into the curriculum, and fostering a sense of care and community within the learning environment [16]. Culturally responsive educators serve as mediators between the community and the classroom, ensuring that the content of computing lessons resonates with learners' experiences, cultures, and perspectives both within and outside of the school environment [21, 41]. This approach can be operationalized in programming activities through open-ended tasks that afford learners increased autonomy to incorporate their cultural interests and identities [34].

Professional development activities can increase teachers' confidence to adapt computing resources to make them more culturally relevant to their learners [25]. A study with nine female elementary and middle school teachers in the US found that after professional development, teachers planned to implement CRP with their learners through student-centered pedagogies, awareness of culture, creating a sense of inclusion and belonging, and prioritizing equality of access to computing [5]. Another small study with ten (10) K-12 CS teachers in Hawaii explored their perceptions of the principles and processes of designing and implementing culturally relevant CS lessons [19]. Participating teachers described a tension between ensuring that CS lessons incorporate culturally appropriate content and adhering to CS standards. It can be challenging and time-consuming for teachers to modify existing activities while maintaining the original learning objectives of the curriculum [37]. So, an essential part of culturally responsive activity design is incorporating the experiences and perspectives of a diverse group of experienced teachers [20]. Therefore, this study focuses on teachers' views on integrating culturally relevant content into programming activities for learners across Botswana.

3 Methodology

CSEdBotswana[1] is a non-profit organization that works to expand access, support teacher professional development, and increase students' participation in CS by organizing a national programming outreach activities. This study examines the design of a national outreach programming activity held in March 2024 for Senior Secondary School students (ages 15-17) [38] using Hedy [2] programming platform, which supports the translation of other non-English languages. To ensure the cultural relevance of the outreach activities, the research team engaged educators in a participatory design (PD) process before the national outreach activity, as detailed below.

3.1 Using Participatory Design

The goal of our PD sessions was to leverage the expertise of stakeholders, namely K-12 teachers and programming instructors, to curate culturally relevant programming materials that reflect the culture of the African region in which this study was conducted. PD methods were chosen as the inquiry method because they are recognized as a tool for generating knowledge by collaborating with stakeholders and viewing them as *equal* design partners [4, 6, 9].

3.2 Participants

For this study, we recruited eight participants with varying coding experience and knowledge. They comprised of four teachers, two university lecturers, and two post-secondary students (i.e., one graduate student serving as a coding club facilitator and an undergraduate student who also acted as a teaching assistant) to engage in our professional development (PD) sessions. Our participating stakeholders are further described in Tab. 1. Ethical approval for this study was obtained from Botswana's Ministry of Education and Skills Development, and all participants provided informed consent.

[1] https://www.csedbotswana.org/
[2] https://hedy.org/

Table 1: Description of participants in participatory design sessions

Pseudonym	Gender	Profession	Teaching Subject	Programming Experience	Attended PD Session		
					PD1	PD2	PD3
Christabelle	F	K-12 teacher	Computer studies	No	Yes	No	Yes
Gifty	F	Graduate student & coding club teacher	N/A	Yes	Yes	Yes	Yes
Kario	F	Undergraduate student & teaching assistant	N/A	Yes	Yes	Yes	Yes
Kala	F	K-12 teacher	Computer studies	Yes	Yes	No	Yes
Mohammed	M	University Faculty & Head of Department	Math and Science	Yes	Yes	No	No
Moustapha	M	K-12 teacher	Computer studies	Yes	Yes	Yes	Yes
Serafina	F	K-12 teacher	All general subjects	Yes	Yes	Yes	Yes
Serena	F	University Faculty	Mathematics	No	Yes	Yes	Yes
					8	**5**	**7**

3.3 Context of Participatory Design Sessions

Although Botswana is a majority bilingual country, English is the primary medium of instruction in the classroom. Many students are accustomed to English textbooks with potentially unfamiliar or unreliable examples [35]. This context informed the design of the materials discussed in the three PD sessions, each described below.

3.3.1 ***Understanding Cultural Relevance.*** The first session (PD1 in Tab. 1) explored the intersection of CRT and computing (CRC) [27], with a focus on the challenges of designing culturally relevant programming content. Participants were asked to reflect on how 'culture' should be defined in this context and to consider potential tensions between traditional and modern cultures, urban and rural cultures, and whether language might serve as a more universally shared experience. In response, participants engaged in discussions about the complexities of cultural representation and the role of language in making programming content more relevant and accessible. These insights led to the inclusion of language as a key aspect of culturally relevant programming activities for the national outreach initiative.

3.3.2 ***Exploring the Hedy Programming Language and Refining Ideas.*** Building on the challenges identified in PD1, the second session (PD2) introduced participants to Hedy. The researchers explained and demonstrated culturally inclusive activities developed from PD1 discussions and invited participants to provide feedback. The decision to incorporate a restaurant-themed activity was intentional, as it resonated with participants' everyday experiences and cultural backgrounds, particularly through the lens of food. The participants then collaborated to try out a restaurant-themed coding activity in English (prompting customers to order food) in the context of exploring Hedy's features and completing its first three levels. The session provided insights into participants' perceptions of Hedy as a programming language and the potential to integrate cultural elements.

3.3.3 ***Integrating National Languages.*** The final session (PD3) addressed participant questions from PD2, regarding the feasibility of incorporating other non-English languages into Hedy (i.e., Setswana). The researchers presented a selected restaurant programming activity prototype translated into Setswana. The participants used the prototype and provided feedback, discussing where the national language should be integrated into coding keywords or instructions. The guiding questions included "*What potential benefits and challenges do you anticipate in integrating a national language into coding activities?*" and "*Which specific cultural elements or language aspects do you plan to incorporate into your activity, and what is the significance or rationale behind your choices?*" This feedback informed the refinement of the programming activities and preparation for the national outreach activity, providing comprehensive data on the meaningful integration of national languages and cultural contexts into programming activities.

3.4 Data Collection

This qualitative study involved eight participants in three 3-hour PD sessions held in January 2024. These in-person sessions took place at a large institution and aimed to collaboratively design culturally relevant programming activities with the research team. To facilitate deeper engagement and richer insights, all discussions were conducted bilingually (English and Setswana). Sessions began with lunch and were recorded via Microsoft Teams, ensuring accurate documentation, secure storage, and easy access for subsequent transcription and analysis.

3.5 Data Analysis

Our analysis proceeded chronologically First, the transcribed discussions, originally in Setswana, were translated into English and imported into an Excel spreadsheet. This step allowed the researchers to become familiar with the data and the range of ideas expressed by the participants. Following this familiarization phase, a systematic

coding process was undertaken where we identified the repeated patterns within the dataset and assigned initial codes. This coding process was conducted within the spreadsheet to facilitate the organization and management of the coded data. Each code represented a distinct concept or idea present in the corresponding data segment. Next, these initial codes were examined and grouped into potential themes based on their relevance to the research questions. This involved identifying broader patterns that reflected underlying meanings or concepts within the data. Finally, these themes were iteratively refined. Both researchers independently reviewed and revised the coded data, discussing any disagreements or uncertainties in theme development until consensus was reached.

The process encompassed several steps to maintain the rigor and depth of our analysis. We first started by transcribing data from the recorded sessions, which was systematically done by the first and last authors, who each focused on a specific research question to ensure reliability. The data were coded within a spreadsheet to facilitate organization. These initial codes were assigned to segments of data, representing distinct concepts or ideas [23]. The codes were then organized into potential themes based on their relevance to the research questions. This involved identifying patterns that reflected underlying meanings or concepts within the data. The themes were refined iteratively through the review and revision of the coded data. Any disagreements or uncertainties in the development of the theme were addressed through discussion and consensus among all authors.

4 Thematic Findings

In this section, we present our themes. 4.1 presents teacher considerations when designing culturally relevant material and 4.2 illustrates teachers' considerations when including Botswana's national language in the national outreach programming activities.

4.1 Cultural Elements Educators Prioritize

4.1.1 ***Uniformity is Needed.*** Most teachers expressed enthusiasm for incorporating cultural and contextual elements in PLs, recognizing their potential to boost student engagement and comprehension. However, some teachers also express the need to carefully consider how much uniformity is necessary when incorporating elements such as relatable examples and cultural references. While most teachers favored a balanced approach that respects cultural diversity, clarity, and coherence in learning materials, one teacher cautioned that "*overly standardizing approaches may overlook the richness of students' cultural experiences.*" Most teachers emphasized the importance of *clearly* defining "culture" and "context," given the distinction between the two. Participants described the goal of uniformity as ensuring consistency and coherence throughout the curriculum for all students, regardless of their geographical location or type of school (e.g., government-run or private[3]), which can vary significantly in terms of resources and cultural knowledge. As one teacher explained, "*Students in private schools may have limited understanding of local traditions compared to those in government schools, while there may be differences in technological resources between students in southern and northern regions of the country.*"

[3] ***NB:*** *Private schools include international students who represent different nationalities.*

4.1.2 ***Contextualizing Concepts.*** All teachers highlighted the importance of including relatable examples that resonate with students' cultural and contextual backgrounds. These examples, drawn from local food, language, images, and real-life scenarios, help bridge the gap between abstract programming concepts and students' existing knowledge.

Moustapha shared an experience where "*[he] wrote an English Cambridge exam and failed because [he] could not relate to the context of the scenarios.*" They believed integrating familiar elements into programming tools and content material was crucial for students because it could enhance their accessibility and help them better connect their learning to existing knowledge. Participants felt it was essential to help students understand abstract programming concepts through relatable examples such as images, references, and analogies. Some of the teacher participants suggested developing a restaurant system featuring local cuisine commonly found in the school's tuckshop, naming it 'Semausu,' to reflect local Setswana naming conventions. For instance, Serafina shared an experience in which, after initially explaining a Math concept without cultural context, she would have to re-explain it using culturally relevant examples, such as a tuckshop (Semausu) scenario, to teach concepts like counting and addition. She would ask students to imagine themselves buying items from the tuckshop.

4.2 Navigating Linguistic and Cultural Elements

4.2.1 ***Double Translation Burden.*** While most teachers expressed enthusiasm for the potential of a PL in their national language, initial experiences with the participants using the Setswana version of Hedy revealed a necessity for constant dual translation. This meant that they had to first translate the given instruction and their code from Setswana to English to fully make sense of the programmatic logic. Only after understanding in English, could they then translate their thoughts and code into Setswana to continue writing their program. This 'double translation' process placed a considerable cognitive burden on participants as it demanded extra mental effort and slowed down their progress and increased the potential for errors. Some teachers also highlighted the potential for misinterpretation due to linguistic ambiguities. As one teacher, Kala explained, "*if a student reads these Hedy instructions completely in Setswana, it may confuse them.*" Other teachers also expressed that reading instructions in their national language increased the time required to understand the content, and they anticipated similar challenges for their students.

4.2.2 ***Direct Translation Challenges.*** All the participants reflected on how direct translation of programming concepts and terms is complicated due to the diverse dialects within Setswana. They were shown Hedy PL keywords, such as 'print,' which, when translated, is 'gatisa.' Upon seeing this, Serena commented, "*The word 'gatisa' in Setswana can have multiple meanings outside of 'print' which can lead to potential confusion among students.*" Others added that 'gatisa' could also mean 'pressing on an object,' 'pressing clothes with an iron,' or 'publishing something.' However, they found it difficult when asked to suggest an alternative word, demonstrating the challenges of direct translation. As one teacher said, "*The keywords are difficult to translate, and even if we do translate them, we end up [confusing] the languages,*" while the other said,

(a) Bilingual code sample written by Serena

```
dino_tsididi is gemere, morula, motlopi
print 'Ntlelentle ya dino '
dino is ask 'O batla go nwa eng?'
if dino in dino_tsididi print ' Bongwe ' dino ' Ee tla! '
```

(b) Bilingual code sample written by Kala

```
print Welcome to Ikgomotseng's semausu!
print Today we're seling dinawa or sengana.
food is ask otla batla go ja eng?
print Great choice! The food is my favorite!
```

"*The issue is the diversity of the Setswana. It has a diverse dialect, making it challenging to determine the best approach.*" This highlights issues such as the diverse dialects within a language and the lack of direct translations for certain programming words and concepts.

4.2.3 ***Bilingual Integration.*** Most teachers had bilingual fluency in English and Setswana. They adapted a restaurant programming activity that represented the local context of Botswana, recognizing the cultural significance of food and the prevalence of code-switching between English and Setswana. Most participants suggested modifying the English-only activity to be more relatable, and the teachers explored which programming elements should be in Setswana and which in English. They suggested using the national language for programming elements such as variable names, print statements, and input strings, while programming (hard-coded) keywords should remain in English due to translation difficulties and a lack of flexibility in renaming these keywords.

Serena, demonstrated this in their coding program (see Fig. 1a). The program defines a list of three types of drinks. It also asks for user input: "*O batla go nwa eng?*" that translates to "*What do you want to drink?*" in English. If the user's response is one of the provided items in the list, it confirms that their choice will be available. This program includes keywords in English, variables, print statements, and input strings in Setswana.

Kala also demonstrated bilingualism in her program (see Fig. 1b). This program welcomes the user to a restaurant called "Ikgomotseng's Semausu" and presents two food options: 'dinawa' or 'sengana.' It then asks the user what they would like to eat. If the user responds with either option, the program prints: "*Great choice! The food is my favorite!*" This program has keywords in English while the rest of the code is bilingual (both Setswana and English). In both examples shown in the figures, which are representative of the programs written by the participants, teachers incorporated the national language along with contextualized and cultural examples of food (*gemere, morula,* and *motlopi*) and restaurant names (*semausu*) in their code.

5 Discussion

5.1 Prioritizing Cultural Elements (RQ1)

Some participants advocate for incorporating cultural elements (i.e., language, images, songs, symbols) into PL tools and instruction to maintain uniformity. The participants believe that a uniform approach ensures effective participation in computing for all students, regardless of the type or geographical location of their school. The phenomenon of this is described as an *additive approach* [2]). The additive approach provides balance because teachers can add cultural content, themes, and perspectives to the existing curriculum. The use of contextualized examples for CS1 has been developed by African CS researchers and is supported by evaluations from African CS instructors at the university level [18]. Additionally, African instructors have supported this additive approach. Other studies have shown that students enjoy and feel comfortable with programming instruction in their national language, with coding in their national language further suggesting a connection between cultural identity and educational engagement [1, 38].

Our findings show that, in contrast, other teachers favor a student-centered approach, emphasizing the importance of personalization in integrating diverse cultural perspectives into the curriculum. However, similar debates exist in the literature [19], emphasizing that the need for cultural relevance is balanced with the risk of inadequately structured resources. It is essential to exercise caution when integrating culture into PLs and course materials to avoid overlooking the richness and diversity of students' cultural backgrounds. The discourse among teachers indicated that while much more research is needed to determine the degree of uniformity of the culture applied to PL, the fact that they see it as a need is a factor that should not be overlooked [43].

Another strategy some teachers emphasize is ensuring students are provided with relatable examples, which can be an essential tool for bridging programming concepts with students' everyday experiences, as also suggested in [13, 31]. By connecting abstract concepts to students' lived experiences, teachers can make learning more accessible and meaningful, as reported in [31, 44]. However, the effectiveness of relatable examples may vary depending on students' cultural backgrounds and experiences.

5.2 Navigating Native Language (RQ2)

Most teachers face significant challenges when integrating cultural elements, such as national language, into class materials and PLs, largely due to translation difficulties, as presented in our findings. However, the literature also attributes these challenges to gaps in technological, pedagogical, and content knowledge [30] as well as insufficient resources and training [43]. Translating materials requires a specific skill set, making the process more demanding.

When participants were introduced to Hedy in Setswana, double-translation among teachers was necessary and was identified as a potential challenge, as the inherent linguistic back-and-forth could confuse students. Similar translation challenges have also been reported in a study that translated robotics terminology from English into eleven Indigenous languages in South Africa [26]. While some teachers are exploring alternative means of translation, such as leveraging the language knowledge of community members [11], the teachers in this study initially expressed enthusiasm for PLs in their national language. To address these challenges, further research could explore the use of bilingualism to integrate national languages while maintaining accessibility for English-proficient students. In addition, strategies to manage students' cognitive load, such as subgoal labelling [32], could benefit students.

Direct translation of cultural elements is not always straightforward, as specific terms or concepts may lack direct equivalents

in other languages [10]. Furthermore, language evolution influenced by globalization and cultural shifts adds complexity to this process [26]. Teachers highlight the variability in what resonates with students across different regions, emphasizing the need for regular meetings to determine which language aspects best engage their students. This highlights the importance of flexibility and adaptability in incorporating cultural elements into PLs and course materials.

5.3 Implications

Researchers should acknowledge the significant challenges educators face when integrating cultural elements into programming interventions (i.e., course materials and PLs), particularly in the global South. The scarcity of adequate resources and training is a significant obstacle in these regions that needs to be addressed. One solution is to encourage more global North-South collaborations. Researchers should also consider the complexities of translating English-only materials into other languages. A potential solution is to work alongside teachers in the Global South. Another solution is translanguaging [40], but this requires careful consideration, as it involves intentionally leveraging students' full linguistic repertoires by blending their home languages and the language of instruction to support meaning-making, rather than rigidly separating languages, which may not always align with formal educational policies or teacher preparedness.

Teachers should understand the cultural and linguistic diversity of students that exists in their classrooms. Integrating elements of student cultures into programming activities, particularly contemporary aspects, can make learning more engaging, meaningful, and relevant [19, 24]. Teachers must continue to provide the best learning experiences for all students, recognizing the variability in what resonates with students across regions and emphasizing the need for an adaptable curriculum design.

Curriculum Designers should prioritize engaging teachers in professional development sessions focused on integrating cultural elements into programming education, especially in Africa. Involving teachers in the development process ensures cultural relevance and resonance with diverse student populations. Furthermore, incorporating PD approaches [7] can improve the effectiveness of curriculum development by fostering ownership and investment between stakeholders.

5.4 Limitations

While this study provides valuable insights into teachers' perspectives on incorporating cultural elements into PLs, there are limitations that we would like to address. Firstly, we acknowledge the size of our participant sample. While they may not fully represent the diversity of viewpoints within the teaching community in Botswana, the participants effectively represented all key stakeholders. Additionally, the study focused on a specific context, an informal national programming activity, so our findings may not be generalizable to formal educational contexts. Future research could benefit from incorporating multiple data sources, such as student perspectives or classroom observations, to provide a more comprehensive understanding of the challenges and opportunities associated with integrating cultural content into programming education in the global South. Finally, the authors call for further research to explore the specific challenges and opportunities related to programming in other non-English languages, as well as the role of bilingualism in facilitating learning in culturally diverse classrooms.

6 Conclusion

This study presents initial findings on teachers' perspectives regarding the integration of local culture and language into a programming intervention for Senior Secondary School students in Botswana. While educators recognize the importance of contextualization in the programming curriculum and express a desire for student representation, they also seek uniformity within culturally relevant programming activities. Bilingualism emerged as a possible consideration, reflecting the nuanced linguistic diversity of Botswana. Although teachers suggested incorporating relatable elements (e.g., visual aids and modern vernacular), this study shows that this process is complex, given students' varied, yet evident, backgrounds and experiences. Despite these challenges, the positive feedback from the participants and their interest in future sessions highlight the value of working with teachers [4].

Our findings point to the need to address translation, particularly in determining which aspects of the programming intervention should be fully or partially translated into national language(s). As we strive to broaden participation in computing among K-12 students, we encourage further exploration of these themes and have identified some initial considerations for cultural inclusion in programming tools. The insights gained, particularly regarding the use of national language and culturally relevant examples, have broader implications (as discussed in 5.3). As demonstrated by research in other contexts (e.g., [18, 38]), incorporating national language(s) and culture-specific examples into PLs and materials can significantly enhance student engagement and comprehension, offering a valuable model for diverse educational settings around the world.

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