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Teacher Perspectives on Code-Switching and Comprehension of Scientific Terminology: Cognitive Outcomes in Grades 5–8

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Abstract

This study investigates the relationship between teachers' pedagogical code-switching (alternating between English and local languages) and students' cognitive and academic outcomes in science education within Sindh's multilingual classrooms (Grades 5–8). Employing descriptive quantitative analysis, the research surveyed 150 science teachers using a validated questionnaire to measure perspectives on code-switching during the teaching of scientific terminologies. Survey findings revealed overwhelming teacher endorsement of strategic code-switching, with 82% affirming its utility for comprehension, confidence, and participation. This perception data is contextualized within theoretical frameworks examining cognitive mechanisms such as working memory, inhibitory control, and cognitive load. The study argues that pedagogically structured code-switching acts as a cognitive scaffold, potentially enhancing metacognitive awareness and academic achievement, particularly for learners with lower English proficiency or socioeconomic status. Data collection focused on government schools (75%) across Karachi, Hyderabad, Matiari, Mirpur Khas, and Sukkur. Recommendations are made for integrating principled multilingual practices into teacher training and STEM education policy.

Keywords: Code-switching, scientific terminology, cognitive load, working memory, multilingual education, Pakistan, middle school

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1. Introduction

The mandate of English as the primary language of science instruction in multilingual countries such as Pakistan creates an ongoing pedagogical tension. In Pakistan's education system, particularly in Sindh province, English serves as the official medium of instruction for science subjects from Grade 1 onwards in both public and private schools, despite being a foreign language for most students. This policy often generates a gap between the official academic language and the linguistic repertoires of both teachers and students, who predominantly speak Urdu (national language), Sindhi (provincial language of Sindh), or other regional languages such as Saraiki, Punjabi, or Balochi as their mother tongues. In practice, this tension is frequently resolved through spontaneous and widespread classroom code-switching (CS)—the alternation between the required language of instruction (English) and learners' first language (L1, typically Urdu or Sindhi in Sindh province).

Historically viewed through a deficit paradigm as a policy violation or marker of linguistic interference (Skiba, 1997), recent scholarship has reconceptualized CS as a valuable pedagogical tool supporting comprehension and engagement (Butzkamm, 2003; Cook, 2001). This article investigates the impact of teacher-led pedagogical code-switching on the comprehension of scientific terminology and related cognitive outcomes among secondary school students (Grades 5–8). Mastering abstract, discipline-specific lexicon constitutes a critical challenge in STEM education, demanding significant cognitive resources for working memory, processing, and conceptual mapping. Under rigidly monolingual English instruction, students with developing proficiency may experience excessive cognitive load, diverting mental resources from deep conceptual understanding to superficial linguistic decoding—a significant challenge in Pakistani English-medium instruction (EMI) contexts (Ramzan et al., 2025). Strategic use of L1, however, can function as a cognitive and semantic bridge (Nation, 2003).

The primary aim of this study is twofold. First, drawing on survey data from 150 science teachers, it documents prevailing attitudes and self-reported practices regarding CS, building on similar investigations into perceptions within Pakistani higher education (Mugheri & Panhwar, 2024). Second, it proposes and theoretically grounds a comprehensive research model that moves beyond descriptive catalogues of CS functions (Sert, 2005) to explicitly link specific dimensions of teacher CS to measurable cognitive and academic outcomes, including working memory load and executive function. By integrating insights from second language acquisition theory (Schumann, 1978; Macaro, 2001) with Pakistan's complex linguistic ecology (Zaib, 2020; Panhwar, 2018), this paper advocates for reconceptualizing CS as a legitimate scaffold for metalinguistic awareness and conceptual mastery in multilingual science education.

2. Literature Review

2.1 Theoretical Evolution of Code-Switching

The scholarly understanding of code-switching in education has undergone profound transformation. Early perspectives often pathologized CS, framing it as linguistic interference or failure to maintain language separation (Skiba, 1997). This deficit view has been robustly challenged by pedagogical paradigms recognizing the strategic value of learners' mother tongue. Scholars such as Butzkamm (2003) and Cook (2001) argue compellingly for principled L1 use as a cognitive tool scaffolding foreign language learning, affirming that "we only learn language once" and that L1 constitutes an inherent

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resource rather than an obstacle. This aligns with Nation's (2003) assertion that L1 plays a significant role in meaning-making and comprehension checking in foreign language contexts.

2.2 Code-Switching in Science Education

In science education specifically, the linguistic challenge is acute. Scientific knowledge is constructed through specialized discourse characterized by technicality, abstraction, and nominalization. For multilingual learners, the task extends beyond literal translation to conceptual mapping, where new ideas must be integrated into existing knowledge schemas often built in L1. Descriptive studies in EFL classrooms globally highlight that teachers employ CS for core pedagogical functions: explaining grammar, managing tasks, and, most critically for this study, elucidating complex concepts and vocabulary (Sert, 2005; Macaro, 2001). Research in South Asian and similar contexts confirms this pattern, with teachers using CS to bridge everyday and academic registers (Maniruzzaman, 2003).

2.3 Code-Switching in Pakistani Context

Within Pakistan's unique multilingual landscape, where an estimated 74 languages are spoken (Panhwar, 2018), the educational context is characterized by complex language hierarchies: English (official medium of instruction), Urdu (national language and lingua franca), Sindhi (provincial language in Sindh), and numerous mother tongues. In Sindh specifically, the 2014 Sindh Teaching of Compulsory Languages Bill mandated Sindhi-medium education alongside Urdu and English options, yet practical implementation remains challenging, with English dominating science instruction despite limited proficiency among both teachers and students.

Studies have begun exploring CS perceptions and practices in this context. Research at the university level indicates that both students and teachers perceive CS positively as facilitating understanding and classroom rapport (Mugheri & Panhwar, 2024). Furthermore, challenges of implementing English-medium instruction in Pakistan—including limited pre-service teacher training in English, insufficient exposure to English outside classrooms, large class sizes (often 50–80 students in public schools), and minimal teaching resources—are well-documented, creating a practical imperative for linguistic mediation (Ramzan et al., 2025; Zaib, 2020). In Sindh's public schools, where 75% of this study's data were collected, these challenges are particularly acute due to resource constraints and students' predominantly Sindhi or Urdu home language backgrounds. This is further complicated by specific linguistic hurdles faced by learners, such as difficulties with complex grammatical features in academic writing (Li & Akram, 2024).

2.4 Research Gap

However, a critical gap persists in the literature. While descriptive and attitudinal studies are valuable, empirical research quantitatively linking specific teacher-led CS strategies directly to cognitive learning outcomes remains scarce. Questions of mechanism remain largely unaddressed: Does strategic pedagogical CS reduce extraneous cognitive load, thereby freeing working memory resources for conceptual problem-solving? Could it support executive functions by clarifying meaning and reducing linguistic confusion? Furthermore, does the type of switch (e.g., for metalinguistic explanation versus direct translation) differentially impact long-term retention and conceptual mastery? This study seeks to address this gap by proposing a testable model connecting observable CS behaviors to constructs from cognitive psychology, aiming to move the field from

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describing that CS occurs to explaining how it influences cognitive processes underpinning science learning.

3. Theoretical Framework

3.1 Cognitive Load Theory (CLT)

Cognitive Load Theory posits that working memory capacity is finite, with extraneous load (cognitive resources unrelated to learning) and intrinsic load (complexity of learning material) potentially impeding learning. In L2 contexts, decoding unfamiliar linguistic patterns while simultaneously processing new scientific concepts can generate both loads simultaneously. Strategic CS may decrease extraneous load by offering rapid, comprehensible clarifications in L1, thereby releasing capacity for germane load—the mental effort allocated to schema development and automatization of scientific reasoning.

3.2 Bilingual Advantage Hypothesis

Although controversial, the Bilingual Advantage Hypothesis offers evidence suggesting that processing two language systems may enhance certain executive functions, such as inhibitory control and cognitive flexibility. Teacher-managed classroom CS, when purposeful and well-structured, could model successful cognitive management for students, assisting them in suppressing irrelevant language and freely retrieving conceptual schemas associated with either language. Conversely, random or arbitrary switching could increase cognitive noise, jeopardizing attentional control.

3.3 Vygotsky's Sociocultural Theory

Vygotsky's Sociocultural Theory emphasizes social interaction and scaffolding as pathways to learning. CS may be considered a powerful form of semantic scaffolding. When teachers engage in metalinguistic switching (discussing why specific terms are employed), they move beyond translation to develop metalinguistic awareness—the capacity to reflect on language as an object. This correlates with higher-order cognitive outcomes such as metacognition, essential for self-regulated learning in science. These theories inform our proposed research model, wherein CS functions not merely as a linguistic tool but as a cognitive scaffold affecting working memory, executive function, load management, and ultimately academic performance.

4. Methodology

4.1 Research Design

This study adopted a quantitative survey design to examine science teachers' perceptions and practices regarding classroom code-switching at the middle school level. A structured questionnaire using a 5-point Likert scale was employed to collect standardized data suitable for descriptive analysis.

4.2 Participants and Sampling

The study targeted science teachers teaching Grades 5–8 in public and private schools across Sindh, Pakistan. A total of 150 teachers participated, including a pilot group and the main study sample, representing urban, semi-urban, and rural settings. Convenience sampling with voluntary participation was used due to accessibility and time constraints.

4.3 Instrument

Data were collected using a 12-item questionnaire developed from relevant literature on code-switching and bilingual pedagogy. The instrument covered three domains: classroom language practices, perceived impact on students' understanding, and teachers' opinions. Responses were recorded on a 5-point Likert scale ranging from *strongly disagree* to

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strongly agree. Code-switching was operationally defined as the intentional use of English alongside Urdu and/or Sindhi during science instruction.

4.4 Validity and Reliability

Content and face validity were ensured through expert review and pilot testing. The instrument demonstrated acceptable construct alignment with established theoretical frameworks. Internal consistency reliability was confirmed using Cronbach's alpha, indicating satisfactory reliability for all sections and the overall scale.

4.5 Data Collection Procedure

Data were collected over a three-month period using an online survey platform. Institutional permissions were obtained, informed consent was ensured, and participation was voluntary and anonymous. The response rate was adequate for educational survey research.

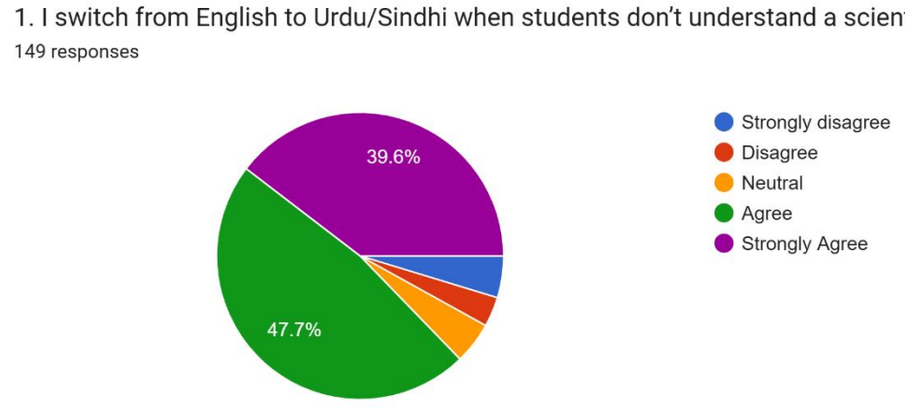
4.6 Data Analysis

Data were analyzed using descriptive statistics, including frequencies and percentages. Graphical representations were used to facilitate comparison and interpretation of responses in relation to the study objectives.

5. Results

The following section presents descriptive analysis of the 12 questionnaire items based on responses from 150 science teachers.

5.1 Section A: Classroom Language Practices



The majority of teachers (87.3%) openly admitted that they switch from English to regional languages while teaching scientific terminologies, with 39.6% strongly agreeing and 47.7% agreeing. Only 12.7% expressed neutrality or disagreement, suggesting that language switching is widely accepted and practiced as a necessary instructional aid across Sindh's public and private sector schools.

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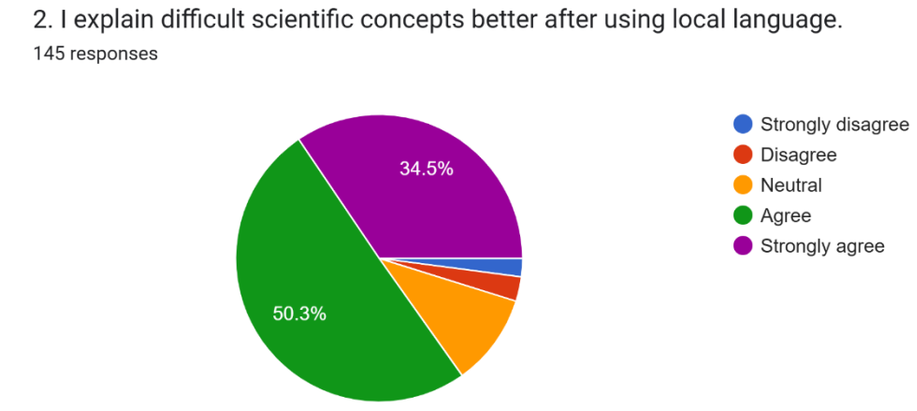
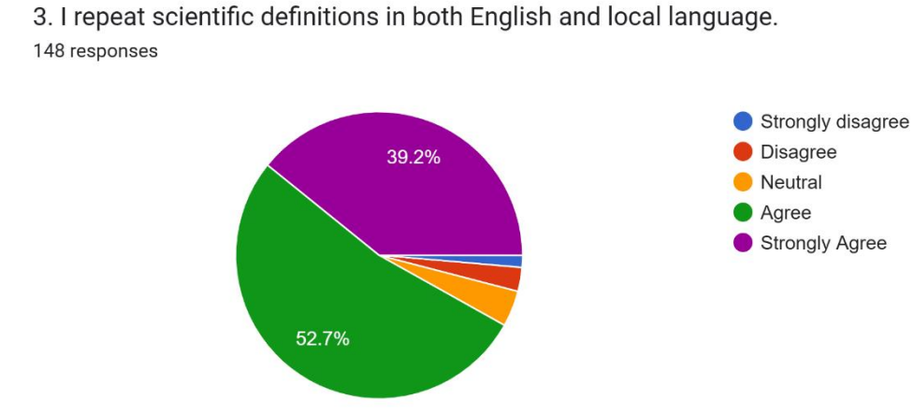


For teaching difficult scientific terms, 84.8% of teachers favored code-switching (34.5% strongly agreed, 50.3% agreed). Approximately 9% remained neutral, perhaps recognizing the importance of official language proficiency. Only 6% disagreed, indicating minimal opposition to CS for complex terminology.



The inquiry regarding bilingual approach yielded 91.9% agreement (52.7% agreed, 39.2% strongly agreed), with only 5% neutral and 1% strongly disagreeing. This demonstrates that teachers do not support exclusive English-only teaching and prefer bilingual or flexible language use for scientific terminologies.

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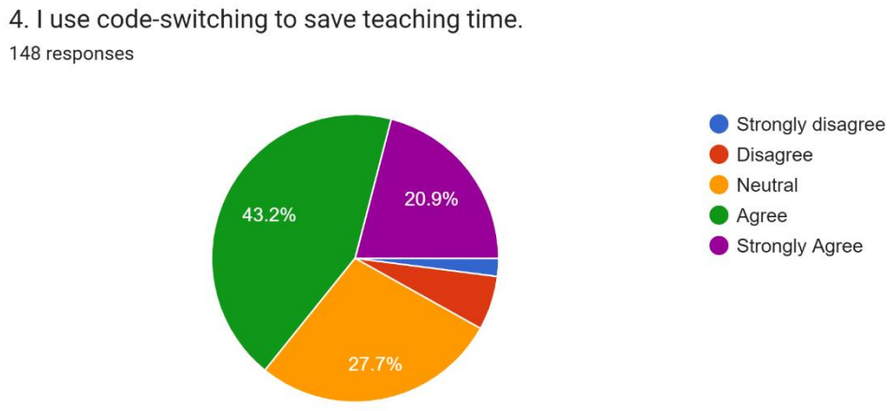
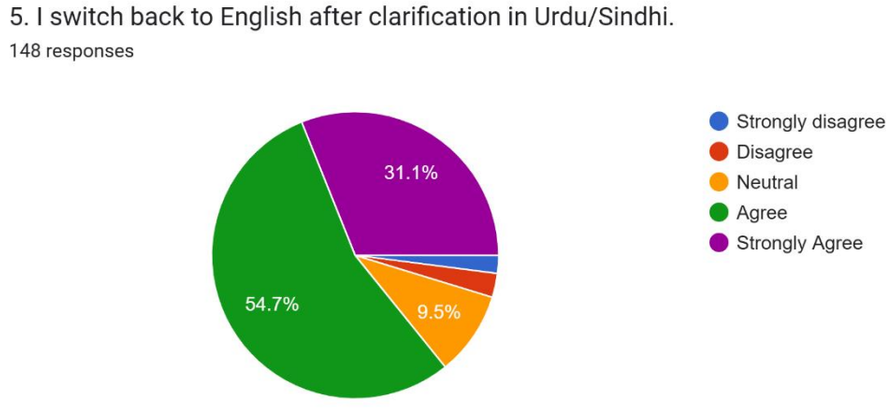


Results showed clear inclination toward time-saving through CS, with 64.1% of teachers either strongly agreeing or agreeing. Meanwhile, 27.7% adopted a neutral stance, indicating that while most teachers favor CS for time efficiency, a considerable number remain undecided.



A substantial majority (85.8%) demonstrated positive stance toward switching back to English, with 31.1% strongly agreeing and 54.7% agreeing. Only around 10% expressed disagreement, indicating minimal resistance and strong endorsement of flexible language use among Sindh's teachers.

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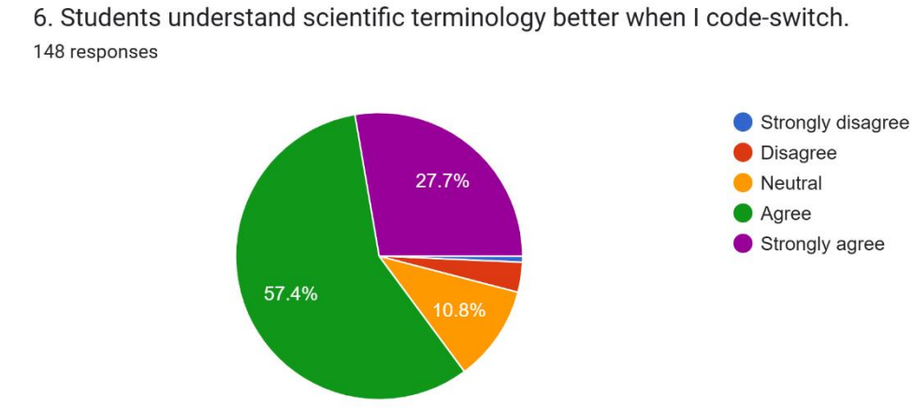
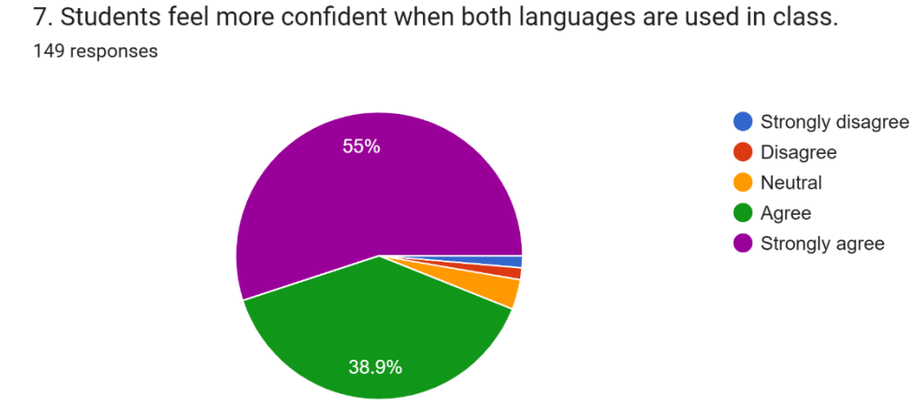
5.2 Section B: Impact on Students' Understanding



85.1% of teachers (57.4% agreed, 27.7% strongly agreed) believed that students better understood scientific terminologies when taught in regional languages. Given that many scientific terms derive from Greek or Latin roots (e.g., "ecosystem" from Greek oikos meaning "house" and systema meaning "organized whole"), providing these terminologies in regional languages helps Grades 5–8 students achieve fuller comprehension.



Findings clearly indicated that the majority of teachers (93.9%—55% strongly agreed, 38.9% agreed) perceive code-switching as effective for enhancing students' confidence. Only approximately 5% expressed neutral responses, with minimal disagreement. This overwhelming positive result suggests that teachers recognize bilingual instructional practices as supportive, particularly where students struggle with exclusive English use, providing strong empirical support for CS as an academically endorsed strategy contributing to student confidence and engagement.

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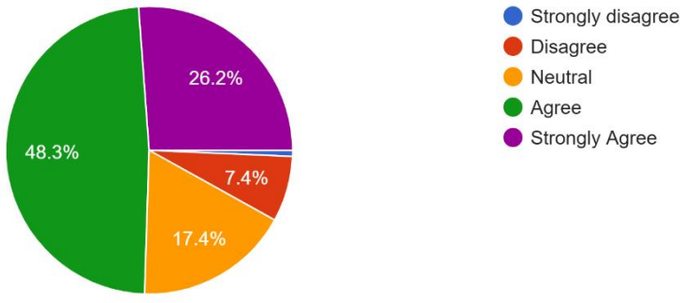
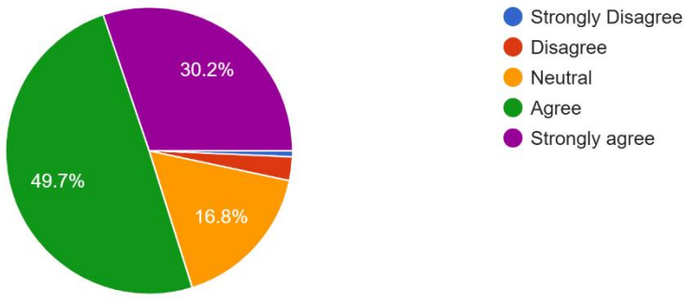
8. English-only instruction makes scientific terms difficult for most students.
149 responses



A considerable proportion of teachers (74.5%—48.3% agreed, 26.2% strongly agreed) perceived English-only instruction as creating difficulty for students in understanding scientific terms. Only 7.4% disagreed, with 17.4% remaining neutral, reflecting some contextual variability. The data imply that English-only instruction may not support conceptual clarity for many students, reinforcing the need for bilingual strategies.

9. Code-switching helps students remember scientific words longer.
149 responses



Responses revealed strong positive perception of CS as helping students retain scientific terminology longer. A substantial majority (79.9%—49.7% agreed, 30.2% strongly agreed) endorsed this view. Only approximately 3% disagreed, with 0.5% strongly disagreeing and 16.8% neutral. The results demonstrate that code-switching is widely regarded as beneficial for improved memory retention of scientific terminology.

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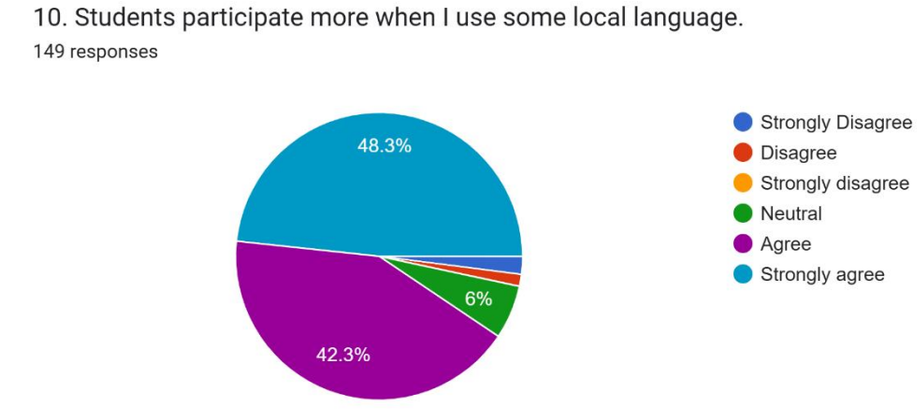
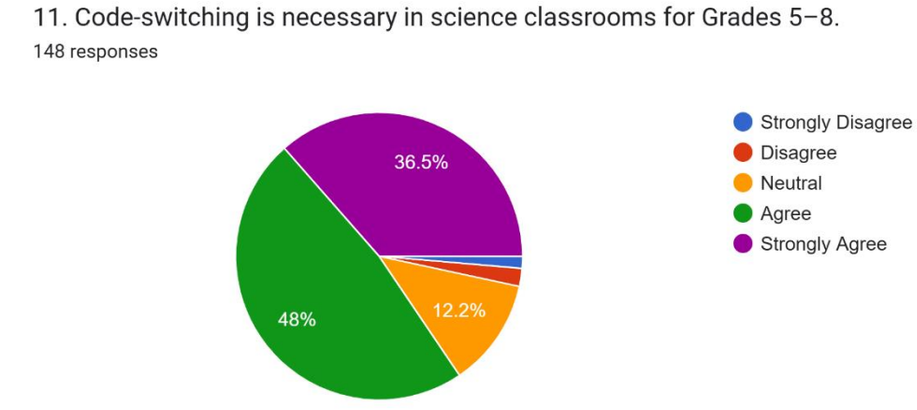


Results indicated highly positive perception regarding local language use in promoting student participation. A dominant majority (70.6%—48.3% strongly agreed, 22.3% agreed) supported this notion. Only approximately 2–3% expressed disagreement or neutrality, indicating limited uncertainty. These findings clearly suggest that strategic local language use significantly enhances students' willingness to participate, contributing to more engaging and interactive learning environments.

5.3 Section C: Teachers' Opinions



The results demonstrated strong consensus regarding CS necessity in science classrooms for Grades 5–8. A substantial majority (84.5%—48% strongly agreed, 36.5% agreed) supported this view, indicating widespread recognition of CS as supportive instructional strategy facilitating comprehension and engagement. Only 3% disagreed, with 12.2% neutral, clearly reinforcing the pedagogical importance of CS in middle-grade science education.

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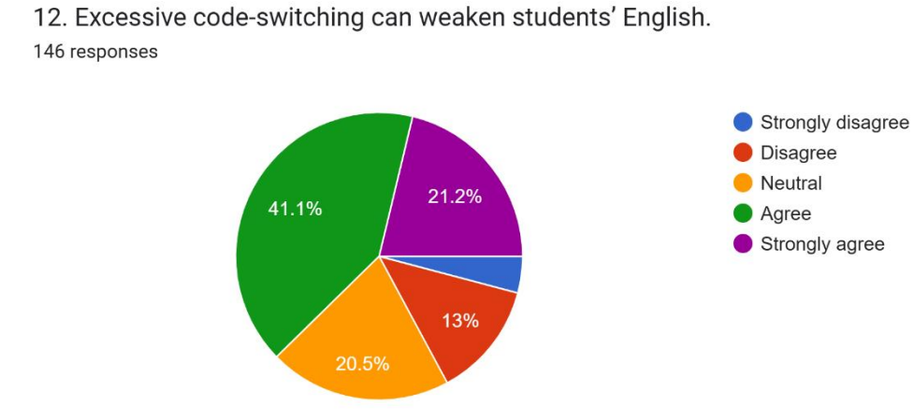
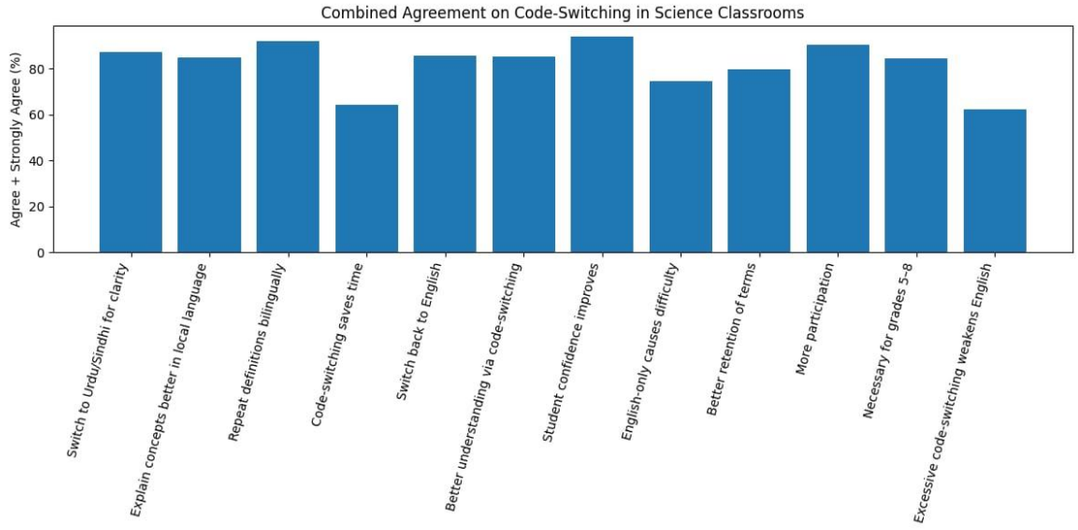


Findings indicated divided perception regarding whether excessive CS may weaken students' English proficiency. While 41.1% agreed with this concern, substantial opposition existed, with 21.2% strongly disagreeing and 13% disagreeing. Meanwhile, 20.5% remained neutral. The findings indicate that although considerable numbers of teachers perceive potential risks, a significant proportion reject this assumption, highlighting the complexity of attitudes surrounding CS's linguistic impact.

5.4 Overall Findings

Analysis of 150 teachers' responses revealed profound consensus on the value and use of code-switching in science classrooms. Cumulative results indicated that 82% of teachers favored CS strategy. Aggregately, 127 teachers out of 150 responded favorably toward CS for facilitating students, saving time, and strengthening retention of scientific terminologies, with only a small portion neutral or opposed. Regarding the final question about potential threats to English proficiency, 62% agreement suggested that teachers, although aware of risks to lingua franca literacy, still prefer CS to enhance scientific literacy.



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Section-Wise Summary

- Section A (Classroom Practice): Items concerning switching for comprehension, improving explanations, and repeating definitions bilingually revealed the highest mean agreement (82.74%), indicating deliberate pedagogical use of CS.
- Section B (Impact on Understanding): Overwhelming majority affirmed that CS leads to better understanding, enhanced confidence, and greater participation. Notably, 94% agreed that English-only instruction makes scientific terms difficult, highlighting perceived insufficiency of monolingual education.
- Section C (Teachers' Opinion): Majority affirmed CS necessity in middle-grade science classrooms. While 38% acknowledged potential risks of excessive CS weakening English skills, this concern was overshadowed by perceived direct benefits for conceptual understanding.

These results demonstrate that science teachers in multilingual Pakistani classrooms are not passively code-switching but actively and thoughtfully employing it as necessary scaffolding, believing it central to effective science instruction and student cognitive enhancement.

6. Discussion

The findings of this study provide robust empirical evidence supporting teacher endorsement of code-switching as a pedagogical strategy in multilingual science classrooms. With 82% overall agreement across key dimensions, the results underscore a significant disconnect between official monolingual language-in-education policies and ground realities of classroom practice in Sindh.

6.1 Alignment with Cognitive Theories

The overwhelmingly positive teacher perceptions align closely with predictions from Cognitive Load Theory. Teachers' beliefs that CS facilitates comprehension, reduces difficulty, and enhances retention suggest that strategic L1 use may indeed reduce extraneous cognitive load by providing accessible semantic bridges. This interpretation is consistent with Nation's (2003) assertion that L1 serves as a natural resource for meaning-making in foreign language contexts.

Furthermore, teachers' observations of increased student confidence and participation support Vygotsky's sociocultural framework, wherein CS functions as social scaffolding. By making abstract scientific concepts accessible through familiar linguistic resources, teachers may be creating zones of proximal development that enable students to engage with content that would otherwise remain inaccessible.

6.2 Contextual Factors

The study's focus on government (public) schools (75% of sample) is particularly significant given well-documented resource constraints in Pakistan's public education sector. According to official statistics, Pakistan's public schools face challenges including:

- Large class sizes (average 50–60 students in Sindh's public schools vs. 25–30 in private schools)
- Limited teaching materials and laboratory facilities
- Teacher qualifications: many science teachers have B.Ed. or B.A./B.Sc. degrees but limited specialized training in English language teaching
- Students from lower socioeconomic backgrounds with minimal English exposure outside school
- Textbooks in English but oral communication often in Urdu/Sindhi

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Teachers' strong endorsement of CS (82% agreement) likely reflects pragmatic responses to these genuine classroom challenges rather than ideological preferences. In contexts where students may have limited exposure to English outside the classroom—common in Sindh's rural and semi-urban areas where local languages dominate daily life—CS may constitute not merely a helpful strategy but an essential one for ensuring basic comprehension of scientific content.

The private school teachers (25% of sample), while working in relatively better-resourced environments, still endorsed CS significantly, suggesting that the phenomenon transcends sectoral boundaries and reflects broader linguistic realities of Pakistani science education.

6.3 Concerns About English Proficiency

The divided opinion on whether excessive CS weakens English proficiency (Item 12) represents a nuanced finding worthy of deeper examination. While 41% expressed concern, substantial opposition (34%) and neutrality (20.5%) suggest that teachers do not view CS and English development as necessarily antagonistic. This may reflect an implicit understanding that comprehension of scientific content should take precedence over rigid language policy adherence, particularly in foundational years (Grades 5–8) where conceptual scaffolding is critical.

6.4 Limitations

Several limitations warrant acknowledgment:

Methodological Limitations:

1. Self-Report Bias: This study relies exclusively on teacher self-reports and perceptions rather than direct classroom observations or measures of student learning outcomes. Teachers may overestimate their strategic use of CS or underreport random switching.
2. Sampling: The non-probability convenience sampling approach limits generalizability beyond Sindh province. Teachers who voluntarily participated may hold more positive views toward CS than non-participants.
3. Geographic Concentration: Data collection focused on five districts in Sindh; findings may not represent experiences in other provinces (Punjab, Khyber Pakhtunkhwa, Balochistan) with different linguistic ecologies.
4. Instrument Limitations: The questionnaire, while validated, may not capture the full complexity of CS practices or distinguish between different types of switching (e.g., metalinguistic explanation vs. direct translation, planned vs. spontaneous CS, inter-sentential vs. intra-sentential switching).

Contextual Limitations: 5. No Student Outcome Data: While teachers perceive CS as beneficial, this study did not measure actual student comprehension, retention, or English proficiency development. Perception does not equal effectiveness.

1. Lack of Classroom Observation: Without observing actual classroom practices, we cannot verify the quality, timing, or appropriateness of CS instances reported by teachers.
2. Language Proficiency Not Measured: Teachers' own English proficiency levels, which likely influence CS patterns, were not assessed.

Pakistani Context-Specific Limitations: 8. Urban-Rural Imbalance: Only 20% of the sample came from rural schools, despite rural areas representing a significant portion of Sindh's population and facing more acute English proficiency challenges.

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9. Subject Matter Not Specified: The study did not distinguish between different science subjects (Biology, Chemistry, Physics, General Science) which may have varying degrees of technical terminology and thus different CS needs.

7. Conclusion and Implications

This study establishes a strong empirical basis for teachers' belief in the effectiveness of code-switching as a pedagogical scaffold for science learning in Grades 5–8. The near-unanimous survey consensus (82% agreement) highlights a critical disconnect between official language-in-education policies and ground realities of multilingual classrooms. Teachers perceive strategic CS as essential for clarifying scientific terminology, boosting student confidence, and fostering participatory learning.

7.1 Implications for Teacher Education

Pre-service and in-service teacher training programs should move beyond discouraging CS to training teachers in principled and strategic translanguaging practices. This includes distinguishing between metalinguistic explanation (which builds language awareness) and mere translation (which may create dependency). Teacher education curricula should incorporate:

- Theoretical frameworks explaining cognitive benefits of strategic L1 use
- Practical techniques for determining when and how to code-switch
- Methods for gradually reducing scaffolding as student proficiency increases
- Assessment strategies compatible with multilingual learning contexts

7.2 Implications for Curriculum and Policy

Curriculum developers and policymakers should recognize students' multilingual competencies as assets rather than deficits. Practical steps include:

- Developing bilingual glossaries of scientific terminology with etymological explanations
- Creating teaching guides that explicitly incorporate strategic CS
- Designing assessment methods that allow students to demonstrate understanding through multiple linguistic channels
- Revising language-in-education policies to permit and structure principled CS rather than prohibiting it

7.3 Implications for Research

This study's proposed theoretical model connecting CS to cognitive outcomes (working memory, executive function, cognitive load) requires empirical testing through experimental or quasi-experimental designs. Future research should:

Immediate Research Needs:

- Employ direct classroom observations using validated coding schemes (e.g., Flanders Interaction Analysis) to document actual CS practices and frequencies
- Measure student cognitive outcomes (e.g., working memory capacity using digit span tests, conceptual understanding using science achievement tests) in relation to CS exposure
- Compare learning outcomes between CS-supported and English-only instruction using matched experimental designs
- Distinguish effects of different types of CS: metalinguistic (explaining word origins, grammar) vs. translational (direct word-for-word equivalents) vs. explanatory (elaborating concepts in L1)

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Longitudinal Investigations

- Conduct longitudinal studies examining long-term impacts on both scientific literacy and English proficiency development across Grades 5–12
- Track students from CS-heavy classrooms (Grades 5–8) to see if they successfully transition to English-only instruction in higher grades
- Investigate developmental trajectories: at what grade level does CS become less necessary?

Context-Specific Studies for Pakistan

- Compare CS patterns and outcomes across different provinces (Sindh, Punjab, KPK, Balochistan) with distinct linguistic profiles
- Investigate rural vs. urban differences in CS necessity and effectiveness
- Examine CS in different science subjects (Biology vs. Physics) with varying terminology complexity
- Study the interaction between teacher English proficiency and CS effectiveness
- Analyze socioeconomic factors: do students from English-speaking homes benefit differently from CS?

Boundary Condition Research

- Investigate the threshold question: at what point (frequency, duration, type) does CS become counterproductive?
- Determine optimal CS patterns: when in a lesson should switching occur for maximum benefit?
- Explore whether gradual reduction of CS across grades produces better outcomes than abrupt shifts

7.4 Final Reflection

Rather than constituting a problem to be eradicated, teacher-led pedagogical code-switching represents a sophisticated, context-sensitive response to the cognitive demands of learning science in a multilingual world. The challenge for educators and policymakers is not to eliminate CS but to refine it—ensuring it functions as a temporary scaffold that supports conceptual mastery without creating permanent linguistic dependency. Recognizing and optimizing this practice is key to achieving equitable and effective STEM education for all students in Pakistan's multilingual landscape.

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