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Accessibility meets the Science of Reading in Spanish English Dual language classrooms

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Abstract: This article advances a conceptual framework defining inclusive biliteracy—the coordinated development of literacy across Spanish and English within instructional systems designed to be equitable by default—and argues that effective biliteracy instruction requires coordinated design across four dimensions: structured literacy, cross-linguistic development, UDL-based accessibility, and technology-supported instruction. Drawing on an integrative review across cognitive reading science, bilingual education, accessibility research, and educational technology, the article establishes that foundational literacy components remain essential in bilingual contexts when coordinated across languages and supported by oral language development and cross-linguistic transfer; that multilingual learners with disabilities achieve strong outcomes under systematic, scaffolded, accessible instruction; and that assistive and AI-mediated technology extends access when aligned with instructional goals. The framework positions inclusive biliteracy as both an educational construct and an infrastructural condition for equity and human capital development, and generates five testable propositions operationalizable through multilevel modeling, structural equation modeling, or cluster-randomized designs. The contribution is conceptual: a theoretically grounded, multi-domain model specifying the conditions under which biliteracy instruction becomes inclusive for all learners.

Keywords: accessibility; bilingual education; Science of Reading; Spanish English dual language; AI-mediated learning.

1. Introduction

U.S. public schools educate a large and growing population of students who develop literacy across more than one language. English learners represented 10.6% of all public-school students in 2021, or approximately 5.3 million learners, with higher concentrations in the early grades. In kindergarten, this proportion reaches 14.7% before declining as some students are reclassified as English proficient (National Center for Education Statistics, 2024). Multilingualism is not peripheral to elementary education. It is a defining condition that must shape the design and delivery of literacy.

Spanish–English dual language immersion (DLI) programs respond directly to this reality. These programs aim to develop bilingualism, biliteracy, and academic achievement through sustained instruction in two languages. National reports document their continued expansion across states and districts. The What Works Clearinghouse defines dual language programs as models that provide at least 50% of instruction in a partner language and extend across the elementary grades. Evidence from RAND and related studies shows positive long-term academic outcomes, particularly for English learners (Institute of Education Sciences, What Works Clearinghouse, 2022; Steele et al., 2017).

Early literacy remains a critical threshold within this context. In grades K–3, approximately 15% of students are multilingual learners. By third grade, students are expected to transition from learning to read to reading to

learn, a shift that continues to shape instructional priorities and intervention systems. Students who do not develop strong foundational literacy skills during this period face increased risk of long-term academic difficulty (Amplify Education, 2023; Annie E. Casey Foundation, 2010). Literacy design in the early grades carries lasting consequences for multilingual learners.

The Science of Reading (SoR) has become a dominant force in shaping literacy policy and instructional practice. The term refers to converging evidence from cognitive psychology, linguistics, neuroscience, and education on how reading develops and how it can be taught effectively. In practice, SoR is associated with explicit and systematic instruction in phonological awareness, phonics, decoding, word recognition, fluency, vocabulary, oral language, and comprehension (Castles et al., 2018; Snowling et al., 2022). These principles influence legislation, curriculum adoption, and teacher preparation across the United States.

Current SoR implementation frameworks, however, contain three specific structural limitations that this article directly addresses. First, most presuppose phonemic inventories and orthographic features native to English, creating a phonological mismatch when applied to Spanish-dominant learners without modification. Second, existing SoR frameworks lack a principled model for cross-language instructional bridging – for determining when and how to make the relationships between two linguistic systems explicit. Third, the monolingual assessment benchmarks embedded in prevailing SoR-aligned policy frameworks (e.g., state literacy laws) increase the risk of misidentification for multilingual learners and fail to account for the bilingual development trajectories documented in the research literature. These are not peripheral concerns; they are structural gaps that undermine the effectiveness of SoR implementation in dual language contexts (Kittle et al., 2024; National Academies of Sciences, Engineering and Medicine, 2017).

Spanish–English bilingual learners illustrate these dynamics clearly. Spanish and English share alphabetic features but differ in orthographic transparency, phonology, and morphology. Spanish supports early decoding through consistent grapheme–phoneme relationships, while English introduces greater variability. Skills such as phonological awareness, vocabulary, and metalinguistic knowledge operate across languages when instruction makes these relationships explicit. Cross-linguistic transfer supports reading development when instruction is coordinated across both languages (Míguez-Álvarez et al., 2022; Sun et al., 2021; van der Velde et al., 2019).

Literacy instruction in dual language classrooms must address linguistic complexity alongside learner variability. Students differ in language proficiency, disability status, prior educational experience, and access to resources. Instruction that assumes uniform development creates barriers to participation. Accessibility is not an additional layer. It is a core condition of effective literacy instruction in bilingual settings.

Universal Design for Learning (UDL) provides a framework for designing instruction that anticipates variability from the outset. UDL emphasizes multiple means of engagement, representation, and action and expression (Meyer et al., 2014). In bilingual literacy contexts, this includes multimodal supports, scaffolded language opportunities, and a clear separation between learning goals and the means used to access them. UDL supports rigorous instruction by ensuring that all learners can engage with it.

Bilingual learners with disabilities require explicit inclusion within these systems. Research shows that these students achieve biliteracy and academic success in dual language programs when instruction is intentional, coordinated, and adequately supported (Genesee et al., 2022). Exclusion reflects institutional design, not learner capacity. Bilingualism serves as an asset for cognitive and academic development when supported by equitable instructional practices (Cummins, 1983; Genesee et al., 2022).

Educational technology further shapes literacy instruction. Digital tools, assistive technologies, and AI-mediated systems support access, practice, and feedback. In Spanish–English contexts, these tools provide multimodal input, pronunciation support, text-to-speech, and structured language scaffolds. For students with disabilities, they reduce barriers related to decoding, written expression, and language production. Their effectiveness depends on alignment with instructional goals and pedagogical design (Hurwitz et al., 2022; Wood et al., 2018).

This article defines literacy instruction in Spanish–English dual language settings as an integrated system. It advances a conceptual framework that aligns structured literacy, bilingual development, accessibility, and technology-supported instruction. The analysis examines how SoR-informed instruction operates across languages, how UDL supports access, and how technology extends biliteracy development. This framework positions inclusive biliteracy as a condition for equitable and sustainable educational systems.

2. Literature Review

This review draws on five intersecting bodies of scholarship: cognitive reading science, bilingual education, sociocultural theory, accessibility-oriented instructional design, and educational technology. Together, these domains explain how literacy develops in bilingual learners, how instruction operates across languages, and how access is structured for diverse learners. The review focuses on points of convergence that support a coherent model of biliteracy instruction.

2.1 Science of Reading and Foundational Literacy

The Science of Reading (SoR) literature establishes reading as an integrated process involving decoding and linguistic comprehension. The Simple View of Reading defines comprehension as the product of these two components (Gough & Tunmer, 1986; Hoover & Gough, 1990). Scarborough's Reading Rope extends this model by identifying the interacting strands that contribute to reading development, including phonological awareness, decoding, vocabulary, language structures, and background knowledge (Scarborough, 2001).

The National Reading Panel identified phonemic awareness, phonics, fluency, vocabulary, and comprehension as central components of effective instruction (National Reading Panel, 2000). Subsequent work situates these components within broader linguistic systems, including morphology, syntax, and semantics (Snowling et al., 2022; Seidenberg, 2017).

This body of research is widely applied in policy and practice. However, its original scope did not center on multilingual learners, and the current SoR-aligned policy framework has largely extended monolingual models without systematic adaptation. Critics have noted that applying phonics-first SoR models without modification can pathologize reading development that follows a bilingual rather than a monolingual trajectory (cf. Paris, 2005). This framework directly addresses that concern: the problem is not with structured literacy as such, but with its decontextualized application to populations whose linguistic development differs structurally from the populations on which the original research was conducted. Current scholarship extends SoR principles to bilingual contexts by examining how foundational skills operate across languages (Castles et al., 2018; Kittle et al., 2024).

2.2 Bilingual Literacy and Cross-Linguistic Development

Literacy development in bilingual learners is shaped by cross-linguistic interaction. August and Shanahan (2006) demonstrate that literacy-related skills transfer across languages and that instruction must address oral language, linguistic relationships, and prior experiences with print. The National Academies (2017) define home languages as developmental resources that support cognition, identity, and academic learning. Cummins's theory of linguistic interdependence explains how proficiency in one language supports literacy development in another through shared underlying processes (Cummins, 1979).

Research on cross-linguistic transfer specifies these relationships. Transfer depends on orthographic structure, typological similarity, oral language proficiency, and metalinguistic awareness. In Spanish-English contexts, phonological awareness, decoding, and metalinguistic skills transfer across languages when instruction makes these relationships explicit. Vocabulary development requires direct instruction in both languages (Míguez-Álvarez et al., 2022; Sun et al., 2021; van der Velde et al., 2019). Biliteracy development, therefore, requires coordinated instruction across languages: foundational skills remain central, but their acquisition is shaped by linguistic interaction rather than isolated instruction.

2.3 Dual Language Education and Program Design

Research on dual language education defines the institutional and instructional conditions that support biliteracy. Lindholm-Leary (2001) shows that sustained implementation and instructional quality are central to long-term outcomes. Howard et al. (2018) define dual language education as a comprehensive model that integrates curriculum, assessment, leadership, and community engagement. Biliteracy development depends on coordinated program design rather than language allocation alone. Large-scale studies confirm that dual language programs support academic achievement while promoting bilingualism and biliteracy (Institute of Education Sciences, What Works Clearinghouse, 2022; Steele et al., 2017). These findings establish that structured literacy and bilingual instruction operate within the same instructional system, not as parallel but unconnected tracks.

2.4 Sociocultural Perspectives on Literacy

Literacy development in bilingual contexts is shaped by social interaction and cultural meaning-making. Vygotsky's theory positions learning as socially mediated, with language functioning as a central tool in cognitive development. The concept of funds of knowledge demonstrates that learners draw on cultural and linguistic resources in meaning-making processes (Moll et al., 1992).

The multiliteracies framework (New London Group, 1996) and translanguaging theory (García & Wei, 2014) both expand what counts as literacy beyond print and monolingual norms. Translanguaging theory defines bilingual language use as an integrated system in which learners mobilize their full linguistic repertoire dynamically rather than switching between two separate codes. This framework draws productively on this insight while noting an important boundary: translanguaging frameworks center language use but do not operationalize instruction in SoR-aligned foundational skills. Multiliteracies theory expands the definition of text but does not

address disability access systematically. The integrated model proposed here extends both frameworks by adding explicit instructional design requirements (structured literacy) and proactive accessibility planning (UDL) that neither framework addresses in depth. This is the specific contribution of the inclusive biliteracy framework over existing approaches.

2.5 Accessibility and Universal Design for Learning

Universal Design for Learning (UDL) provides a framework for designing instruction that anticipates learner variability rather than retrofitting accommodations after barriers emerge. UDL defines three core principles: multiple means of engagement, representation, action and expression (Meyer et al., 2014). In literacy instruction, UDL supports access to rigorous content by varying how learners engage with material and demonstrate understanding. Foundational skills instruction remains explicit and systematic, while access pathways are flexible.

Accessibility in bilingual contexts includes both disability-related supports and linguistic access. Instruction must remove barriers related to decoding, language comprehension, and expression. UDL operationalizes access by aligning instructional goals with multiple entry points, ensuring that the construct being assessed is not conflated with the mode of access. This distinction between what is taught and how it is accessed is critical for maintaining both rigor and equity.

2.6 Bilingual Learners with Disabilities

Research on bilingual learners with disabilities establishes inclusion as a core condition of equitable literacy instruction. Cummins (1983) challenged deficit-based assumptions that restricted access to bilingual education for students with disabilities. Recent research confirms that bilingual learners with disabilities achieve strong academic and linguistic outcomes in dual language programs when instruction is coordinated and supported (Genesee et al., 2022). Exclusion reflects institutional barriers rather than incompatibility between bilingualism and disability.

This literature also identifies persistent issues of misidentification and disproportionality. Assessment systems that do not account for bilingual development increase the risk of inappropriate classification. Instructional systems must distinguish language development from disability and provide equitable access to biliteracy pathways.

2.7 Educational Technology

Educational and assistive technology expands access to, practice of, and feedback in literacy instruction. Assistive tools such as text-to-speech, read-aloud systems, and speech recognition support comprehension and expression for students with reading and language-based disabilities (Wood et al., 2018). Digital literacy platforms support structured skill development when integrated with explicit instructional goals (Hurwitz et al., 2022). In bilingual contexts, translation scaffolds, bilingual glossaries, and pronunciation tools support vocabulary and comprehension when used as part of coordinated instruction.

AI-mediated tools represent an emerging layer with potential for adaptive feedback and personalized practice (Paglialunga & Melogno, 2025). The evidence base remains preliminary. Critics have raised a substantive concern: that AI-mediated and algorithmic literacy tools risk reducing instruction to decontextualized skill rehearsal, displacing teacher judgment and culturally sustaining practice (cf. Selwyn, 2019, on the datafication of education). This framework addresses this concern directly by establishing that technology must be pedagogically aligned and teacher-mediated; it cannot function as a standalone solution. This constraint is a feature, not a limitation, of the model.

2.8 Synthesis and Theoretical Positioning

Literature establishes a coherent model of literacy development. Reading science defines foundational processes. Bilingual education research shows that these processes operate across languages through transfer and coordinated instruction. Sociocultural theory positions literacy as socially mediated and culturally grounded. UDL defines access as a core feature of instructional design. Research on bilingual learners with disabilities establishes inclusion as essential to equitable systems. Technology literature identifies conditions under which digital tools support rather than displace learning.

These domains converge on a single conclusion: biliteracy instruction requires coordinated design across linguistic, cognitive, social, and accessibility dimensions. The framework proposed in this article is distinguished from existing models in three specific ways. First, unlike translanguaging frameworks, it operationalizes foundational skill instruction explicitly across languages rather than treating language use as inherently flexible and student-directed. Second, unlike multiliteracies frameworks, it systematically addresses the needs of learners

with disabilities through UDL. Third, unlike SoR implementation frameworks as currently applied in policy, it builds cross-linguistic transfer and bilingual developmental trajectories into the architecture of literacy instruction rather than treating them as supplementary adaptations.

3. Conceptual Framework for Inclusive Biliteracy

3.1 Framework Overview

This article advances a conceptual framework for inclusive biliteracy built on four coordinated dimensions: (1) structured literacy aligned with the Science of Reading, (2) bilingual and cross-linguistic development, (3) accessibility through Universal Design for Learning (UDL), and (4) technology-supported instruction.

Inclusive biliteracy, as a construct, is defined along four corresponding dimensions. The linguistic dimension refers to proficiency and literacy development in both Spanish and English, including the ability to mobilize cross-linguistic knowledge to support comprehension and production. The accessibility dimension refers to the proactive removal of barriers for learners with disabilities and linguistic differences, designed into instruction from the outset rather than added as accommodation after the fact. The instructional design dimension refers to coordinated, cross-linguistic, structured instruction aligned with SoR, and to explicit, cumulative, and systematically adapted instruction across both languages. The participation dimension refers to equitable engagement in biliteracy pathways regardless of disability status or language background. This four-part definition distinguishes inclusive biliteracy from general biliteracy frameworks (which do not systematically address disability access) and from UDL-only approaches (which do not address cross-linguistic transfer). The term "inclusive biliteracy framework" is used throughout to refer to the instructional design model; "inclusive biliteracy" refers to the educational outcome construct.

The framework defines literacy instruction as a system rather than a sequence of independent components. Structured literacy establishes the developmental architecture of reading. Bilingual development determines how those skills are acquired and applied across languages. Accessibility ensures that all learners can engage with instruction. Technology extends access and supports differentiation. When a single dimension is isolated or underdeveloped, instructional coherence breaks down, and access is reduced.

3.2 Core Constructs

3.2.1 Structured Literacy (Science of Reading)

Structured literacy defines the essential components of reading development: phonological awareness, phonics, fluency, vocabulary, and comprehension. Instruction is explicit, systematic, and cumulative. In bilingual contexts, these components are not duplicated across languages. They are coordinated to reflect differences in orthography, phonology, and morphology. Spanish supports early decoding through consistent sound-symbol correspondence; English requires greater flexibility in mapping print to sound. Instruction must account for both shared and language-specific features, making structural differences visible through explicit metalinguistic comparison.

3.2.2 Bilingual and Cross-Linguistic Development

Biliteracy develops through interaction between two linguistic systems. Skills such as phonological awareness, decoding, and metalinguistic knowledge transfer across languages when instruction makes these relationships explicit. Spanish and English differ in transparency, phonotactics, and morphological structure. Instruction must address these differences directly while supporting cross-linguistic connections, including attention to cognates, morphological patterns, syllable structures, and phoneme-grapheme correspondences.

3.2.3 Accessibility and Universal Design for Learning (UDL)

Accessibility is a design condition, not an accommodation. UDL operationalizes this principle through multiple means of engagement, representation, and action and expression. In bilingual literacy contexts, accessibility includes both disability-related supports and linguistic access. The critical distinction is between the construct being taught and the mode through which it is accessed. This distinction allows rigorous content to remain stable while access pathways vary. Inclusion of multilingual learners with disabilities is not a specialized pathway; it is the baseline expectation of equitable instructional design.

3.2.4 Technology-Supported Instruction

Technology serves as instructional support, extending access to practice and feedback. It serves two distinct functions: a compensatory function (reducing barriers to access for students with disabilities) and a developmental function (supporting practice and skill acquisition). These functions are not interchangeable. Instruction must distinguish between tools that provide access and those that build capacity and must deploy each accordingly. Technology is effective when it is aligned with instructional goals and integrated within the broader literacy system. When used in isolation, it does not produce sustained learning outcomes.

3.3 Relationships Among Constructs

The four constructs operate as an integrated system with reciprocal relationships:

- Structured literacy defines what is taught.
- Bilingual development defines how literacy skills transfer and develop across languages.
- Accessibility defines who can participate and under what conditions.
- Technology defines how instruction is extended and supported.

Instructional effectiveness depends on alignment across all four dimensions. Structured literacy that is not coordinated across languages limits transfer. Bilingual instruction that does not incorporate accessibility restricts participation. Technology that is not aligned with pedagogy functions as an add-on rather than as an instructional support. Alignment produces coherence. Misalignment produces fragmentation.

3.4 Outcome: Inclusive Biliteracy Development

The immediate outcome of this framework is inclusive biliteracy development, defined as:

- Proficiency in reading across Spanish and English
- Development of cross-linguistic awareness and transfer
- Access to grade-level literacy instruction for learners with diverse profiles
- Sustained participation through accessible and responsive design

At the broader level, inclusive biliteracy functions as part of the educational infrastructure. It determines whether learners can access, engage with, and benefit from schooling, and downstream, whether they can participate in multilingual economies, civic institutions, and professional pathways. The long-term human capital and sustainability outcomes described in Section 5 are contingent on the four instructional dimensions being operative simultaneously. This connection integrates the sustainability argument into the core of the framework rather than appending it as a separate consideration.

3.5 Propositions for Future Research

This framework generates testable propositions that can guide empirical research:

Proposition 1: Coordinated structured literacy instruction across Spanish and English produces stronger biliteracy outcomes than monolingual implementation models. Measurable outcomes: Oral Reading Fluency (ORF) and Developmental Reading Assessment (DRA) scores in both languages. Feasible design: quasi-experimental comparison using multilevel modeling (students nested within classrooms and schools).

Proposition 2: Explicit cross-linguistic instructional design strengthens transfer of phonological, morphological, and metalinguistic skills. Measurable outcomes: phonological awareness task performance across languages, morpheme identification scores. Feasible design: pre-post experimental study with cross-linguistic bridging as the instructional condition.

Proposition 3: Accessibility-informed literacy instruction increases participation and reading outcomes for multilingual learners, including students with disabilities. Measurable outcomes: participation rates in biliteracy pathways, longitudinal literacy trajectory data by disability status. Feasible design: longitudinal comparison of UDL-implementing vs. non-implementing DLI programs.

Proposition 4: Technology enhances differentiation and access when it is aligned with structured literacy and UDL principles. Measurable outcomes: comprehension scores, task completion rates for students with and without assistive technology. Feasible design: randomized assignment to technology-integrated vs. technology-as-supplement conditions within classrooms.

Proposition 5: Alignment among structured literacy, bilingual development, accessibility, and technology yields more equitable and sustained literacy outcomes than the isolated implementation of any single component. Feasible designs: (a) structural equation modeling estimating path coefficients among the four dimensions toward a latent biliteracy outcome; (b) cluster-randomized trial comparing whole-framework vs. partial implementation conditions.

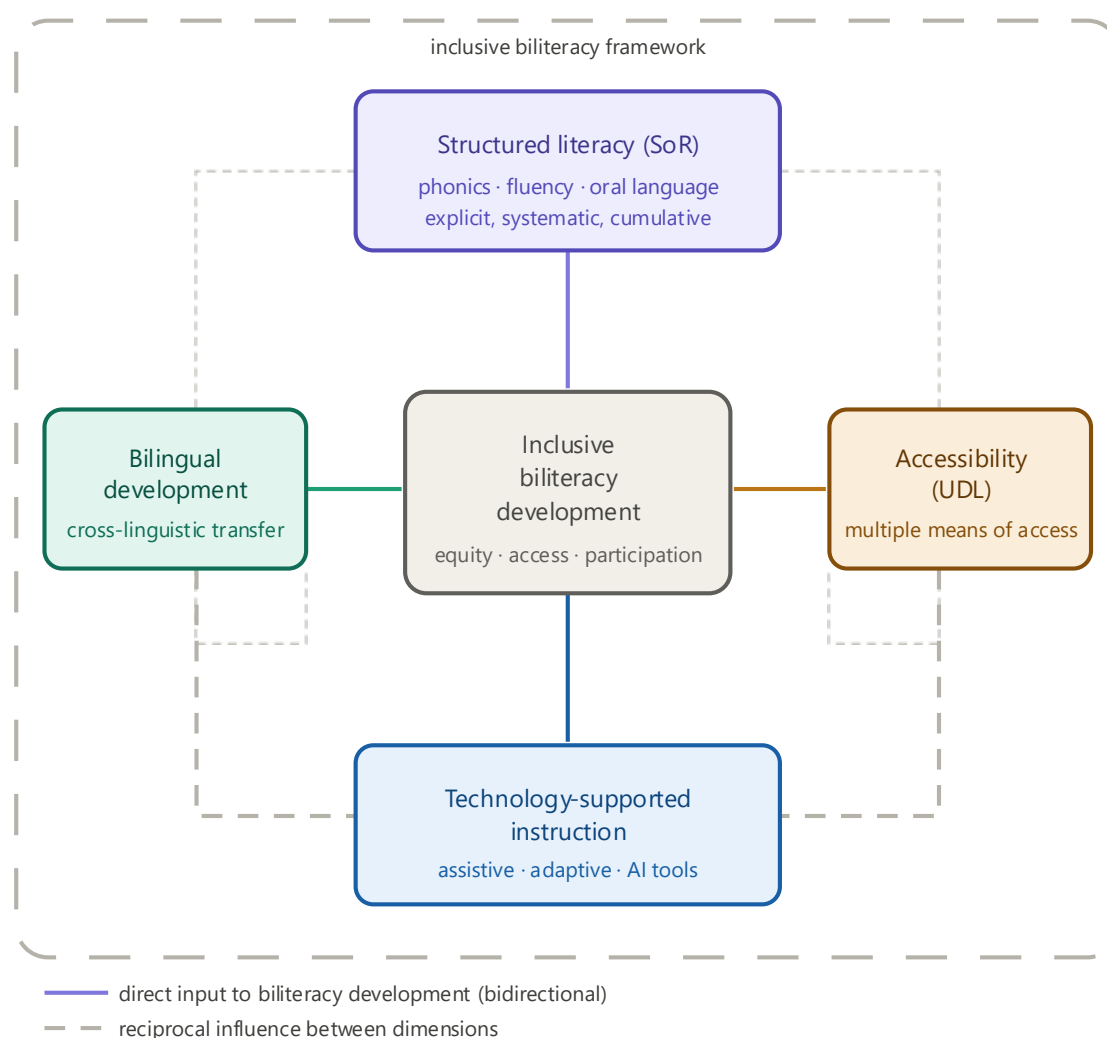


Figure 1. Conceptual framework for inclusive biliteracy integrating structured literacy (SoR), bilingual development, accessibility (UDL), and technology-supported instruction.

Figure 1 presents the framework. Each of the four dimensions provides direct, bidirectional input to inclusive biliteracy development (solid arrows) and exerts reciprocal influence on the other dimensions (dashed lines), within an integrated instructional system.

4. Materials and Methods

4.1 Research Design

This study uses an integrative theoretical literature review to synthesize scholarship across multiple domains and to construct a conceptual framework for literacy instruction in Spanish–English dual-language contexts. Integrative reviews are suited to research problems that span disciplines, incorporate diverse forms of evidence, and require conceptual development rather than narrow intervention analysis (Torraco, 2005, 2016; Whittemore & Knafl, 2005; Snyder, 2019). The research problem requires engagement with cognitive reading science, bilingual education, sociocultural theory, accessibility and disability studies, Universal Design for Learning, and educational technology. No single domain captures the full structure of biliteracy instruction. This design supports the identification of key constructs, the analysis of relationships among them, and the development of a unified explanatory model (Jabareen, 2009). This study is theory-building. Systematic review principles inform it, but it does not function as a meta-analysis or a bounded systematic review of intervention effects (Grant & Booth, 2009).

4.2 Review Purpose and Guiding Questions

The purpose of the review is to synthesize interdisciplinary scholarship to answer the following conceptual question: How can Science of Reading–informed literacy instruction be designed for Spanish–English dual language classrooms through coordinated attention to bilingual development, accessibility, and technology?

Four guiding questions structure the analysis:

- What scholarship defines the core components of Science of Reading–aligned literacy instruction?
- What does the literature on bilingualism and biliteracy indicate about cross-linguistic transfer and language-specific adaptation?
- How do UDL, accessibility research, and disability studies inform equitable participation in literacy instruction?
- How does educational and assistive technology extend access and support biliteracy development?

4.3 Search Strategy and Source Identification

The review used a structured, iterative search process across five domains: reading science, bilingual education, sociocultural and inclusive theory, accessibility and UDL, and educational technology. Search methods included keyword searches across academic databases (ERIC, PsycINFO, Google Scholar), backward and forward citation tracking from anchor studies, and targeted identification of foundational and highly cited works. Search terms included combinations of: “Science of Reading,” “structured literacy,” “dual language education,” “Spanish–English bilingual,” “biliteracy,” “cross-linguistic transfer,” “multilingual learners,” “Universal Design for Learning,” “accessibility,” “students with disabilities,” “assistive technology,” and “AI in literacy.”

The final corpus comprised approximately 35 sources spanning the period 1979–2025, distributed across five domains: cognitive reading science, bilingual and dual language education, sociocultural and inclusive theory, accessibility and disability studies, and educational technology, with three policy and institutional reports included for contextual grounding. Foundational works established theoretical grounding, while recent studies captured current developments in multilingual literacy and technology.

4.4 Inclusion and Exclusion Criteria

Sources were included if they: established theoretical or conceptual foundations in reading science, bilingual education, UDL, sociocultural theory, or disability inclusion; provided empirical or synthesized evidence relevant to literacy, biliteracy, or multilingual learners; addressed Spanish–English contexts, cross-linguistic transfer, accessibility, or instructional design; or focused on multilingual learners, students with disabilities, or their intersection. Sources were excluded if they: focused exclusively on monolingual populations without transferable relevance, lacked methodological rigor or scholarly grounding, presented technical descriptions without instructional or conceptual implications, or duplicated stronger or more comprehensive sources. Policy and practitioner documents were included selectively to contextualize implementation.

4.5 Source Appraisal and Analytic Procedure

Sources were evaluated based on their contribution to the conceptual framework rather than treated as equivalent in evidentiary weight. Empirical studies were assessed for methodological transparency and alignment between evidence and claims. Foundational and theoretical works were evaluated for conceptual clarity and sustained scholarly influence.

The analytic process was qualitative and iterative. Sources were organized into a domain-based matrix: cognitive reading science, bilingualism and biliteracy, sociocultural and inclusive theory, accessibility and disability, and educational technology. Within each domain, texts were coded for: core constructs (e.g., decoding, transfer, accessibility), instructional principles, theoretical claims, and points of convergence across domains. Codes were grouped into higher-order themes, including structured literacy, cross-linguistic transfer, oral language development, learner variability, accessibility through UDL, inclusive participation, and technology as instructional support. Constant comparison across sources ensured that claims reflected patterns across the literature rather than individual studies (Braun & Clarke, 2006; Saldaña, 2016).

Where sources produced conflicting findings, patterns were evaluated based on the preponderance of the evidence rather than on individual studies. Conflicts arising from differences in sample characteristics (e.g., monolingual vs. bilingual populations, age range, disability status) or instructional context were noted and incorporated as boundary conditions within the framework’s propositions rather than treated as disconfirming evidence. This approach is consistent with established integrative review methodology (Whittemore & Knafl, 2005).

4.6 Framework Construction, Reflexivity, and Limitations

The final stage translated thematic patterns into a conceptual model. The analysis adopts a defined interpretive stance: it focuses on Spanish–English dual language contexts in U.S. elementary education, treats bilingualism and disability as dimensions of learner variability rather than deficits, and distinguishes reading science as a body of scholarship from its policy interpretation.

Several limitations apply. The review synthesizes heterogeneous sources and does not provide pooled effect sizes or formal evidence grading. The inclusion of both empirical and conceptual work requires interpretive judgment. Technology and AI literature are evolving, and some findings remain preliminary. The contribution of this study is conceptual: it provides a theoretically grounded framework that organizes existing scholarship into a coherent model for inclusive biliteracy instruction.

5. Results

The literature establishes that the core components of the Science of Reading, including phonological awareness, phonics, word recognition, fluency, vocabulary, oral language, and comprehension, remain essential in Spanish–English dual language programs. These components do not change in bilingual contexts. Their implementation does.

Instruction must account for the interaction between two linguistic systems. Foundational skills develop through coordinated exposure to Spanish and English rather than through isolated, monolingual sequences. A recent synthesis of research on multilingual learners confirms that SoR-aligned instruction supports reading development when it incorporates oral language, linguistic assets, and the relationship between decoding and language proficiency (Kittle et al., 2024). Cross-linguistic transfer functions as a central mechanism in this process. Skills developed in one language support reading development in another, particularly in domains such as phonological awareness, decoding, and metalinguistic knowledge. A meta-analysis of bilingual learners identifies consistent relationships between phonological awareness and reading outcomes across languages (Míguez-Álvarez et al., 2022). Longitudinal research on Spanish–English learners shows that early literacy development in Spanish supports later word reading in English (Sun et al., 2021).

Transfer is not automatic; it depends on the explicit instructional design described in Section 3.2. Empirically, when learners engage in structured cross-linguistic comparison, they develop metalinguistic awareness that strengthens reading development in both systems (Míguez-Álvarez et al., 2022; Sun et al., 2021; van der Velde et al., 2019).

Oral language operates as a structural component of reading development. Vocabulary, syntax, and discourse knowledge support comprehension across languages. Multilingual learners often develop these domains unevenly across Spanish and English. Instruction must integrate oral language development with foundational skills rather than treat it as a separate domain (Kittle et al., 2024; National Academies of Sciences, Engineering, and Medicine, 2017). The evidence supports a unified instructional model. Structured literacy and bilingual pedagogy operate within the same system. When foundational skills instruction is explicit and coordinated across languages, dual language programs support both reading development and bilingual proficiency (Howard et al., 2018; Lindholm-Leary, 2001; Steele et al., 2017).

Accessibility defines participation in biliteracy instruction. Multilingual learners with disabilities have historically been excluded from bilingual programs through referral practices, program design, and deficit-based assumptions about capacity. The literature rejects these assumptions: multilingual learners with disabilities develop biliteracy and academic competence when instruction is coordinated, scaffolded, and sustained (Genesee et al., 2022). Outcomes are not constrained by bilingualism. They are shaped by access to instruction.

Applying the UDL principles defined in Section 3.2.3, accessible biliteracy instruction provides multimodal input, structured language supports, visual representation, and flexible options for demonstrating understanding—keeping learning goals stable while access pathways vary, so that rigor and access are maintained together.

Inclusive biliteracy instruction requires systematic scaffolding: oral language modeling, guided practice, visual supports, and structured opportunities for cross-language interaction. These supports benefit multilingual learners broadly and are essential for students with identified disabilities. Assessment practices must also reflect bilingual development; monolingual assessment systems increase the risk of misidentification, and evaluations must account for language proficiency, cross-linguistic transfer, and variation in language exposure.

Consistent with the compensatory and developmental functions distinguished in Section 3.2.4, the evidence shows technology amplifies rather than replaces foundational teaching. Assistive technologies—text-to-speech, read-aloud systems, speech recognition—provide the strongest evidence of impact, improving access to grade-level content for students with reading and language-based disabilities while instruction continues to develop foundational skills (Wood et al., 2018). Digital literacy tools support structured skill engagement when integrated with explicit pedagogical goals; without that alignment, their impact is limited (Hurwitz et al., 2022).

In bilingual contexts, technology also supports linguistic access through translation scaffolds, bilingual glossaries, and pronunciation tools. AI-mediated tools offer potential for adaptive feedback and personalized

practice, though the current evidence base is preliminary (Paglialunga & Melogno, 2025). The compensatory and developmental functions of technology are distinct and must be deployed accordingly: tools that provide access to content are not substitutes for tools that build literacy capacity, and neither replaces direct instruction.

Technology is effective when aligned with structured literacy, bilingual development, and accessibility principles. When integrated within this system, it extends instructional reach and supports participation. When treated as an independent solution—or when AI tools are allowed to substitute for teacher-mediated, culturally sustaining instruction—it does not produce sustained literacy outcomes and may reinforce the decontextualized skill-rehearsal patterns that critics of educational technology have documented (Selwyn, 2019).

5.1 Relevance to Sustainability, Human Capital, and Public Policy

Inclusive biliteracy instruction carries implications beyond classroom practice that connect directly to the four framework dimensions established in Section 3. The long-term outcomes described in this section—expanded human capital, workforce participation, and intergenerational mobility—are downstream consequences of whether structured literacy is coordinated across languages, whether bilingual development is supported through explicit cross-linguistic design, whether accessibility is embedded through UDL, and whether technology is integrated with rather than substituted for direct instruction. Sustainable educational systems require all four conditions to be operative simultaneously.

International frameworks identify equitable access to education as central to sustainable development. Sustainable Development Goal 4 and the Education 2030 agenda define literacy, inclusion, and participation as core components of educational systems (United Nations, 2015; UNESCO, 2016). These frameworks emphasize access to quality education across linguistic and social contexts, which requires precisely the kind of inclusive instructional design this framework operationalizes.

Biliteracy development contributes directly to human capital formation. Proficiency across languages expands access to academic content, professional pathways, and civic participation. In Spanish–English contexts, biliteracy supports engagement in multilingual economies and institutions (World Bank, 2018). In Latin American and Latinx contexts, language, access to education, and structural inequality shape patterns of opportunity; instructional models that integrate bilingual development, accessibility, and participation expand pathways into education and employment across generations.

The relationship between literacy and economic participation is well established: individuals with strong literacy skills demonstrate higher rates of employment, income stability, and civic engagement. When literacy systems exclude multilingual learners or students with disabilities by failing to address any one of the four framework dimensions, these outcomes are unevenly distributed. Educational design decisions produce long-term consequences for participation at scale.

6. Discussion

The analysis establishes that the Science of Reading, bilingual education theory, and accessibility-oriented design converge on a shared instructional model. This convergence is not incidental. It reflects a consistent pattern across the literature: literacy development depends on the interaction of decoding, language, access, and participation.

Two countervailing positions warrant acknowledgment before elaborating on the implications. First, some scholars caution that rigid phonics-first SoR models can pathologize the reading development of multilingual learners whose phonemic systems differ from English, effectively treating bilingual developmental patterns as deficits (Paris, 2005). This framework addresses this concern by requiring language-specific adaptation of structured literacy rather than wholesale transfer of monolingual SoR models; the problem is in the application, not in structured literacy as a principle. Second, critics of AI-mediated and digital literacy tools argue that algorithmic feedback risks reducing literacy to decontextualized skill rehearsal, displacing teacher judgment and culturally responsive practice (Selwyn, 2019). The framework's condition that technology must align with structured literacy and UDL goals and cannot function as a standalone solution directly addresses this risk. Naming these tensions sharpens the framework's scope conditions.

Structured literacy and bilingual pedagogy operate within the same system. Explicit and systematic instruction in foundational skills supports multilingual learners when it is coordinated across languages. Cross-linguistic transfer, oral language development, and language-specific adaptation shape how these skills develop. Instruction that isolates languages or applies monolingual models limits this process and misses the central mechanism through which biliteracy develops.

Accessibility is embedded in the architecture of effective instruction, not appended to it. Multilingual learners with disabilities participate fully in biliteracy development when supports are proactive and systematically designed. Access to bilingualism is not a specialized pathway; it is part of equitable educational

design. When accessibility is not embedded from the outset, participation is restricted regardless of instructional quality elsewhere in the system.

Technology operates as an instructional mediator within this system. Digital and assistive tools extend opportunities for practice, feedback, and access to content, but only when their compensatory and developmental functions are clearly distinguished and aligned with literacy goals. Technology does not strengthen instruction on its own; it extends instruction that is already coherent.

The current evidence base presents clear limitations. Multilingual learners and students with disabilities remain underrepresented in research that informs large-scale literacy policy. Implementation claims often extend beyond the populations included in foundational studies. Future research must examine cross-linguistic sequencing of foundational skills, the role of oral language in bilingual comprehension, the impact of accessibility on literacy trajectories, and the conditions under which technology produces durable outcomes in authentic classroom contexts. The five propositions in Section 3.5 provide specific, operationalized directions for this research.

Culturally and linguistically sustaining pedagogy remains central to this model. Learners' linguistic resources, cultural knowledge, and identities shape engagement and meaning-making. Instruction that incorporates these dimensions supports comprehension and participation across languages and integrates naturally with the framework's sociocultural foundation.

7. Conclusions

This article establishes that literacy instruction in Spanish–English dual language classrooms operates as an integrated system that aligns structured literacy, bilingual development, accessibility, and technology. The Science of Reading, defined as a multidisciplinary body of evidence on decoding, word recognition, language comprehension, fluency, vocabulary, and meaning-making, supports biliteracy development when implemented within a multilingual and accessibility-oriented framework (August & Shanahan, 2006; Kittle et al., 2024; National Academies of Sciences, Engineering, and Medicine, 2017).

The inclusive biliteracy framework proposed here is distinguished from existing models in three ways: it operationalizes foundational skill instruction explicitly across languages (unlike translanguaging frameworks), it systematically addresses the needs of learners with disabilities through UDL (unlike multiliteracies frameworks), and it builds cross-linguistic transfer and bilingual developmental trajectories into the architecture of instruction (unlike SoR frameworks as currently applied in policy). The four-dimensional construct definition—linguistic, accessibility, instructional design, and participation—provides a basis for operationalization, measurement, and empirical testing.

Structured literacy remains essential. Its implementation requires coordination across Spanish and English to reflect orthographic, phonological, and morphological differences. Foundational skills develop through explicit instruction in both languages, supported by cross-linguistic awareness and sustained oral language development. Biliteracy does not emerge from parallel monolingual instruction; it develops through coordinated design.

Accessibility defines whether learners can participate in biliteracy instruction. Multilingual learners with disabilities develop literacy and academic competence when instruction is scaffolded, linguistically responsive, and systematically designed from the start. Access to bilingualism and biliteracy is a matter of educational equity, not program eligibility.

Technology supports biliteracy development by extending access, practice, and feedback—but only when its compensatory and developmental functions are clearly distinguished and aligned with instructional goals. Emerging AI-mediated tools show potential for adaptive support; the same alignment requirements as other technologies must govern their integration.

Future research should examine cross-linguistic sequencing of foundational skills, the role of oral language in bilingual comprehension, the impact of accessibility on literacy trajectories, and the function of technology in authentic classroom contexts. The five propositions in Section 3.5 provide operationalized directions for this work, with specific outcome variables and research designs.

Inclusive biliteracy functions as part of the educational infrastructure. It shapes access to learning, participation in schooling, and long-term social and economic outcomes. Instruction that integrates structured literacy, bilingual development, accessibility, and technology—all four dimensions, in coordination—supports equitable literacy development and expands educational opportunity in multilingual societies.

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