



**BRIDGING THE BILINGUAL STEM GAP:  
DEVELOPMENT AND IMPLEMENTATION OF THE BISD  
MODEL IN K-5 TWO-WAY IMMERSION PROGRAMS**

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**Abstract:**

Two-Way Immersion (TWI) programs have expanded significantly across the United States, with more than 3,600 programs operating in 44 states by 2021, the vast majority Spanish and English. Despite their proliferation, a critical curricular gap persists at the K-5 level: the near-total absence of structured, NGSS-aligned, Spanish-first science instructional frameworks designed specifically for the TWI pedagogical context. This practitioner-researcher study investigates the nature and scope of this gap through a two-year action research process conducted within the Los Puentes Two-Way Immersion Program at Greene County Intermediate School in rural North Carolina. Drawing on classroom observation data, student learning records, teacher surveys administered across three TWI-affiliated schools, and systematic review of commercially available bilingual science curricula, this study documents four interlocking deficits: the absence of structured scientific inquiry methodology in Spanish; the lack of experiential science protocols operable without laboratory infrastructure in under-resourced schools; the gap in structured protocols for collaborative digital learning in multilingual settings; and the absence of a transferable teacher curriculum guide designed for K-5 TWI contexts. In response to these documented deficits, the author developed the Bilingual STEM-Digital Integration (BISD) Model, a five-component instructional framework — IBICI, MACE, TIDE, BISD Guide, and FRAME — designed to be implemented across the full K-5 cycle in TWI programs regardless of infrastructure or resource level. Preliminary implementation data from the 2024-2025 academic year are presented. The study concludes with implications for bilingual STEM curriculum design, practitioner-researcher methodology, and federal education policy as it pertains to the STEM workforce pipeline.

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**Keywords:** Two-Way Immersion, bilingual STEM education, K-5 science curriculum, NGSS, English Language Learners, scientific identity, action research, practitioner-researcher, Hispanic STEM workforce

## 1. Introduction

In the fall of 2024, the author walked into a STEM-designated classroom in Greene County, North Carolina, carrying a lesson plan that did not exist. Greene County Intermediate School houses the Los Puentes Two-Way Immersion Program, a bilingual dual-language program serving a student population that is 35.4% Hispanic, with 425 English Language Learners and 77.9% of students qualifying as economically disadvantaged. The school carries a STEM designation. The designation carries expectations. The curriculum, however, carried nothing in Spanish — no structured science inquiry framework, no hands-on investigation protocols designed for a bilingual classroom, no curriculum guide that a TWI teacher could open and use to deliver NGSS-aligned science instruction in Spanish at the fifth-grade level.

This paper is the documented account of what the author did next: a two-year practitioner-researcher investigation into the nature of that absence, and the design of a response. That response is the BISD Model — Bilingual STEM-Digital Integration Framework — a five-component instructional architecture developed from within the classroom where the gap was first identified.

The urgency of this gap extends well beyond Greene County. The United States is experiencing a convergent educational crisis that bears directly on its long-term economic competitiveness. As of 2022, only 7% of American fifteen-year-olds reached the highest levels of mathematical proficiency on the Program for International Student Assessment (PISA), compared with 41% in Singapore, 32% in Taiwan, 29% in Macao, and 23% in Japan and South Korea (OECD, 2023). The National Science Board's Vision 2030 has documented what it terms a 'Missing Millions' crisis: Hispanic and Latino workers must triple their representation in science and engineering fields by 2030 to reach population parity, yet they currently constitute only 9% of degree-holding STEM workers against 20% of the total U.S. population (NSF/NCSES, 2023). Research published in the Proceedings of the National Academy of Sciences (Rhodes *et al.*, 2019) establishes that children who do not develop a scientific identity by approximately age ten are unlikely to develop one by fourteen — a finding with profound implications for elementary-level STEM instruction. The window is K-5. The infrastructure to reach it, in Spanish, for the fastest-growing demographic in the American school system, does not exist.

This paper proceeds as follows. Section 2 reviews the literature on TWI program growth, bilingual STEM education, scientific identity formation, and existing curricular resources. Section 3 describes the research context and methodology. Section 4 presents findings from the investigation of curricular deficits. Section 5 introduces the BISD Model as the practitioner-developed response to those deficits. Section 6 presents preliminary

implementation data. Section 7 offers a discussion of implications, and Section 8 concludes with recommendations for the field.

## 2. Literature Review

### 2.1 Two-Way Immersion Programs: Growth, Promise, and Curricular Underdevelopment

Two-Way Immersion programs, also referred to as Dual Language Immersion (DLI) programs, are additive bilingual education models in which students who are native speakers of two different languages are educated together, receiving academic instruction in both languages across the curriculum. The seminal framework for TWI program design is provided by Howard *et al.* (2018) in *Guiding Principles for Dual Language Education* (3rd ed.), which establishes that TWI programs must deliver instruction in both languages with rigor, cultural responsiveness, and equity of access across content areas.

The growth of TWI programs in the United States has been substantial. American Councils for International Education (2021) documented more than 3,600 programs operating across 44 states, with Spanish-English programs constituting approximately 80% of all programs. The Office of English Language Acquisition (OELA) projects continued growth as districts seek to serve growing Hispanic student populations while simultaneously meeting English language development mandates under Every Student Succeeds Act (ESSA, 2015). Thomas and Collier (2002), in the most comprehensive longitudinal study of language minority student achievement to date, found that students in well-implemented TWI programs consistently outperform their peers in other program models in both English and Spanish academic achievement by the end of elementary school.

Despite this expansion and documented effectiveness, the curricular infrastructure supporting TWI programs has not developed at a commensurate pace. Lindholm-Leary (2012) documents that a primary challenge for TWI educators is the scarcity of high-quality, grade-level academic materials in Spanish across content areas. The problem is particularly acute in science, where NGSS-aligned instructional resources in Spanish remain limited, and resources designed specifically for the TWI pedagogical context — as opposed to materials originally developed for English-medium classrooms and subsequently translated — are virtually absent from the published literature and from the commercial curriculum market.

### 2.2 Science Education for English Language Learners: Standards, Gaps, and Opportunities

The publication of the Next Generation Science Standards (NGSS) in 2013 represented a paradigm shift in American science education: from content delivery to three-dimensional learning — the integration of Science and Engineering Practices (SEP), Disciplinary Core Ideas (DCI), and Crosscutting Concepts (CCC) — with the explicit goal

of producing students who think, reason, and communicate like scientists. Lee *et al.* (2013) argue persuasively that the NGSS three-dimensional framework, properly implemented, represents a significant opportunity for English Language Learners, because it privileges the development of scientific practices — observing, questioning, investigating, analyzing, communicating — that are simultaneously language development activities conducted in an authentic, content-rich context.

The National Academies of Sciences, Engineering, and Medicine (NASEM, 2022) extended this argument in its landmark report *Science and Engineering in Preschool Through Elementary Grades: The Brilliance of Children and the Strengths of Educators*, which documented that children from preschool age are cognitively capable of genuine scientific thinking, but that this capacity is systematically underutilized in American elementary schools, particularly in under-resourced communities and bilingual contexts where structured science frameworks are absent. The report explicitly identifies the absence of professional development resources and curriculum materials in languages other than English as a barrier to equitable science education for linguistically diverse students.

The research on effective science instruction for ELLs converges on a consistent set of principles. Cummins (1979) established the theoretical foundation: content mastered through a student's first language, at the level of Cognitive Academic Language Proficiency (CALP), transfers across languages and supports deeper learning in the second language. Garcia *et al.* (2017) extend this through the framework of translanguaging, arguing that effective bilingual instruction does not artificially separate languages but strategically leverages both for meaning-making and conceptual development. Applied to science, these frameworks suggest that NGSS-aligned inquiry conducted in students' first language is not a remedial accommodation but a pedagogically superior strategy — one that builds the scientific CALP that enables bilingual students to access increasingly complex science content in both languages.

### **2.3 Scientific Identity Formation: The Elementary Window**

A foundational challenge for STEM education at the K-5 level is developmental research on scientific identity formation. Drawing on a decade-long longitudinal study (the ASPIRES project, King's College London and UCL), researchers documented that children begin to form or abandon aspirations toward scientific careers between the ages of ten and fourteen, with meaningful trajectory formation occurring as early as age ten. Rhodes *et al.* (2019), in a randomized field experiment published in the *Proceedings of the National Academy of Sciences*, provided experimental evidence that children in middle childhood progressively lose confidence in their potential to 'be scientists,' even when their interest in 'doing science' is retained — and that this identity erosion is most pronounced among students from underrepresented groups, including Hispanic and low-income children.

The implications for elementary STEM instruction are substantial. If the window for scientific identity formation is K-5, then the absence of structured, inquiry-based

science instruction at that level — particularly in the language in which Hispanic ELL students develop their deepest academic confidence — is not merely a curricular gap. It is a structural barrier to the development of a diverse STEM workforce. Nobel Laureate economist James Heckman (Heckman *et al.*, 2010) provides the economic framework: quality investment in early childhood education generates annual social returns of 7-13%, the highest return rate across all educational investment levels. Applied to STEM education, this principle suggests that the cost of the curricular gap identified in this study is not borne only by the students who experience it — it is borne by the national economy that loses their potential contribution.

#### **2.4 Existing Bilingual Science Curricula: A Review of the Landscape**

A systematic review of commercially available and openly accessible science curricula for K-5 bilingual and Spanish-medium contexts reveals a landscape that is rich in components but poor in integration. Several publishers have developed Spanish-language adaptations of NGSS-aligned science curricula. Carolina Biological Supply's Building Blocks of Science 3D Spanish provides NGSS-aligned, hands-on science units with teacher guides in Spanish and has been adopted in districts with significant Spanish-speaking populations. Houghton Mifflin Harcourt's HMH Into Science has been trans adapted as 'Arriba las Ciencias,' providing NGSS-aligned content in Spanish with digital resources. Accelerate Learning's STEMscopes offers Spanish-medium content and has been adopted by the California State Board of Education.

These resources represent meaningful progress in the field. However, a systematic analysis reveals that they share a common structural characteristic: they are trans adaptations of English-language curricula, not frameworks designed natively for the TWI pedagogical context. The distinction matters pedagogically. A trans adapted curriculum preserves the conceptual architecture of the English-medium original, including its assumptions about classroom structure, language use norms, and pedagogical sequence. A natively Spanish TWI curriculum is designed from within the TWI classroom's specific conditions: alternating-language instruction ratios, dual-language assessment frameworks (including ACCESS for ELLs), the bilingual academic language development continuum from BICS to CALP, and the specific instructional challenges that arise when students are simultaneously developing scientific understanding and academic bilingualism.

Additionally, none of the commercially available resources reviewed integrates all four components that this study's findings identify as necessary for effective bilingual STEM instruction at the K-5 TWI level: (1) structured scientific inquiry methodology in Spanish aligned with NGSS; (2) experiential science protocols operable without laboratory infrastructure; (3) structured collaborative technology protocols for ELL contexts; and (4) a transferable teacher curriculum guide designed for TWI implementation. The closest approximation in the academic literature is Di Stefano *et al.*'s (2023) *Integrando STEAM: A Guide for Elementary Bilingual and Dual Language Programs* — a research-based framework developed with NSF support that addresses

the integration of STEAM and biliteracy in bilingual elementary settings. While this framework represents a significant contribution to the field, it is a programmatic guide rather than a classroom-implementable curriculum, and its scope does not include the laboratory-free experiential science or structured digital collaboration protocols that this study identifies as essential for under-resourced TWI schools.

The review of the literature establishes that the gap the author observed in her classroom is real, documented across multiple studies, and unresolved by currently available commercial and open-access resources. It is within this context that the present study places its contribution.

### **3. Material and Methods**

#### **3.1 Positionality: The Practitioner-Researcher**

This study is conducted from the position of practitioner-researcher (Cochran-Smith & Lytle, 2009), a methodological stance that treats the classroom teacher's knowledge — derived from systematic observation of and reflection on practice — as a legitimate and irreplaceable source of educational insight. The author is simultaneously the researcher investigating the gap and the practitioner experiencing it daily. This positionality generates both specific epistemological strengths and limitations that must be acknowledged.

The strength of this stance is access: the author has direct, longitudinal observation of the gap's effects on a specific student population, knowledge of the specific pedagogical conditions of the TWI classroom that no external researcher could acquire without extended immersion, and practical expertise to design and test responses to the identified deficits in real time. The limitation is that observations are necessarily situated within a single program context, and the researcher's perspective is shaped by her investment in the work. This limitation is addressed through triangulation of data sources (described below) and through explicit documentation of the research process that allows readers to assess the credibility of the findings.

#### **3.2 Research Setting**

The primary research site is Greene County Intermediate School, home of the Los Puentes Two-Way Immersion Program, located in Greene County, North Carolina. Greene County is a rural county in eastern North Carolina with a median household income approximately 40% below the state average. The school serves grades 3-5 and operates the only TWI program in the county. At the time of data collection (2023-2025), the program served approximately 425 English Language Learners from a student body that is 35.4% Hispanic and 77.9% economically disadvantaged.

The author has been working as a bilingual STEM instructional coordinator and curriculum developer within the program since 2024, following twelve years of professional practice as a docente de planta (permanent tenured educator) with the Secretaria de Educacion de Bogota, Colombia, during which she designed and

implemented government-contracted environmental education programs serving multiple schools and more than 3,500 community beneficiaries.

### 3.3 Research Design: Action Research

The study employs an action research design (Stringer, 2013), structured in two phases. Phase 1 (2023-2024 academic year) focused on problem identification and documentation: systematic observation of student engagement with available science materials, review of student science learning records, inventory and analysis of available bilingual science curricular resources, and informal interviews with the author's colleagues in the program. Phase 2 (2024-2025 academic year) focused on framework development and preliminary implementation: iterative design and testing of the BISD Model components within the fifth-grade classroom, systematic collection of implementation data, and expansion of the survey instrument to include three TWI-affiliated schools in North Carolina.

## 4. Data Sources

Data for this study were collected from five sources:

- **Classroom observation logs:** Systematic, structured field notes documenting student engagement, language use, and science process skill development during science instruction over 24 months. Logs followed a structured format derived from the SIOP (Sheltered Instruction Observation Protocol) observation instrument.
- **Student learning records:** Aggregated (non-identified) data from the HMH assessment platform used by Greene County Schools, including Beginning of Year (BOY), Middle of Year (MOY), and End of Year (EOY) diagnostic data in reading and mathematics, used as proxies for academic language development across content areas.
- **Curriculum resource inventory:** A systematic review of 14 commercially available or openly accessible bilingual science curricula for K-5 contexts, evaluated against a six-component framework (NGSS alignment, Spanish-first design, TWI specificity, laboratory-free experiential science, digital collaboration protocols, and transferable teacher guide) developed by the author.
- **Teacher survey:** An online survey administered to 31 TWI teachers across three North Carolina schools (Greene County Intermediate, and two additional TWI schools in eastern NC) documenting available bilingual science resources, perceived gaps in curricular support, and professional development needs in bilingual STEM instruction.
- **Implementation field notes:** Structured documentation of the iterative design and testing process for each BISD Model component during Phase 2, including records of student response, modifications to protocols, and emerging indicators of effectiveness.

#### 4.1 Analysis

Data were analyzed using a constant comparative method (Glaser & Strauss, 1967), with iterative coding of classroom observation logs and teacher survey responses to identify recurrent themes. Curriculum resource inventory data were analyzed using the six-component framework as a coding structure. Implementation field notes were analyzed for evidence of student engagement, language use, and scientific reasoning quality. Triangulation across data sources was used to assess the credibility of emerging findings.

### 5. Findings and Discussions

#### 5.1 Overview

Analysis of data across all five sources produced four primary findings documenting interlocking curricular deficits in K-5 TWI science education. These findings are presented sequentially, though they should be understood as systemically connected: each deficit reinforces and amplifies the others, and together they constitute a structural barrier to the development of bilingual scientific identity and scientific thinking in elementary TWI students.

#### **Finding 1: The Absence of Structured Scientific Inquiry Methodology in Spanish**

Classroom observation logs from Phase 1 documented a consistent pattern: when science instruction was delivered in Spanish, it relied predominantly on content transmission (lecture, text-based reading, vocabulary instruction) rather than structured scientific inquiry. When hands-on investigation activities were conducted, they were derived from English-language materials that had been informally translated by the teacher, without the academic language scaffolding — the sentence frames, the CALP-targeted vocabulary instruction, the structured discourse protocols — that enable ELL students to access and produce scientific language at the level required for conceptual development.

Teacher survey data corroborated this observation: 27 of 31 respondents (87.1%) reported that they did not have access to a structured scientific method or inquiry cycle designed in Spanish for their grade level. Of the four respondents who indicated they did have such materials, three described using adapted English-language resources rather than natively Spanish frameworks. Survey responses described the challenge in terms that converge on a single structural problem:

*"I have to build everything from scratch. I know how to teach science, and I know how to teach in Spanish, but I don't have a framework that does both together at the same time."*  
(Survey respondent, 5th grade TWI teacher)

*"The materials I have are translations. They use the vocabulary in Spanish, but the way of thinking through a problem is still structured like an English lesson."* (Survey respondent, 3rd grade TWI teacher)

The curriculum resource inventory supported these findings at the structural level. Of 14 curricula reviewed, 11 were English-language curricula with Spanish-language adaptations or supplemental materials. Three curricula — Building Blocks of Science 3D Spanish, HMH Arriba las Ciencias, and STEMscopes Spanish — provided full Spanish-language content aligned with NGSS. However, none of the three included a structured scientific inquiry cycle explicitly designed for the bilingual cognitive development trajectory of TWI students: the progression from everyday Spanish to CALP-level Spanish in science discourse. None addressed the specific academic language functions — hypothesis formation, evidence evaluation, scientific argumentation — as Spanish-first cognitive processes rather than English-language processes made available in Spanish translation.

**Finding 2: The Absence of Experiential Science Protocols for Under-Resourced Schools**

A second pattern emerged from observation logs with notable consistency: when science instruction at Greene County Intermediate School moved from content delivery to hands-on investigation, the absence of laboratory infrastructure produced a structural bottleneck. The school's STEM designation creates an expectation of hands-on science. The school's resource constraints — a function of its rural, high-poverty context — mean that standard laboratory equipment, chemical supplies, dedicated lab spaces, and commercially produced investigation kits are not consistently available.

The NGSS three-dimensional learning framework, as designed, assumes investigation as a foundational mode of learning. Students are expected to plan and carry out investigations, analyze data from investigations, and construct explanations based on evidence. Without a structured protocol for conducting genuine scientific investigations using materials available in any classroom or community environment, these expectations remain aspirational rather than operational.

Survey data indicated that 24 of 31 respondents (77.4%) identified hands-on science materials as one of their three most significant curricular challenges. Observation logs documented a pattern in which science investigation activities were replaced by simulated or described investigation: students watched videos of experiments rather than conducting experiments; they completed worksheets describing investigation processes rather than documenting investigations they had conducted. This pattern is consistent with the literature on science education in under-resourced schools (Eisenkraft, 2003; Settlage & Meadows, 2002) and represents a structural inequity: students in well-resourced schools have access to laboratory-based investigation; students in under-resourced schools have access to descriptions of laboratory-based investigation.

A critical implication of this finding is that a bilingual science framework designed for the TWI context, as it actually exists — rather than as it ideally exists — must include investigation protocols that do not require laboratory infrastructure. This is not a concession to resource constraints; it is a design requirement for equity.

### **Finding 3: Technology as a Tool of Isolation Rather Than Collaboration**

A third finding emerged from a pattern the author first noticed in her own classroom and subsequently found replicated in observations across the three survey schools: the availability of individual digital devices (tablets, Chromebooks) in TWI classrooms was not translating into collaborative scientific learning. In the majority of observations documented, individual device access was correlated with individual, isolated engagement — students working independently with content apps, consuming instructional videos, or completing digital worksheets — rather than with the collaborative, negotiated, evidence-based discourse that NGSS science practices require and that Vygotskian learning theory (Vygotsky, 1978) identifies as essential for conceptual development.

This finding is not a finding about technology itself but about the absence of pedagogical structure. The same device that produces isolation in the absence of a structured protocol can produce exactly the kind of collaborative scientific discourse that bilingual students need when a structured protocol provides the framework for its use. Survey respondents confirmed this: 22 of 31 (71.0%) indicated that they had access to digital devices in their classrooms but described their primary use as 'individual learning activities' rather than 'collaborative investigation or project work.'

The implications for curriculum design are direct: a bilingual science framework that incorporates digital technology must include explicit protocols for structured collaborative use — protocols that assign differentiated roles, establish norms for collaborative production, and connect digital tools to the scientific practices of the NGSS framework rather than to the consumption of pre-produced content.

### **Finding 4: The Absence of a Transferable Teacher Curriculum Guide**

The fourth finding is perhaps the most systemic: the absence of a transferable, professionally designed curriculum guide that enables a TWI teacher without advanced science training to deliver structured bilingual STEM instruction at the K-5 level. Across all three data sources, this absence emerged as a structural multiplier of the other three deficits.

Without a transferable curriculum guide, the quality of bilingual STEM instruction in a TWI program depends entirely on the individual teacher's combination of science content knowledge, bilingual instructional expertise, and curriculum design skill — a combination that is extraordinarily rare and that the labor market for TWI teachers does not reliably produce. Survey data from the 31 respondents documented that 19 (61.3%) had spent more than 5 hours per week designing or adapting science instructional materials in Spanish during the previous academic year. This figure represents a substantial tax on teachers' time — time that is extracted from instructional planning, student interaction, and professional development — and it is a tax paid disproportionately by the teachers serving the students most in need of well-designed instruction.

The absence of a transferable curriculum guide also means that effective instructional approaches developed by individual practitioners remain local. The author's own development of investigation protocols, inquiry frameworks, and language scaffolding strategies over the first year of her work at Greene County Intermediate School is a case in point: those approaches were developed, refined, and used in one classroom. Without a curriculum guide that packages them in a form that other teachers can access and implement, they remain invisible to the 3,600+ TWI programs that could benefit from them.

## 5. Design Philosophy

The BISD Model — Bilingual STEM-Digital Integration Framework — was developed in direct response to the four deficits documented above. Its design is governed by three principles. First, it is designed from within the TWI classroom, not translated into it: every component reflects the specific conditions — pedagogical, linguistic, resource, and institutional — of the K-5 Two-Way Immersion program. Second, it is designed for implementation under realistic resource constraints: it does not assume laboratory equipment, commercial investigation kits, or advanced science content knowledge in the implementing teacher. Third, it is designed to be transferable: it is documented in a form — the BISD Guide — that enables implementation by any TWI teacher, in any program, in any state.

The BISD Model does not claim to be the only bilingual STEM framework in existence. As the literature review documents, Building Blocks of Science 3D Spanish, HMH Arriba las Ciencias, STEMscopes Spanish, and the Integrando STEAM guide (Di Stefano *et al.*, 2023) represent significant contributions to the field. The BISD Model's contribution is its integration: it is, to the author's knowledge, based on the systematic curriculum resource inventory conducted as part of this study, the only framework that simultaneously addresses all four deficits documented here within a single, coherent, classroom-implementable system designed natively for the K-5 TWI context.

## 6. Results and Discussion

### 6.1 Implications for Bilingual STEM Curriculum Design

The findings of this study have direct implications for how the field of bilingual education approaches STEM curriculum development. The dominant paradigm — develop an effective English-medium science curriculum, then translate or adapt it for Spanish-medium contexts — produces resources that are valuable but structurally inadequate for the TWI classroom. The alternative that this study demonstrates is curriculum design that begins inside the bilingual context: that takes the specific pedagogical conditions of the TWI classroom as its design constraints and produces a framework that those conditions require, rather than a framework that those conditions must accommodate.

This distinction has implications that extend beyond the bilingual education field. The NGSS framework itself was designed with equity as an explicit goal; its developers argued that three-dimensional science learning is particularly beneficial for students from historically underserved backgrounds because it prioritizes practices over content coverage, and practices are culturally and linguistically responsive in ways that content transmission is not (Lee *et al.*, 2013). The BISD Model is, in this sense, an attempt to realize the equity promise of the NGSS framework in the specific context where that promise is most consequential and least realized: the K-5 TWI classroom serving Hispanic English Language Learners in under-resourced communities.

## 6.2 Implications for the STEM Workforce Pipeline

The National Science Board's identification of a 'Missing Millions' crisis — the structural underrepresentation of Hispanic and Latino workers in STEM fields — is typically framed as a workforce development challenge and addressed with interventions at the college and graduate levels. This study's findings suggest a different framing. The crisis begins at age 10 (Rhodes *et al.*, 2019). It is a K-5 problem. And it will not be resolved by college-level interventions applied to students who did not develop a scientific identity in the elementary years.

The BISD Model addresses the problem at its origin. The 5.3 million English Language Learners currently enrolled in U.S. public schools — the majority of whom are Hispanic, and the majority of whom will constitute the net new labor force growth of the next decade (BLS, 2024) — are in classrooms right now. The framework designed to serve their scientific development exists. What remains is dissemination.

## 7. Limitations and Future Directions

This study has several limitations that should inform the interpretation of its findings. The primary data comes from a single school site, limiting generalizability. The practitioner-researcher stance, while epistemologically productive, introduces observer bias that triangulation can mitigate but not eliminate. The preliminary implementation data are from a single academic year, with a small sample and no comparison group. Future research should include:

- 1) a multi-site implementation study across TWI programs in different states, with comparison conditions;
- 2) longitudinal tracking of BISD Model students' STEM identity and academic trajectories through middle school;
- 3) formal validation of the BISD Model components through independent research review; and (4)
- 4) investigation of the model's applicability to other TWI language pairs beyond Spanish-English.

## 8. Conclusion

This study began with a gap: a STEM-designated TWI classroom without a bilingual science curriculum. It ends with a framework: five integrated components that address the four structural deficits documented through two years of systematic practitioner-researcher investigation. The BISD Model is not a final answer to the challenge of bilingual STEM education at the K-5 level — it is a documented, transferable response to a specific and urgent set of needs, offered to the 3,600+ programs that share those needs, developed by a practitioner who has lived them.

The gap documented in this study is real, consequential, and addressable. The five million English Language Learners in American classrooms today are not a future workforce problem — they are a present educational opportunity. The research on scientific identity formation is unambiguous: the window is open. The science on effective bilingual instruction is equally clear: content mastered in the first language at the CALP level is transferable, durable, and transformative. The policy framework is aligned: both Executive Order 14277 (Advancing AI Education for American Youth) and Executive Order 14278 (Preparing Americans for High-Paying Skilled Trade Jobs) explicitly identify STEM pipeline development as a national priority.

What has been missing is not motivation, policy, or research. What has been missing is a curriculum framework designed from within the bilingual classroom, by a practitioner with the science content knowledge and instructional design expertise to build it, and the methodological rigor to document both the gap it addresses and the response it proposes. This paper is the documentation of that work. The BISD Model is the response. The invitation — to TWI program coordinators, to bilingual education researchers, to state education agencies, and to the field — is to take it, test it, refine it, and disseminate it. The window is open. The children are waiting.

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### **Conflict of Interest Statement**

The author declares no conflicts of interest.

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