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Interdisciplinary English-Science Curriculum and the Development of English Proficiency and Scientific Inquiry Skills among Primary School Students: A Mixed-Methods Action Research Study

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Abstract

This study examined whether an interdisciplinary English-science curriculum could improve primary school students' English proficiency and scientific inquiry skills while identifying practical challenges associated with implementation. A mixed-methods action research design was adopted across three urban primary schools in Xi'an. The quantitative strand used a quasi-experimental pre-test-post-test design involving 300 students: 150 students in experimental classes and 150 students in control classes. Experimental classes received interdisciplinary teaching that connected English language use with scientific concepts, inquiry tasks, experimental design, and data analysis, whereas control classes continued with traditional English and science instruction. Paired-sample t-tests were used to evaluate within-group changes. The experimental groups showed substantial gains in English scores across the three schools, increasing from 72.3 to 85.2, 71.9 to 84.5, and 73.4 to 83.8, respectively ($t = 12.67$-14.12, $p = .001$). Scientific inquiry scores also increased from 73.5 to 87.1, 72.0 to 86.2, and 73.2 to 85.4 ($t = 13.34$-15.20, $p = .001$). Improvements in control classes were much smaller. Qualitative analysis of teacher interviews, classroom observations, and student reflection logs identified three implementation themes: the importance of cross-subject teacher collaboration, constraints in teaching resources and planning time, and strong student engagement with authentic real-world tasks. Students generally reported greater interest and perceived relevance, although some experienced difficulty balancing English language demands with scientific content. The findings suggest that carefully designed interdisciplinary curriculum can simultaneously strengthen language application and scientific inquiry, but sustainable implementation requires structured collaboration, appropriate scaffolding, and institutional resource support.

Keywords: Interdisciplinary Curriculum, English Education, Scientific Inquiry, Action Research,Mixed Methods, Primary Education

Introduction

Educational systems worldwide have increasingly shifted from knowledge-transmission models toward competency-oriented learning frameworks. Contemporary educational reform emphasizes not only academic achievement but also students' abilities to communicate effectively, think critically, solve complex problems, and apply knowledge across contexts. Primary education is a particularly important stage in this transition because students begin to establish relationships among different areas of knowledge and develop foundational approaches to understanding real-world problems. Consequently, interdisciplinary learning has become increasingly prominent in educational and social-science research (Kanmaz, 2022; Çoban & Selvi, 2023).

Language education has an important role in this transformation because language is not merely a subject to be mastered; it is also a tool for constructing, communicating, and evaluating knowledge. English, as an international medium of academic and scientific communication, enables learners to describe observations, explain concepts, interpret evidence, and participate in knowledge-building activities. However, conventional primary-school English instruction frequently separates language practice from disciplinary inquiry and authentic application. This separation may restrict students' ability to use English for reasoning, explanation, collaboration, and problem solving.

An interdisciplinary curriculum offers a potential response by creating learning environments in which students use knowledge from more than one discipline to address meaningful tasks. The integration of English and science is especially relevant because the two areas can support each other: science provides authentic contexts involving observation, experimentation, explanation, and evidence-based reasoning, while English provides the linguistic resources needed to discuss procedures, compare findings, and communicate conclusions. Previous studies have associated interdisciplinary learning with stronger engagement, knowledge integration, and higher-order thinking (Leahey, 1999; Uştu et al., 2021; Çoban & Selvi, 2023).

The selection of an English-science interdisciplinary curriculum as the focus of this study is therefore based on both educational and social considerations. Contemporary societies require individuals who can interpret information from multiple perspectives, communicate evidence clearly, and respond to problems that extend beyond isolated disciplinary boundaries. Schools are consequently expected to cultivate transferable competencies alongside subject knowledge. Investigating these processes at the primary level contributes to current debates concerning curriculum innovation, competency development, and the practical organization of interdisciplinary education (McPhail, 2017; Kanmaz, 2022).

Despite growing interest in interdisciplinary education, important research gaps remain. First, many studies have emphasized conceptual models or teachers' perceptions while providing comparatively limited empirical evidence about measurable student outcomes. Second, English proficiency and scientific inquiry have often been examined separately, leaving insufficient understanding of how one instructional intervention may influence both dimensions simultaneously. Third, although teacher collaboration, curriculum coordination, limited planning time, and resource constraints are repeatedly identified as implementation barriers, fewer studies connect these organizational conditions with quantitative evidence of student learning in authentic primary school settings (Wang et al., 2020; Munkebye et al., 2021; Keller, 2023).

From a social-science perspective, interdisciplinary curriculum development is not only an instructional technique but also a socially and institutionally situated process. Its outcomes are shaped by interactions among curriculum structures, teacher collaboration, school resources, classroom relationships, and students' learning experiences. Examining these relationships provides evidence about how educational innovations are implemented, adapted, and sustained. The present study therefore links curriculum reform with classroom practice by evaluating student outcomes while also examining the experiences and constraints reported by teachers and students.

To address these gaps, this study adopts a mixed-methods action research design to investigate the effects of an interdisciplinary English-science curriculum on primary school students' English proficiency and scientific inquiry skills. The quantitative component uses a quasi-experimental pre-test-post-test design, while the qualitative component draws on classroom observations, teacher interviews, and student reflection logs. The study is guided by the following research questions:

(1) What changes occur in students' English proficiency and scientific inquiry skills after participating in an interdisciplinary English-science curriculum?
(2) What challenges do teachers encounter during the design and implementation of interdisciplinary teaching?
(3) What instructional and institutional strategies can support sustainable interdisciplinary curriculum implementation?

Literature Review

Interdisciplinary Curriculum Design and Implementation

Effective interdisciplinary curriculum is more than the simple combination of content from different subjects. Meaningful integration requires a clear conceptual connection, coherent sequencing, and tasks in which knowledge from more than one discipline is necessary to complete the learning activity. DelliCarpini (2009) showed that collaboration between language teachers and mainstream teachers can support the development of thematic units, highlighting the importance of shared planning. McPhail (2017) similarly warned that curriculum integration can become superficial when disciplinary connections are imposed rather than conceptually justified.

Teacher preparedness is therefore central. Kanmaz (2022) reported broadly positive teacher attitudes toward interdisciplinary teaching but also identified the need for clearer implementation guidance and stronger support. Wang et al. (2020) found that insufficient planning time was a major obstacle to STEM integration, while Munkebye et al. (2021) emphasized curriculum coherence and inter-teacher collaboration. These findings indicate that interdisciplinary curriculum must be treated as an organizational process as well as a classroom methodology.

The present study responds to this literature by using an action research cycle of planning, action, observation, and reflection. In the planning phase, English and science objectives were aligned around a common thematic focus. During implementation, researchers and participating teachers documented classroom processes and adjusted language scaffolding and activity design. Observation and reflection then provided evidence for interpreting both learning outcomes and implementation challenges.

Interdisciplinary Learning, Language Use, and Scientific Inquiry

A major premise of interdisciplinary learning is that students develop stronger understanding when knowledge is applied across contexts. Leahey (1999) reported positive effects of integrated mathematics and science teaching on achievement and engagement. Uştu et al. (2021) showed that integrating art into STEM learning could support students' ability to synthesize knowledge, and Çoban and Selvi (2023) argued that interdisciplinary approaches in English curriculum can broaden students' perspectives and interpretive abilities.

For language learning, authentic disciplinary activity can create an immediate communicative purpose. Students need vocabulary and sentence structures to describe observations, compare results, propose explanations, and communicate evidence. This purpose may strengthen language application because communication is embedded in a task rather than practiced in isolation. Scientific inquiry can also benefit because students are required to articulate questions, procedures, and interpretations. The reciprocal relationship between language and inquiry is particularly relevant for primary learners, who may need explicit scaffolding to connect disciplinary reasoning with appropriate linguistic expression.

Recent educational research has also emphasized multimodal and technology-supported learning. Mohammad et al. (2024) reported the potential of multimodal English teaching to improve learning efficiency. Although the present intervention was not an artificial-intelligence-based curriculum, this literature reinforces a broader principle: teaching innovation should be evaluated through multiple forms of evidence and should connect pedagogical tools to clearly defined learning outcomes.

Teacher Support and Research Gap

Teachers are curriculum designers, disciplinary specialists, collaborative planners, and classroom facilitators in interdisciplinary education. Keller (2023) highlighted the professional learning potential of interdisciplinary collaboration, but studies consistently identify insufficient collaboration time, resources, and professional development as implementation barriers. Zulkarnain and Md (2023), in a review of teachers' perspectives on AI-supported ESL teaching, similarly found that positive attitudes toward innovation can coexist with concerns about technical capacity and training.

Three gaps motivated this study. First, the literature provides many general arguments for integration but fewer classroom-based frameworks that link curriculum design, implementation, and reflective revision in primary English-science education. Second, studies often examine language outcomes or subject outcomes separately rather than assessing both English proficiency and scientific inquiry within the same intervention. Third, implementation barriers are frequently reported descriptively without being integrated with quantitative evidence of student learning. The present mixed-methods action research study addresses these gaps by examining dual learning outcomes and interpreting those outcomes alongside teacher and student experiences.

Methodology

Research Design

The study employed a mixed-methods action research design. Action research was selected because the study sought both to evaluate an instructional intervention and to improve it through an iterative cycle of planning, action, observation, and reflection. The quantitative component used a quasi-experimental pre-test-post-test design with experimental and control classes. The qualitative component used classroom observation, semi-structured teacher interviews, and student reflection logs to explain how the curriculum was implemented and experienced.

The intervention focused on interdisciplinary integration between primary school English and science using the theme of exploring natural phenomena. During planning, English and science teachers aligned language objectives with scientific concepts and inquiry activities. The experimental classes completed tasks that required students to use English to discuss observations, collaborate in groups, describe experimental procedures, and interpret data. Control classes continued with conventional English and science instruction. The intervention and data collection process lasted nine months: pre-testing occurred in the first month, curriculum implementation and observation took place from months two to seven, and post-testing was conducted during months eight and nine. Teacher interviews and student reflection activities occurred throughout the study period.

Participants and Sampling

Purposive sampling was used to select three urban primary schools in Xi'an: Xi'an Primary School, Greenland Chanba Primary School, and Xi'an Foreign Language School. The schools were selected because their teacher-student structures were considered broadly representative of urban primary school settings in the study context and because participating English and science teachers had relevant experience or willingness to engage in interdisciplinary teaching.

A total of 300 students participated. Each school contributed 100 students, with 50 students assigned by existing parallel classes to the experimental condition and 50 to the control condition. Thus, the total quantitative sample consisted of 150 experimental-group students and 150 control-group students. The quasi-experimental design used intact classes rather than complete random assignment. Nine English and science teachers were involved across the three schools, with three participating teachers associated with each school.

Table 1
Participant Distribution by School

School	Total Students	Experimental	Control	Teachers Involved
Xi'an Primary School	100	50	50	3
Greenland Chanba Primary School	100	50	50	3
Xi'an Foreign Language School	100	50	50	3
Total	300	150	150	9

Measures and Data Collection

English proficiency was assessed before and after the intervention using a common scoring framework covering listening, speaking, reading, and writing. The source study emphasized vocabulary, fluency, accuracy, and students' ability to apply English in learning tasks. Scientific inquiry was assessed through scientific concept comprehension, experimental design, and data analysis. The same outcome dimensions were used at pre-test and post-test to support comparison over time.

Classroom observations documented teacher-student interaction, group collaboration, the use of English during collaborative activity, and language scaffolding such as sentence frames and targeted linguistic support. Teacher interviews were conducted during early, middle, and late stages of implementation and focused on curriculum design, collaboration, resource constraints, teaching strategies, and the balance between language objectives and science content. Student reflection logs documented learning experiences, perceived difficulties, interest, and the relevance of interdisciplinary activities.

The mixed-methods design supported triangulation. Quantitative results indicated whether measurable changes occurred, whereas observations, interviews, and reflections provided contextual explanations for those changes. The repeated collection of qualitative evidence across the intervention also supported the reflective function of action research.

Data Analysis

Quantitative data were analyzed in SPSS using descriptive statistics and paired-sample t-tests. Means were used to summarize pre-test and post-test performance for experimental and control classes in each school. Paired-sample t-tests evaluated within-group changes over time. The original analysis plan also included independent-sample comparisons between experimental and control groups; however, the present report focuses on the paired-test statistics and group-specific pre-post means available in the study dataset.

Qualitative data from teacher interviews and student reflection logs were analyzed thematically. Coding focused on recurring implementation issues, teacher experiences, student engagement, perceived relevance, and learning challenges. Classroom observation evidence was used to support or challenge patterns identified in interview and reflection data. Cross-source comparison was used to strengthen interpretation and reduce reliance on a single qualitative source.

Validity, Reliability, and Scope of Inference

The pre-test-post-test control-group structure strengthened internal comparison by showing the pattern of change under interdisciplinary and conventional instruction. Standardized outcome dimensions and common scoring criteria were used across measurement occasions. Qualitative credibility was supported through triangulation of interviews, observations, and reflection logs. The study also documented the implementation process to improve methodological transparency.

The use of purposive sampling and intact classes limits causal and population-level generalization. The results should therefore be interpreted as evidence from three urban primary schools rather than as estimates for all primary or secondary school contexts. The action research design also places researchers close to the instructional process, creating a risk of interpretive bias. These limitations were considered when integrating the quantitative and qualitative findings.

Results

English Proficiency

English scores improved in all three experimental groups. At Xi'an Primary School, the experimental-group mean increased from 72.3 to 85.2 (t = 13.45, p = .001). At Greenland Chanba Primary School, the mean increased from 71.9 to 84.5 (t = 14.12, p = .001). At Xi'an Foreign Language School, the mean increased from 73.4 to 83.8 (t = 12.67, p = .001). The corresponding increases in control classes were 1.4, 1.0, and 1.2 points. The experimental-group gains were therefore substantially larger in practical magnitude across all three schools.

Table 2

Paired-Sample t-Test Results for English Proficiency

School	**Group**	**Pre-test Mean**	**Post-test Mean**	**t**	**p**
Xi'an Primary	Experimental	72.3	85.2	13.45	.001
Xi'an Primary	Control	73.1	74.5	2.34	.050
Greenland Chanba	Experimental	71.9	84.5	14.12	.001
Greenland Chanba	Control	72.8	73.8	2.98	.030
Xi'an Foreign	Experimental	73.4	83.8	12.67	.001
Xi'an Foreign	Control	74.2	75.4	3.12	.020

Across the experimental classes, teachers and classroom observers noted particularly visible improvement in students' willingness to speak during group tasks and in their ability to produce written explanations linked to science activities. These observations are consistent with the quantitative pattern and suggest that the curriculum created repeated opportunities to use English for a specific communicative and cognitive purpose. The results do not imply that every language subskill improved equally, because the available summary dataset reports overall English means rather than separate inferential tests for listening, speaking, reading, and writing.

Scientific Inquiry Skills

Scientific inquiry outcomes showed a similar pattern. At Xi'an Primary School, the experimental-group mean increased from 73.5 to 87.1 (t = 14.88, p = .001). At Greenland Chanba Primary School, the mean increased from 72.0 to 86.2 (t = 15.20, p = .001). At Xi'an Foreign Language School, the mean increased from 73.2 to 85.4 (t = 13.34, p = .001). Control-group gains were much smaller, ranging from 0.8 to 1.2 points.

Table 3
Paired-Sample t-Test Results for Scientific Inquiry Skills

School	Group	Pre-test Mean	Post-test Mean	t	p
Xi'an Primary	Experimental	73.5	87.1	14.88	.001
Xi'an Primary	Control	74.0	75.2	3.22	.020
Greenland Chanba	Experimental	72.0	86.2	15.20	.001
Greenland Chanba	Control	73.3	74.1	2.45	.040
Xi'an Foreign	Experimental	73.2	85.4	13.34	.001
Xi'an Foreign	Control	74.1	75.0	3.05	.030

Observation records indicated that experimental-class students became more active in discussing experimental procedures, interpreting results, and connecting observations with explanatory language. The largest practical improvements described in the study were in experimental design and data analysis application. These outcomes support the proposition that inquiry skills may be strengthened when students repeatedly engage in structured tasks that require both disciplinary reasoning and communication.

Teacher Interview Themes

Three recurring themes were identified in teacher interviews: collaboration, resource availability, and student engagement. Teachers considered cross-subject planning essential because English and science objectives had to be aligned before a learning task could function as a genuinely interdisciplinary activity. At the same time, teachers reported that available collaboration time was insufficient for the amount of joint planning required. Resource limitations included a lack of suitable integrated teaching materials and limited access to collaborative planning platforms. Despite these constraints, teachers consistently described high student engagement, especially when tasks were linked to observable natural phenomena or other real-world applications.

Table 4
Themes from Teacher Interviews

Theme	Interpretive Summary
Teacher collaboration	More cross-subject planning time was needed to align English and science objectives and coordinate instruction.
Resource availability	Limited integrated materials and collaboration resources constrained effective subject integration.
Student engagement	Students were highly engaged in interdisciplinary tasks, particularly authentic and real-world activities.

Student Reflection Themes

Student reflections also produced three themes: increased interest, real-world relevance, and challenge. Many students reported stronger interest in lessons that connected English with science. Students frequently described interdisciplinary activities as more closely related to real-life situations than conventional subject-separated lessons. However, some students found the tasks demanding because they needed to manage English expression while simultaneously understanding scientific content. This difficulty was especially evident at the beginning of the intervention and reinforces the importance of language scaffolding.

Table 5
Themes from Student Reflection Logs

Theme	Interpretive Summary
Increased interest	Students reported greater interest in lessons integrating English and science.
Real-world applications	Students perceived a clearer connection between school learning and real-life situations.
Challenges	Some students found it difficult to balance English language demands with scientific content.

Discussion

The quantitative and qualitative findings converge on the conclusion that the interdisciplinary English-science curriculum was associated with meaningful improvement in both English proficiency and scientific inquiry. Across the three schools, experimental-group English gains ranged from 10.4 to 12.9 points, whereas control-group gains ranged from 1.0 to 1.4 points. Experimental-group scientific inquiry gains ranged from 12.2 to 14.2 points, compared with 0.8 to 1.2 points in control classes. The consistency of this pattern across three school settings strengthens the practical interpretation of the intervention effect, even though the intact-class quasi-experimental design does not provide the same causal certainty as individual random assignment.

The English results support the view that language learning can benefit from authentic, content-rich use. In the interdisciplinary classes, English was not limited to decontextualized drills. Students used language to describe phenomena, collaborate, explain procedures, and communicate interpretations. This type of purposeful use is consistent with the broader interdisciplinary literature, which argues that integrated learning can strengthen engagement and knowledge transfer (Leahey, 1999; Uştu et al., 2021; Çoban & Selvi, 2023). The teacher and student data further suggest that real-world relevance was an important mechanism. Students were more engaged when they could see why they needed specific language to complete a science-related task.

The scientific inquiry results also indicate that the relationship between English and science was reciprocal. English functioned as a tool for externalizing scientific reasoning. Requiring students to discuss observations, justify procedures, and explain results may have made the inquiry process more explicit. This does not mean that language instruction alone produces scientific competence. Rather, the curriculum created a learning environment in which disciplinary reasoning and communication were repeatedly practiced together. The strong gains in experimental design and data analysis described in the study are compatible with this interpretation.

The qualitative findings show that successful interdisciplinary teaching depends on implementation conditions. Teacher collaboration was not an optional addition; it was a structural requirement of the curriculum. This finding aligns with DelliCarpini (2009), Wang et al. (2020), and Munkebye et al. (2021), all of whom emphasize collaboration and coherence in integrated curriculum. When teachers lack shared planning time, the risk is that one subject becomes dominant and the other is reduced to a superficial add-on. In the present study, teachers' requests for more collaboration time indicate that sustained implementation would require timetable and administrative support rather than relying only on individual teacher effort.

Resource constraints were another barrier. Integrated curriculum materials are less readily available than subject-specific textbooks and worksheets, so teachers may need to design or adapt tasks themselves. This increases workload and can reduce consistency across classrooms. A practical implication is the development of reusable interdisciplinary units with clearly mapped English objectives, science objectives, inquiry stages, language scaffolds, and assessment criteria. Shared digital repositories and collaborative planning platforms may also reduce duplication of teacher effort.

Student difficulty in balancing language and scientific content should not be interpreted as evidence against interdisciplinary learning. Instead, it identifies a cognitive-load and scaffolding problem. Some students may understand a scientific concept but lack the English resources to express it, while others may focus on language form and lose track of the inquiry task. Instruction should therefore include staged language support, such as vocabulary previews, sentence frames for hypothesis and evidence statements, model explanations, visual organizers, and opportunities to rehearse ideas before whole-class communication. Scaffolding should be gradually reduced as students gain confidence.

The study contributes to educational research in three ways. First, it evaluates dual outcomes within the same intervention rather than treating language learning and scientific inquiry as separate educational goals. Second, it connects statistical evidence with teacher and student experience, allowing implementation conditions to be interpreted alongside learning outcomes. Third, it demonstrates the value of an action research cycle for refining interdisciplinary curriculum in authentic school settings. The research therefore adds a practice-oriented perspective to literature that has often emphasized conceptual arguments for interdisciplinarity without documenting the combined pattern of language and inquiry outcomes.

The findings should nevertheless be interpreted within the study's limitations. The sample was purposively drawn from three urban primary schools in Xi'an, and existing classes were used. Regional, institutional, teacher, and student characteristics may affect transferability. The intervention lasted nine months, which is sufficient to observe short-term educational change but not long-term persistence. The research also relied on researcher-involved action research, creating potential interpretive bias in observations and qualitative analysis. Finally, the available summary results do not include effect sizes, confidence intervals, or subscale-level inferential statistics. Future research should report these measures and use multilevel or repeated-measures models where school and class clustering are relevant.

Conclusion

This mixed-methods action research study examined an interdisciplinary English-science curriculum across three primary schools in Xi'an. Experimental classes demonstrated substantial pre-test-post-test gains in English proficiency and scientific inquiry skills, while control classes showed much smaller changes. Teacher interviews, classroom observations, and student reflections indicated that authentic real-world tasks increased engagement and helped students connect language use with disciplinary problem solving. At the same time, the research identified teacher collaboration time, resource availability, and the need for language-content scaffolding as central implementation issues.

For classroom practice, interdisciplinary units should begin with a genuinely shared problem or phenomenon rather than a superficial combination of two subjects. English objectives and science inquiry objectives should be mapped together, and students should be given explicit linguistic support for asking questions, describing procedures, interpreting evidence, and explaining conclusions. For school leaders, timetable arrangements should protect cross-subject planning time and provide common repositories of integrated materials. Teacher professional development should focus not only on interdisciplinary theory but also on joint task design, scaffolding, and dual-outcome assessment.

Future research should extend the intervention to different regions, school types, and grade levels and should use longer follow-up periods to determine whether gains persist. Randomized or stronger matched designs would improve causal inference. Quantitative reporting should include effect sizes, confidence intervals, and multilevel analysis where appropriate. Further research could also explore how digital tools and artificial intelligence support personalized language scaffolding, collaborative inquiry, and formative feedback without weakening the central role of teacher-designed pedagogy.

Overall, the findings indicate that interdisciplinary curriculum can be an effective approach to integrating language learning with scientific inquiry in primary education. Its value lies not merely in combining subject content but in creating learning tasks in which students must use English to think, investigate, collaborate, and communicate. Sustainable implementation, however, depends on deliberate curriculum alignment, institutional support for teacher collaboration, and scaffolding that enables students to manage the simultaneous demands of language and disciplinary learning.

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