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From Language Training to Interdisciplinary Learning: A Case Study of Task Reconstruction in Vocational Undergraduate College English

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Abstract

This paper reports a qualitative practice-based case study of task reconstruction in a vocational undergraduate College English course in China. Situated in the emerging policy context of Chinese vocational undergraduate education, the study addresses a pedagogical problem that is increasingly visible in public English courses: students are expected to develop communicative competence, examination readiness, humanistic understanding, professional expression, and interdisciplinary reasoning, yet classroom practice often remains constrained by decontextualised language exercises and test-oriented expectations. Using the unit Bamboo Rhythm: Where Ancient Roots Meet Modern Roads as the central case, the teacher reconstructed a reading lesson into an interdisciplinary learning chain connecting bamboo culture, material properties, engineering processes, sustainable design, knowledge management, peer assessment, and project-based output. Data were drawn from lesson plans, revised teaching slides, classroom interaction records, student notes, knowledge-management sheets, student artefacts, peer-evaluation materials, and reflective teaching documents. The materials were analysed thematically to examine how classroom tasks moved students from familiar experience to disciplinary reasoning, from vocabulary learning to knowledge organisation, and from teacher-led assessment to participatory evaluation. The paper argues that vocational undergraduate College English can function not merely as language training, but as a pedagogical space where language, vocational knowledge, cultural interpretation, and learner agency are integrated through carefully scaffolded tasks.

Keywords— vocational undergraduate education; College English; task reconstruction; interdisciplinary learning.

I. INTRODUCTION

College English in China has long served as a public foundation course for non-English-major students. In vocational undergraduate institutions, however, its role is becoming increasingly complex. It is still expected to support students' basic language development and examination-related needs, especially preparation for College English Test Band 4 and Band 6. At the same time, vocational undergraduate education emphasises professional

application, industrial relevance, complex problem-solving, and the cultivation of high-level technical and skilled professionals. This creates a tension for public English teaching: if College English remains limited to vocabulary explanation, grammar practice, sentence translation, and test preparation, it may fail to respond to the broader educational purposes of vocational undergraduate education.

In the Chinese policy context, vocational undergraduate education is neither a vocationalised

version of general undergraduate education nor a simple extension of junior-college-level higher vocational education. It is expected to reflect the type-specific characteristics of vocational education, maintain the positioning of cultivating high-level technical and skilled professionals, and align professional education with industrial and occupational development (Ministry of Education of the People's Republic of China [MOE], 2021a). The revised Vocational Education Law of the People's Republic of China further emphasises that vocational education is a type of education as important as general education and should support technical skill development, professional ethics, and social participation (National People's Congress of the People's Republic of China, 2022). Although the national English curriculum standard for vocational education currently applies directly to junior-college-level higher vocational education, it remains an important reference point because it defines English as a public foundation course with both instrumental and humanistic value (MOE, 2021b). Similarly, the Guidelines for College English Teaching (2020 edition) positions College English as a course that supports language competence, intercultural communication, autonomous learning, and broader educational development (College Foreign Language Teaching Steering Committee under the Ministry of Education, 2020).

This paper is situated within this policy and pedagogical context. The case involved a large intact class of first-year vocational undergraduate students in engineering-related programmes. The students had relatively adequate receptive language foundations, but many were reluctant to speak, write, evaluate, or use English for disciplinary expression. Three recurring student attitudes were observed during classroom teaching and reflection: "I am not good at English," "Will this be tested?" and "If artificial intelligence can translate, why should I still learn English?" These statements were not treated as individual deficits. Rather, they were interpreted as historically and institutionally shaped responses to prior learning experiences, current assessment pressures, and future-oriented value anxieties.

The study therefore asks how a vocational undergraduate College English reading lesson can be reconstructed from language training into interdisciplinary learning, and how classroom tasks can help students experience confidence, exploration, and tangible learning gains rather than merely

complete isolated language exercises. To address these questions, the paper reports a case of task reconstruction based on *Bamboo Rhythm: Where Ancient Roots Meet Modern Roads*, a reading text that connects bamboo culture, material properties, craftsmanship, engineering processes, and sustainable innovation.

The paper makes three contributions. First, it contextualises vocational undergraduate College English as a public foundation course that must respond simultaneously to language development, professional relevance, and student growth. Second, it proposes task reconstruction as a practical design principle for integrating language, content, cognition, culture, and assessment. Third, it provides classroom-level evidence showing how students can be repositioned as participants, knowledge organisers, evaluators, and project producers in an English course.

II. LITERATURE REVIEW

2.1 Vocational Undergraduate Education and College English

Vocational education should not be understood narrowly as low-level skill training. Billett (2011) argues that vocational education involves the development of capacities for working life, occupational participation, personal formation, and institutional contribution. This broader understanding is particularly relevant to vocational undergraduate education in China, where students are expected to develop applied technical competence alongside higher-level cognitive, communicative, and professional abilities.

In this context, English teaching needs to move beyond decontextualised language instruction. English for Specific Purposes (ESP) emphasises that language teaching should be responsive to learners' academic, professional, and communicative needs (Dudley-Evans & St John, 1998). English for Academic Purposes also highlights the role of language in disciplinary participation, knowledge construction, and academic communication (Hyland, 2006). For vocational undergraduate students, this implies that College English should not only train general linguistic accuracy but also support students in explaining processes, describing systems, presenting professional ideas, and evaluating solutions.

At the same time, vocational undergraduate College English cannot be reduced to narrow

occupational English. As a public foundation course, it also carries humanistic and developmental functions. It should help students understand cultural meanings, organise knowledge, communicate across domains, and develop a language-mediated relationship with their professional and social worlds. This dual requirement creates a need for pedagogical designs that are both language-centred and contextually meaningful.

2.2 CLIL, Interdisciplinary Learning, and Task Reconstruction

Content and Language Integrated Learning (CLIL) provides a useful framework for designing language learning that simultaneously addresses content, communication, cognition, and culture. Coyle et al. (2010) define CLIL as a dual-focused educational approach in which an additional language is used for learning both content and language. Dalton-Puffer (2011) further notes that CLIL practice invites attention to how classroom discourse, conceptual development, and subject-related language interact. Cenoz et al. (2014), however, warn that CLIL should not be treated as a vague label; the relation between language and content needs to be theoretically and pedagogically specified.

This caution is important for the present study. Interdisciplinary College English does not mean adding more technical facts or background information to an already crowded English lesson. Rather, it requires task reconstruction: the deliberate redesign of classroom tasks so that language learning, content exploration, thinking development, and assessment are aligned around meaningful learning purposes. In this paper, task reconstruction refers to a process of transforming text-based language learning into a structured learning chain in which students understand content, organise concepts, use language to explain processes, evaluate ideas, and produce tangible outcomes.

Task-based language teaching also informs this design. Ellis (2003) argues that tasks should involve learners in meaning-focused language use while creating opportunities for attention to language form and outcome. In vocational undergraduate College English, this means that tasks should not merely ask students to answer comprehension questions. They should create a need to use language for explanation, comparison, process description, justification, and evaluation. Such tasks can help students move from receptive language knowledge to meaningful language-mediated disciplinary reasoning.

2.3 Project-Based Language Learning and Visible Output

Project-based language learning supports the move from classroom input to visible output. Stoller (2006) argues that project-based learning in second and foreign language contexts can integrate content learning, inquiry, collaboration, language use, and tangible products. A more recent review of project-based learning in higher education also suggests that well-designed projects can support a range of student outcomes, including knowledge development, skills, motivation, and engagement (Guo et al., 2020). In vocational undergraduate education, project-based output is particularly relevant because students' learning should ideally become visible through artefacts, explanations, designs, presentations, or proposals.

For College English, project output can function as a bridge between language learning and professional imagination. It encourages students to use English not only to reproduce textbook knowledge but also to explain choices, describe processes, present designs, and communicate value. In the present case, project-based tasks included bamboo bicycle modelling and heritage-inspired entrepreneurial proposals. These outputs were designed not as optional add-ons but as evidence that students could integrate language knowledge, cultural understanding, vocational literacy, and professional reasoning.

2.4 Motivation, Knowledge Construction, and Assessment

Students' willingness to participate is shaped by motivation, perceived value, emotional experience, and opportunities for agency. Self-determination theory suggests that autonomy, competence, and relatedness are important conditions for sustained motivation (Ryan & Deci, 2000). Pekrun's (2006) control-value theory of achievement emotions also indicates that students' emotions are closely related to perceived control and task value. In the present case, students' negative English-learning memories, examination-oriented thinking, and AI-related doubts were interpreted as pedagogically meaningful signals rather than simple resistance.

Learning also requires students to actively organise knowledge. Fiorella and Mayer (2015) argue that generative learning occurs when learners actively select, organise, integrate, explain, visualise, or apply knowledge. Cognitive load theory similarly reminds teachers that students may struggle when complex

tasks are introduced without sufficient scaffolding (Sweller, 1988). For this reason, the case design used familiar life processes, structured knowledge-management templates, and staged tasks to help students move from everyday understanding to professional reasoning.

Finally, formative and peer assessment were important to the reconstruction. Black and Wiliam (1998) show that assessment can support learning when evidence of student understanding is used to adapt teaching and guide next steps. Nicol and Macfarlane-Dick (2006) argue that feedback should support self-regulated learning by helping students understand standards, compare current performance with desired performance, and act on feedback. Topping (1998) demonstrates that peer assessment can support student achievement and attitudes when carefully structured. More recently, Carless and Boud (2018) use the concept of feedback literacy to describe students' capacity to understand, interpret, and use feedback. In this study, assessment was therefore reconstructed as a learning task: students were invited not only to receive feedback but also to evaluate answers, notes, processes, learning difficulties, and improvement possibilities.

III. METHODOLOGY

3.1 Research Design and Questions

This study adopts a qualitative practice-based case study design. Case study research is appropriate when researchers seek to understand a contemporary phenomenon in its real-life context and when the boundaries between the phenomenon and its context are not easily separated (Yin, 2018). The purpose of this paper is not to claim causal effects or statistically measured learning gains. Rather, it is to examine how one vocational undergraduate College English unit was reconstructed and what classroom-level pedagogical affordances emerged from that reconstruction.

The study was guided by three research questions:

1. How was a College English reading unit reconstructed into an interdisciplinary learning chain in a vocational undergraduate classroom?
2. What forms of student participation, knowledge organisation, and evaluative activity became visible through the reconstructed tasks?
3. What pedagogical affordances and limitations does the case suggest for vocational undergraduate College English teaching?

3.2 Context and Participants

The case was situated in a first-year College English course in a vocational undergraduate university in China. The students were mainly from engineering-related programmes, and the class size was approximately 60 to 70 students. The class represented a common public-course teaching context: large enrolment, mixed learning foundations, limited opportunities for individualised feedback, and strong pressure to balance examination preparation with broader language development.

The students generally had acceptable receptive language foundations, but many lacked confidence in oral or written output. Some had strong CET-related expectations; others questioned the value of learning English in the age of AI translation. These features made the classroom an appropriate site for examining how task reconstruction could respond to language-learning reluctance, instrumental thinking, and future value anxiety.

3.3 Teaching Unit and Intervention

The main unit was Bamboo Rhythm: Where Ancient Roots Meet Modern Roads. The text discusses bamboo culture, traditional craftsmanship, bamboo as an engineering material, and bamboo bicycles as an example of sustainable innovation. The teacher reconstructed the unit around the guiding question: How can a plant become an engineering material and a carrier of cultural innovation?

The intervention was not a single activity but a learning chain. It began with students' existing life experience, moved to text comprehension and process language, expanded into cultural and material reasoning, and culminated in project-based output. The main task sequence included: (a) activating familiar procedural knowledge through daily-life examples; (b) reading and analysing the bamboo bicycle text; (c) organising key concepts through knowledge-management notes; (d) discussing material properties and engineering processes; (e) using English to explain processes and judgements; (f) conducting peer and teacher-supported evaluation; and (g) producing project artefacts such as bamboo bicycle models or culture-based innovation proposals.

3.4 Data Sources

Data included teaching plans, revised teaching slides, online classroom interaction records, handwritten student notes, knowledge-management templates, teacher comments on student notes, student

artefacts such as function-based career-planning diagrams, peer-evaluation materials, classroom observation materials, and reflective teaching notes. These materials were naturally generated during routine teaching and were used to examine how students were invited to participate, organise knowledge, connect disciplines, and produce evidence of learning.

3.5 Data Analysis and Trustworthiness

The analysis followed a thematic approach informed by Braun and Clarke (2006). First, the teaching materials and reflective notes were reviewed to identify the intended pedagogical logic of the intervention. Second, classroom interaction records, student notes, and student artefacts were examined for recurring forms of participation, language-mediated reasoning, knowledge organisation, and assessment activity. Third, emerging themes were compared across data sources to identify convergent evidence and to avoid relying on a single type of classroom material.

To strengthen trustworthiness, the analysis used data triangulation across teaching plans, interaction records, student notes, artefacts, peer-evaluation materials, and teacher reflection. The teacher-researcher role was also treated reflexively. Because the author designed and taught the unit, the analysis could benefit from rich contextual knowledge but also carried the risk of positive bias. For this reason, claims are presented cautiously as pedagogical affordances observed in one classroom case rather than as generalisable effects.

3.6 Ethical Considerations

All student names, student numbers, avatars, and other personally identifiable information were removed from the manuscript. Student examples are discussed in anonymised and aggregate form. If classroom screenshots or student artefacts are reproduced in a later version of the manuscript, consent and institutional ethical procedures should be confirmed according to the author's local requirements. The manuscript is prepared for double-blind review and does not include identifying author information.

IV. CASE DESIGN: RECONSTRUCTING A READING UNIT INTO AN INTERDISCIPLINARY LEARNING CHAIN

4.1 Starting from Student Experience Rather than Student Deficit

The reconstruction began with a diagnostic understanding of students' learning experiences. The statement "I am not good at English" was interpreted as the result of accumulated negative learning memories. For many students, English had long been associated with mechanical memorisation, repetitive exercises, score anxiety, summative judgement, and teacher-centred correction. It would be unrealistic to reverse these impressions through direct persuasion. The pedagogical response was therefore to provide small but concrete experiences of competence: low-threshold speaking opportunities, short classroom responses, and tasks that allowed students to feel that they could prepare, speak, be heard, and improve.

The statement "Will this be tested?" reflected present-oriented instrumental thinking. Instead of rejecting examination needs, the design used them as a point of entry. CET-related writing and translation concerns were connected with expression selection, generalisation, process description, and logical organisation. In this way, test-related needs were not abandoned, but they were widened into broader communicative and cognitive tasks.

The statement "If AI can translate, why should I learn English?" reflected future-oriented value anxiety. The design responded by reframing English as a tool for questioning, judging, organising, explaining, and using technology intelligently. The aim was not to compete with AI in speed or mechanical translation, but to help students see the continuing value of human judgement, cultural interpretation, and professional communication.

4.2 From Life Process to Engineering Process

One key design move was to begin with familiar life experience. For example, students were asked how to describe the process of cooking a local dish or preparing roast duck/goose legs. This everyday task helped students generate a simple procedural structure: selecting ingredients, processing, cooking, and finishing. The teacher then guided students back to the process described in *Bamboo Rhythm*: selecting mature bamboo stalks, splitting them into strips, drying them under controlled heat, and binding them with plant-based resins.

This move reduced the distance between students' existing knowledge and the disciplinary content of the text. It also helped students understand that procedural language was not only useful for daily-life description but also for engineering explanation. The familiar process functioned as a scaffold for

disciplinary reasoning and lowered the cognitive entry cost without lowering the intellectual demand of the task.

4.3 From Vocabulary to Knowledge Management

Another design move was the use of a knowledge-management template. Students were asked to organise knowledge into three categories: declarative knowledge, procedural knowledge, and strategic knowledge. Declarative knowledge answered "What is it?" Procedural knowledge answered "How is it done?" Strategic knowledge answered "When and why should it be used?" Students also marked their perceived level of mastery.

This template was used to organise vocabulary, concepts, processes, and strategies. For instance, confusing forms such as emergent, emerging, and emergency could be distinguished not only by meaning but also by word class, collocation, context, and common errors. Teacher comments encouraged students to reorganise unclear notes into what/how/why categories. Thus, note-taking became a visible process of knowledge structuring rather than a private act of copying.

4.4 From Cultural Understanding to Engineering Mindset

The Bamboo Rhythm unit also moved from cultural understanding to professional reasoning. Students first explored bamboo culture, Chinese poetic associations, traditional craftsmanship, and the relationship between cultural memory and modern innovation. However, the lesson did not stop at cultural appreciation. Students were guided to consider material properties, process control, stability, reliability, constraints, and sustainability.

Engineering mindset was introduced as a way of thinking rather than as a set of technical facts. Students were asked to identify the stages of engineering thinking. In online classroom interaction, they produced responses such as defining the problem, designing a solution, implementing it, and testing or iterating. These answers were not treated as fixed technical definitions. Instead, they were used as evidence that students were beginning to use process language to conceptualise professional problem-solving.

4.5 From Language Points to Interdisciplinary Task Entrances

The reconstruction also extended beyond the Bamboo Rhythm unit. Several language points were

used as interdisciplinary task entrances. The word formula was connected not only with the Chinese meaning "公式" but also with Descartes, analytic geometry, variable relationships, and logical explanation. Students were encouraged to explain relationships behind formulas rather than merely translate terms.

The phrase career path was connected with function graphs. Students used mathematical curves to represent imagined professional development: linear growth, staged transition, fluctuation and recovery, or accelerated development after accumulation. In this way, mathematical modelling became a tool for self-understanding and career expression.

The term falsification was connected with scientific spirit, critical rationality, evidence, verification, and engineering truth-seeking. These examples show that language points can become conceptual bridges linking English, mathematics, physics, philosophy, career planning, and professional judgement. The design therefore treated vocabulary as an entry point into thinking rather than as an isolated unit of memorisation.

4.6 From Classroom Learning to Project-Based Output

The learning chain culminated in two types of individual project output. One option asked students to design a bamboo bicycle model using CAD or SolidWorks-related modelling tools and submit screenshots, explanations, and, where possible, model files. The other option asked students to develop a culture-inspired innovation or entrepreneurship proposal, drawing on Chinese cultural or intangible heritage resources and presenting the concept through a concise visual document or slides. Both options required students to explain the source of inspiration, the design logic, the integration of cultural and technical elements, and the value of the proposed product or idea.

These outputs were designed to assess more than English vocabulary. They required students to mobilise language knowledge, cultural understanding, process explanation, design judgement, and presentation skills. In this sense, the projects served as evidence of integrated learning rather than as supplementary homework.

V. FINDINGS

5.1 Task Reconstruction Enabled Movement from Familiar Experience to Disciplinary Reasoning

The first affordance was the movement from familiar experience to disciplinary reasoning. Students could more easily enter the lesson when the starting point was a familiar life process. Once they had described how a dish was prepared, they could more readily understand the procedural logic of bamboo processing. This did not simplify the disciplinary content; rather, it created a bridge from everyday procedural knowledge to engineering process expression.

Classroom interaction records showed that students were able to produce process-related responses when asked about engineering mindset. Some identified stages such as problem definition, design proposal, implementation, and testing iteration. Others used similar but differently worded sequences such as goal setting, system design, optimisation, and implementation. These variations suggest that students were not merely repeating the teacher's wording. They were attempting to organise professional thinking through process language.

The finding is significant because it shows how interdisciplinary learning can remain language-centred. Students were not expected to master engineering content at a professional level. Rather, they were guided to use English and English-supported concepts to recognise sequence, causality, constraint, and judgement. Such reasoning is essential for vocational undergraduate students who need to explain technical or professional processes in accessible language.

5.2 Knowledge Management Made Learning Processes Visible

The second affordance was the visibility of knowledge construction. The knowledge-management template helped students move beyond fragmented vocabulary notes. By distinguishing declarative, procedural, and strategic knowledge, students were encouraged to ask not only "What does this word mean?" but also "How is it used?" and "Why is it important in this context?"

Handwritten notes and teacher comments showed that students could use tables, arrows, comparison columns, examples, and correction marks to reorganise confusing knowledge. For instance, when students confused related word forms, the teacher's feedback asked them to classify the differences in terms of meaning, form, context, and usage. This turned feedback into a resource for improving knowledge structure. The process also helped the teacher identify

where students' understanding was incomplete or unstable.

This finding connects task reconstruction with self-regulated learning. Students were not only completing tasks; they were learning how to monitor the type and depth of their understanding. Knowledge management therefore became a bridge between language learning and learning-to-learn competence.

5.3 Participatory Assessment Repositioned Students as Evaluators and Designers

The third affordance was the repositioning of students in assessment. Instead of relying only on teacher judgement, the classroom used dynamic student roles. Based on language foundation, cultural knowledge, academic performance, and learning goals, students were grouped as "breakthrough," "specialised," and "comprehensive" groups rather than as A, B, and C groups. This avoided deficit labelling while still recognising different learning needs.

In classroom questioning, the breakthrough group could answer first to check basic understanding and memory. The specialised group then evaluated the response, focusing on application and flexible use. The comprehensive group added comments on accuracy, completeness, transfer, and expression quality. This sequence allowed students at different levels to participate meaningfully.

Assessment was also extended to learning enthusiasm, classroom notes, learning process, difficulties, and improvement suggestions. Students could evaluate not only whether an answer was correct but also whether the note structure was clear, whether the learning process was complete, and where the next improvement should occur. Cross-class question design was also proposed: one class could design questions for another class around lesson content or CET-related skills. In this process, students moved from test-takers to question designers. They had to consider what knowledge point was being tested, what ability was required, where the difficulty lay, and why the answer was valid.

This finding shows that assessment can become part of task reconstruction. When students participate in evaluation, they are not only judged by standards; they learn to interpret, apply, and question standards. Such participation supports learner agency and makes learning growth more visible.

5.4 Project-Based Output Provided Evidence of Integrated Learning

The fourth affordance was the production of tangible learning evidence. The project tasks required students to move beyond classroom comprehension and produce artefacts that connected language learning with design thinking, cultural interpretation, and professional imagination. In the modelling option, students needed to explain a chosen bicycle type, justify the use of bamboo-related material features, and present the structure or design logic through screenshots and written explanation. In the innovation proposal option, students needed to identify a cultural inspiration, explain how it was transformed into a product or service concept, and present the value of the idea.

These outputs provided evidence that students could mobilise multiple forms of knowledge. They had to use language to explain a design, not merely to translate a sentence. They had to connect cultural meaning with material or product logic, not merely describe cultural symbols. They had to make choices under constraints, which is central to vocational and engineering-oriented learning.

The finding should be interpreted cautiously. The project outputs do not prove measurable gains in English proficiency. However, they indicate that reconstructed tasks created opportunities for students to use English as a medium of explanation, organisation, and presentation. This represents a meaningful expansion of what College English learning can make visible.

VI. DISCUSSION

6.1 Reframing Student Resistance as a Design Problem

This case suggests that student resistance should be interpreted contextually. Students' negative memories, examination orientation, and AI-related doubts are not simply individual weaknesses. They are shaped by previous schooling, current assessment systems, and changing technological conditions. A productive response is not direct confrontation but experience design. When students experience competence, exploration, and tangible gain, they may gradually rebuild their relationship with English learning.

This interpretation aligns with self-determination theory and achievement emotion research. Students are more likely to participate when they experience a sense of competence, see value in tasks, and feel that the classroom allows safe participation. In the present

case, task reconstruction created such conditions by starting from familiar experience, building scaffolded pathways, and making growth visible through notes, evaluation, and projects.

6.2 College English as a Bridge Between Language and Vocational Learning

At the curricular level, College English can act as a bridge between language and vocational learning. In this case, the Bamboo Rhythm unit was not reduced to reading comprehension. It was reconstructed into a learning chain involving cultural interpretation, material understanding, process expression, engineering judgement, sustainable design, and project output. This aligns with the vocational undergraduate requirement for integrated development of knowledge, skills, professional literacy, and complex problem-solving.

The case also contributes to discussions of CLIL and ESP in vocational contexts. It shows that interdisciplinary English teaching does not have to mean adding more technical content to an already crowded language lesson. Rather, the central task is to identify meaningful conceptual bridges and transform them into tasks that students can enter, understand, express, evaluate, and produce. In this sense, task reconstruction offers a practical response to the concern that CLIL or interdisciplinary teaching may remain a slogan unless the language-content relationship is made operational.

6.3 Assessment as Shared Knowledge Construction

At the assessment level, growth becomes visible when evaluation is distributed and formative. Teacher feedback remains important, but students also learn by evaluating answers, notes, processes, difficulties, and questions. When students become evaluators and question designers, they begin to understand standards, task logic, and knowledge structure more deeply. This changes assessment from a final judgement into a shared learning process.

This implication is particularly important for large public English classes. In such classes, it is difficult for the teacher to provide detailed individual feedback to every student at all times. Carefully structured peer assessment and role-based evaluation can expand the feedback network while helping students develop evaluative judgement. However, such assessment requires scaffolding. Students need clear criteria, differentiated roles, and opportunities to revise their understanding.

6.4 International Relevance of a Local Chinese Case

Although this study is situated in a Chinese vocational undergraduate classroom, its relevance is not limited to China. Many higher education contexts face similar pressures: students may hold instrumental attitudes toward language learning, public foundation courses may struggle to demonstrate relevance, and teachers may be asked to support both disciplinary development and transferable competences. The case therefore offers a transferable principle rather than a fixed model: meaningful interdisciplinary language learning requires diagnostic understanding, task alignment, scaffolded knowledge organisation, participatory assessment, and visible output.

At the same time, the local context should not be erased. The emergence of vocational undergraduate education in China, the role of CET-related expectations, and students' AI-related doubts shape the specific problem addressed in this study. Making these local conditions explicit allows international readers to understand both the contextual particularity and the broader pedagogical relevance of the case.

VII. CONCLUSION

This paper has presented a practice-based case study of task reconstruction in a vocational undergraduate College English course in China. By reconstructing Bamboo Rhythm into an interdisciplinary learning chain, the course connected language training with cultural understanding, engineering process, knowledge management, participatory assessment, and project-based output.

The study argues that vocational undergraduate College English should not be understood merely as a supporting course for language tests. It can become a pedagogical space where students regain confidence, explore relationships between self and world, organise knowledge, explain professional processes, and make learning growth visible. The case also shows that task reconstruction requires more than adding interdisciplinary materials. It requires teachers to read student experience, design accessible task pathways, scaffold knowledge organisation, and mobilise students as participants in assessment.

The study has limitations. It is based on one teacher's classroom practice and relies on qualitative process materials rather than experimental measurement. The evidence illustrates classroom-level affordances but cannot establish causal effects or

generalisable proficiency gains. Future research should collect systematic student reflections, pre- and post-task writing samples, peer-assessment data, project rubrics, and follow-up interviews to examine how task reconstruction influences language development, student engagement, and interdisciplinary competence over time.

Nevertheless, the case offers a practical and theoretically grounded model for rethinking public English teaching in vocational undergraduate education. It suggests that when language tasks are carefully reconstructed, College English can move from language training toward interdisciplinary learning and visible student growth.

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Teachers' leadership practices in relation to pupils' academic performance in Piñan District, Schools Division of Zamboanga del Norte

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Abstract

This study aimed to determine the teachers' leadership practices in relation to pupils' academic performance in English, Mathematics, Science, Filipino and Makabayan in Piñan District, Schools Division of Zamboanga del Norte during the school year 2013-2014. A descriptive correlational research method was employed. Frequency count, percentage, weighted mean, standard deviation, t-test and Pearson r Product Moment Coefficient of Correlation were the statistical tools used. There were one hundred thirteen (113) teachers and twenty-two (22) administrators who were involved as respondents of the study. The study revealed that the teachers' leadership practices were found to be often manifested indicating a high level of agreement between teachers and administrators. A significant difference was observed in leadership practices specifically in terms of working with others, whereas no significant difference was found in terms of decision-making regarding teaching, working outside classroom duties, trust among others, and expectations on pupils' academic performance and job satisfaction. The study further revealed that the pupils' academic performance in Mathematics and Science was fair while their academic performance in English, Filipino and Makabayan was good. There existed a low correlation between the teachers' leadership practices and the pupils' academic performance. Based on the findings of the study, the author recommends that the DepEd Key Officials, through the Curriculum Implementation Division (CID) Chief would provide the School Heads with concrete data on teachers' leadership practices for proper monitoring. Teachers would use the findings of this study to enhance their instructional strategies, especially in subjects where performance is low. Pupils would use the results as bases for reflection to improve their learning engagement.

Keywords— teachers' leadership practices, pupils' academic performance, Piñan District, Philippines

I. INTRODUCTION

In today's social and political climate, the emphasis on standardized achievement scores as the primary indicator of a school's effectiveness has placed both teachers and students in a challenging position. Such an environment often prioritizes test performance over authentic learning, leaving little room for creativity,

critical thinking, and holistic development. Many educators argue that this system fosters conditions that are hostile to meaningful and transformative classroom experiences (Sarangapani, 2020). Calls for school reforms should not overlook the leadership potential of classroom teachers, who may be best positioned to make meaningful changes to support schools that work

for teachers and students.

Teacher leadership is defined not merely by holding positions of authority, but by the consistent practice of influencing others and contributing to the school's vision and goals. It encompasses various dimensions such as effective decision-making, collaboration with peers, engagement in community activities, building trust, and maintaining a positive outlook towards learners. These practices allow teachers to go beyond their traditional roles, enabling them to become agents of change who inspire both colleagues and pupils. When teachers actively demonstrate leadership, they create a culture of excellence where high standards are set and met, ensuring that instructional delivery is efficient and effective.

Pupils' academic performance is widely recognized as a multifaceted outcome influenced by both instructional quality and leadership practices within schools. According to Abun (2025), teaching effectiveness encompassing subject knowledge, classroom management, and interpersonal skills has a positive correlation with pupils' academic achievement, which was rated "very satisfactory" in his study. Overa, Bellino, and Bellino (2025) further emphasized that leadership-oriented teaching practices foster improved learning outcomes, suggesting that teachers who demonstrate strong leadership in guiding, motivating, and supporting pupils contribute directly to higher performance levels. Similarly, Largo et al., (2025) highlighted that school heads' leadership skills are strongly linked to teachers' engagement which indirectly enhances pupils' academic success. These findings collectively affirm that pupils' academic performance in contexts such as Piñan District, Schools Division of Zamboanga del Norte is not only a reflection of individual effort but also a product of effective leadership and instructional practices within the school environment.

On the other hand, pupils' academic performance serves as the ultimate gauge of educational success, reflecting the effectiveness of the teaching and learning process. It is measured through the learners' achievement scores across key learning areas such as English, Mathematics, Science, Filipino and Makabayan. High academic performance indicates that pupils have acquired the necessary knowledge, skills and values needed for their development. However, performance often varies across subject areas, influenced by factors such as teaching strategies, learning materials and the learning environment. Ensuring good performance requires a supportive atmosphere where pupils are motivated to learn and are guided by competent educators.

The relationship between teachers' leadership practices and pupils' academic performance is inherently interconnected. Strong leadership among teachers directly translates to better instructional strategies, classroom management and learner support which consequently elevate pupil achievement. Research suggests that when teachers exhibit leadership qualities, they are more likely to implement innovative approaches and maintain high expectations which positively influence pupil motivation and learning outcomes. Thus, leadership is not just an administrative function but a vital pedagogical tool that enhances the quality of education delivered to the learners.

Despite the growing body of literature that underscores the significant role of teacher leadership in enhancing pupil outcomes, limited empirical evidence exists that specifically examines the impact on pupils' classroom performance within the local context of public schools in the Philippines. Based on available records, the Philippines participated in the Program for International Student Assessment (PISA) in 2018 and Trends in International Mathematics and Science Study (TIMSS) in 2019. The results showed scores significantly below international standards indicating challenges in the educational system. These poor results are often attributed to various factors, including instructional quality and school climate. Observably, these conditions are prevalent in rural schools, such as Piñan District, Schools Division of Zamboanga del Norte. Furthermore, there is a scarcity of localized research that directly links the teachers' leadership practices to specific academic outcomes during the period under study.

A review of different theories on leadership in schools finds teacher leadership thrives where transformational administrators sustain learning environments. While various models exist, the specific measurement and manifestation of teacher leadership remain areas requiring deeper investigation particularly in how they translate into actual classroom results. Therefore, this research is necessary to fill this gap and provide evidence-based data on how teachers' leadership practices influence pupil performance in the specific locale.

II. LITERATURE REVIEW

Teacher leadership practices

Teacher leadership practices are increasingly recognized as crucial in shaping effective teaching and learning environments. According to Wenner and

Campbell (2017), teacher leaders extend their influence beyond their classrooms by collaborating with colleagues, mentoring novice teachers, and contributing to school-wide improvement initiatives. These practices foster a culture of professional growth and shared responsibility, which strengthens instructional quality. Similarly, Harris and Jones (2019) emphasized that teacher leadership serves as a catalyst for sustainable educational reform, particularly when schools empower teachers to take active roles in decision-making processes. Such practices highlight the growing importance of teachers not only as facilitators of learning but also as agents of organizational change.

Teacher leadership practices are also closely linked to student achievement and school performance. York-Barr and Duke (2021) noted that teacher leaders create positive ripple effects on student outcomes by fostering collaborative professional communities, sharing effective instructional strategies, and enhancing curriculum development. Likewise, Neumerski et al. (2018) argued that schools that promote teacher leadership tend to improve student engagement and motivation, as leadership practices encourage innovation in teaching approaches. By bridging classroom expertise with school-wide reform, teacher leaders contribute to higher academic performance and more effective student support systems.

In addition, recent research highlights the importance of context in shaping teacher leadership practices. Nguyen, Harris, and Ng (2020) found that the effectiveness of teacher leadership depends on the level of trust, collaboration, and autonomy given by school administrators. Teachers thrive as leaders when they are empowered to participate in curriculum planning, policy formulation, and instructional decision-making. Similarly, Liu, Hallinger, and Feng (2021) stressed that schools fostering teacher leadership create professional learning cultures that directly benefit both teachers' job satisfaction and student learning outcomes. Thus, teacher leadership practices not only enhance instructional effectiveness but also build stronger educational communities.

Working with others

Collaboration, or working with others, is a cornerstone of teacher leadership and professional growth, as it enhances collective capacity to improve teaching and learning outcomes. Research shows that when teachers collaborate through peer mentoring, team teaching, or professional learning communities, they develop stronger instructional practices and foster school-wide

improvement (Nguyen, et al. 2020). Moreover, collaboration builds collective efficacy, which has been found to positively impact student achievement and teachers' job satisfaction (García & Torres, 2019). Recent studies further emphasize that working with colleagues enables knowledge sharing and innovation in pedagogy, making schools more adaptive to changes and challenges in education systems (Liu et al. 2021).

Decision-making regarding teaching

Decision-making in teaching is a critical element of teacher leadership, as it reflects educators' professional autonomy and their capacity to shape classroom learning. Teachers who are empowered to make instructional decisions demonstrate greater commitment to tailoring strategies that address students' diverse needs (Wenner & Campbell, 2017). Recent studies highlight that shared decision-making among teachers enhances instructional innovation and fosters a sense of professional ownership in the teaching process (Poekert, et al., 2016). Furthermore, teacher involvement in pedagogical and curricular decisions has been linked to improved student outcomes, as it aligns classroom practices with learners' contexts while strengthening teachers' leadership identities (Nguyen, et al., 2020).

Working outside classroom duties

Working outside classroom duties is a vital component of teacher leadership, as it extends educators' influence beyond instruction to encompass school improvement and community engagement. Teachers who assume roles such as mentoring colleagues, leading professional development, and participating in policy discussions contribute to a culture of collaboration and organizational growth (York-Barr & Duke, 2017). Recent studies emphasize that these extra-classroom responsibilities enhance teachers' professional identity and empower them to advocate for student-centered reforms (Nguyen, et al., 2020). Moreover, engaging in school-wide and community initiatives not only supports institutional goals but also fosters a stronger sense of teacher potency and collective efficacy (Bingham, 2021).

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Trust among others

Trust among teachers, colleagues, and school leaders is a critical foundation of teacher leadership and overall school effectiveness. When educators trust one another, collaboration becomes more meaningful, leading to

shared decision-making and collective responsibility for student learning (Tschannen-Moran & Gareis, 2015). Studies reveal that trust enhances communication, reduces conflict, and promotes a positive school climate where teachers feel empowered to lead beyond their classrooms (Adams, & Forsyth, 2025). More recent research also highlights that trust in colleagues and administrators strengthens teachers' professional identity and increases their willingness to engage in innovative practices that directly improve student outcomes (Altunay, & Erol, 2024).

Expectations on pupils' academic performance and job satisfaction

Teachers' perceptions of pupils' achievement are closely tied to their own sense of professional satisfaction and motivation. When educators witness improvements in pupils learning, they often report higher levels of job fulfillment and commitment to teaching (Collie et al., 2016). Research further suggests that teachers derive satisfaction not only from academic outcomes but also from students' holistic growth, such as improved confidence and engagement (Toropova et al., 2021). More recent studies confirm that positive beliefs about student achievement foster intrinsic motivation, reduce burnout, and strengthen teachers' sense of purpose in the classroom, ultimately contributing to sustained teacher effectiveness (Wang et al., 2023).

Academic performance

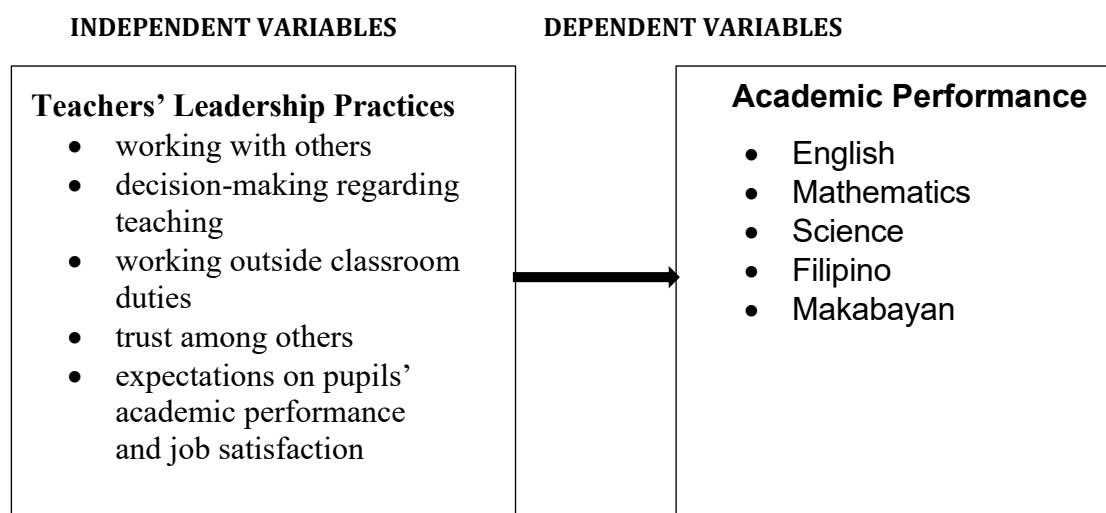
The academic performance of pupils refers to a comprehensive summary of learners' achievements in various subject areas, usually measured through grades, assessments, and other indicators of learning outcomes. It provides a holistic view of pupils' strengths, weaknesses, and learning progress across different competencies. According to Popham (2016), an academic profile not only reflects students' mastery of curriculum standards but also serves as a diagnostic tool for identifying learning gaps that require intervention. Recent studies highlight that performance profiles are influenced by factors such as socioeconomic status, parental involvement, teacher effectiveness, and

learning resources (Tomaszewski, et al. 2020). Moreover, academic performance profiling is important for schools in designing targeted support programs, ensuring equity in learning, and enhancing accountability for both teachers and learners (Ahmed, 2024). Pupils' academic performance is widely recognized as a multifaceted outcome influence by both instructional quality and leadership practices within schools.

Ordina and Ebueza (2020) conducted a study revealing that learners' performance is exceptionally good with their academic achievements in core subjects standing out prominently. The study highlights that the high levels of student performance are indicative of outstanding achievements in key areas such as mathematics, science, and language arts. These findings suggest that the educational strategies, teaching methodologies and teachers' leadership practices employed are highly effective in fostering academic excellence. The students' success in core subjects demonstrates their strong understanding and mastery of fundamental concepts reflecting the quality of instruction and the supportive learning environment especially on the teachers' leadership practices.

III. CONCEPTUAL FRAMEWORK

The conceptual framework is presented in figure 1. First, the independent variable which is the teachers' leadership practices categorized into five (5) indicators namely: working with others, decision-making regarding teaching, working outside classroom duties, trust among others, and expectations on pupils' academic performance and job satisfaction with a total of twenty-five (25) items, researcher-made questionnaire but validated and pilot tested. Next, the dependent variable is the pupils' academic performance in English, Mathematics, Science, Filipino and Makabayan taken from the different teacher-advisers. This study intends to determine the teachers' leadership practices in relation to pupils' academic performance.



Source: Researcher-made (Validated)

Source: DepEd Teacher-Advisers

Statement of the Problem

This study aimed to determine the teachers' leadership practices in relation to the pupils' academic performance in English, Mathematics, Science, Filipino and Makabayan in Piñan District, Schools Division of Zamboanga del Norte during the school year 2013-2014. Specifically, it sought to answer the following questions:

1. What is the perceived level of teachers' leadership practices as rated by themselves and the administrators in terms of:
 - 1.1 working with others;
 - 1.2 decision-making regarding teaching;
 - 1.3 working outside classroom duties;
 - 1.4 trust among others; and
 - 1.5 expectations on pupils' academic performance and job satisfaction?
2. What is the level of pupils' academic performance in the five (5) learning areas in Piñan District during the school year 2013 – 2014?
3. Is there a significant difference between the teachers' and administrators' ratings on the perceived level of teachers' leadership practices?
4. Is there a significant relationship between the perceived level of teachers' leadership practices and the level of pupils' academic performance?

Hypotheses

1. There is no significant difference between the teachers' and the administrators' ratings

on the perceived level of teachers' leadership practices.

2. There is no significant relationship between the perceived level of teachers' leadership practices and the level of pupils' academic performance.

Scope and Limitation of the Study

This study was limited to the teachers' leadership practices as rated by the one hundred thirteen (113) teachers themselves and the twenty-two (22) administrators of the elementary schools in Piñan District, Schools Division of Zamboanga del Norte. The scope is limited to five (5) indicators of teachers' leadership practices with twenty-five (25) items as the independent variables such as: working with others; decision-making regarding teaching; working outside classroom duties; trust among others; and expectations on pupils' academic performance and job satisfaction. The dependent variable consists of the pupils' academic performance in English, Mathematics, Science, Filipino and Makabayan during the school year 2013-2014. This study is intended to determine the relationship between the perceived level of teachers' leadership practices and the level of pupils' academic performance.

IV. RESEARCH METHODOLOGY

This study utilized the descriptive-correlational research design. Specifically, it employed the survey method to gather the necessary data. The survey method was used to collect data on teachers' leadership practices through a researcher-made questionnaire which was pilot-tested in another district not involved in the study. The pupils'

academic performances of the five (5) learning areas were taken from the different class advisers. According to Fowler (2020), surveys are highly effective in educational and social science research because they provide reliable insights into participants' attitudes, behaviors, and experiences allowing for the collection of standardized data efficiently. Furthermore, the correlational research design was appropriate as this study aimed to investigate the statistical relationship between two variables: the teachers' leadership practices and the pupils' academic performance. As described by Coe et al. (2021), correlational research is a non-experimental approach that systematically examines the associations among variables without manipulating or interfering with them. This design enabled the researcher to determine whether a significant relationship exists between the leadership practices demonstrated by teachers and the academic performance of their pupils.

The researcher was granted permission by the Schools Division Superintendent to float her questionnaires to the respondents in order to gather data. Ethical consideration was sought from the Ethics and Review Committee of Andres Bonifacio College, Inc. and from the Ethics Committee of the Schools Division of Zamboanga del Norte to proceed with the data gathering and informed consent was given to the individual respondent for his/her approval to participate in the study. The following scoring guide with its range of values and descriptive interpretation was used. The scoring procedure for the teachers' leadership practices and the pupils' academic performance is presented below.

Scoring Procedure

Teachers' Leadership Practices

Scale	Range of Values	Description	Interpretation
5	4.21-5.00	Strongly Agree	Very High /Very Frequent
4	3.41-4.20	Agree	High/Often
3	2.61-3.40	Somewhat Agree	Average/Sometimes
2	1.81-2.60	Disagree	Low/Rarely
1	1.00-1.80	Strongly Disagree	Very Low/Never

Pupils' Academic Performance

The data on academic performance of pupils were taken from the teachers' records and documents they submitted. The interpretation was based on the following:

Scale	Range of Values	Interpretation
5	4.21-5.00	Outstanding
4	3.41-4.20	Very Good
3	2.61-3.40	Good
2	1.81-2.60	Fair
1	1.00-1.80	Poor

V. DATA PRESENTATION AND ANALYSIS

The data are presented according to the statement of the problem. The study answered the following questions.

1.What is the perceived level of teachers' leadership practices as rated by themselves and their

administrators in terms of: working with others, decision-making regarding teaching, working outside classroom duties, trust among others, expectations on pupils' academic performance and job satisfaction?

Table 1 Perceived Level of Teachers' Leadership Practices in Terms of Working With Others

Items	Administrators		Teachers	
	AWV	D	AWV	D
1. Voiced personal thoughts about teaching or learning with other teachers?	4.00	0	4.08	0
2. Assisted another teacher who specifically asked for or needed support?	4.05	0	4.07	0
3. Worked with other teachers to solve a school problem not about your class?	4.02	0	4.05	0
4. Took an action that increased parent participation here at school?	4.03	0	4.08	0
5. Complemented or thanked another teacher for work done to improve the school.	4.00	0	4.10	0
6. Asked another teacher for advice or help with a teaching problem	4.02	0	4.06	0
Overall	4.02	0	4.07	0

AWV=Average Weighted Value, D=Description as O=Often

Table 1 presents the data on teacher leadership practices in terms of working with others. The data show that the average weighted values and overall means fall within the range of 3.41 – 4.20 which is described as “Often” manifested. This means that teachers frequently demonstrate leadership by voicing their opinions regarding teaching and learning, assisting colleagues who need support, collaborating to solve school problems, initiating actions to increase parent participation, expressing appreciation to fellow teachers, and seeking advice when needed. The overall result implies that the teachers in Piñan District possess strong interpersonal skills and a collaborative spirit. They effectively foster camaraderie, cooperation, and healthy professional relationships among teachers. Their willingness to work together establishes a

supportive network that defines a positive and harmonious school culture. This finding is supported by Ngyuyen et al., (2020) who stressed that when teachers collaborate or work through peer mentoring, team teaching, and professional learning communities, they develop stronger instructional practices and drive school-wide improvement. Moreover, Garcia and Torres (2019) affirmed that collaboration or working with others build collective efficacy which significantly impacts pupil achievement and enhances teachers' job satisfaction. Similarly, Liu et al. (2020) emphasized that working closely with colleagues enables knowledge sharing and pedagogical innovation, making schools more adaptive to the changing demands of the educational system.

Table 2 Perceived Level of Teachers' Leadership Practices in Terms of Decision-making Regarding Teaching

Items	Administrators		Teachers	
	AWV	D	AWV	D
1. Sought advice from another teacher, an article, or a book about a better way to teach something?	4.10	0	4.12	0
2. Tried a strategy in your classroom that you had never tried before?	4.12	0	4.00	0
3. Kept note of student behaviors and, as a result, changed teaching strategy?	4.05	0	4.00	0
4. Independently solved a problem that may actually have been an administrator's job to fix?	4.00	0	4.00	0
	4.07	0	4.04	0

AWV=Average Weighted Value D=Description as O=Often

Table 2 shows the data on the teacher leadership practices in terms of decision-making regarding

teaching. The results indicate that the weighted values fall within the range of 3.41 – 4.20 which is interpreted

as “Often” manifested. This implies that teachers frequently make sound decisions regarding instruction. Specifically, they often seek advice from colleagues or references to improve their teaching methods, experiment with new strategies, and adjust their approaches based on observed student behaviors and learning needs. Furthermore, teachers take the initiative to solve problems independently, especially when administrators are occupied with other responsibilities. They act as support systems who supplement the needs of the school and address the gaps whenever necessary, demonstrating resourcefulness and professional maturity. In general, the teachers show competence and

confidence in choosing the appropriate course of action, proving that they are capable of making sound decisions that benefit the teaching and learning process. This finding is supported by Wenner and Campbell (2017) who stated that teachers who are empowered to make instructional decisions demonstrate greater commitment to tailoring strategies that address pupils’ diverse needs. Similarly, Poekert et al. (2016) affirmed that shared decision-making among teachers enhances instructional innovation and fosters a sense of professional ownership leading to improved educational outcomes.

Table 3 Perceived Level of Teachers’ Leadership Practices in Terms of Working Outside Classroom Duties

Items	Administrators		Teachers	
	AWV	D	AWV	D
1. Took time out to help a teacher deal with changes at school.	4.12		O	4.15
2. Met with a teacher to improve their practices to meet school goals.	4.08		O	4.18
3. Spoke out on behalf of pupils whose needs weren’t being met.	4.05		O	4.10
4. Modeled reflection leading to improvement of practices in the classroom which may have impacted other teachers.	4.00		A	4.02
5. Took an action whose goal was increasing the success of all the pupils in this school.	4.05		A	4.08
6. Played an important role in building the professional community here in school.	4.06		A	4.06
Overall	4.03		A	4.05

AWV=Average Weighted Value D=Description as O=Often A=Always

Table 3 reflects the teachers’ leadership in terms of working outside classroom duties. The data reveal that the first three items were rated as “Often” manifested, while the last three items were rated as “Agree” or

“Always” by both groups of respondents. This indicates that teachers actively demonstrate leadership even beyond their regular classroom instruction. They willingly extended assistance to colleagues, support

students with their concerns and dedicate time and effort outside teaching hours to ensure that school objectives are met. Furthermore, their involvement extends to building a strong professional community and engaging in activities that benefit the wider society. By organizing groups and collaborating with local stakeholders, teachers contribute to the development of a better community. These extension services reflect their commitment not only to education but also to social responsibility and public service. This finding is supported by York-Barr and Duke (2017) who

confirmed that teachers who take on roles such as mentoring colleagues, leading professional development, and participating in policy discussions significantly contribute. Moreover, Nguyen, et al., (2020) emphasized that assuming responsibilities beyond the classroom enhances teachers’ professional identity and empowers them to advocate for student-centered reforms. Bingham, (2021) likewise stated that engaging in school-wide and community initiatives not only supports institutional goals but also fosters a stronger sense of teacher potency and collective efficacy.

Table 4 Perceived Level of Teachers’ Leadership Practices in Terms of Trust Among Others

Items	Administrators		Teachers	
	AWV	D	AWV	D
1. Teachers in this school were respectful of the opinions and beliefs, whether they agreed with you or not.	4.12	A	4.18	A
2. It was safe to openly disagree with others during school meetings.	4.15	A	4.15	A
3. The teachers felt supported in the work by other teachers here at school.	4.02	A	4.12	A
4. The teachers welcomed views of other teachers that were different from one’s own here at school.	4.03	A	4.16	A
Overall	4.00	A	4.15	A

AWV=Average Weighted Value D=Description as A=Always

Table 4 portrays the profile of teachers’ leadership practices in terms of trust among others. The results indicate that teachers consistently demonstrate high regard for others by showing respect for diverse opinions, expressing disagreements constructively and feeling supported by their colleagues and superiors. They are open-minded and welcoming of ideas that differ from their own, fostering an atmosphere of mutual respect. This implies that the teachers in Piñan District are exercising leadership at their respective levels by building strong relationships based on trust. Practicing these values is essential because trust is the foundation of effective leadership. If teachers cultivate trust now, they are better prepared to assume higher administrative responsibilities in the future as they have

already developed the interpersonal skills necessary to lead people effectively. This finding is supported by Tschannen-Moran and Gareis (2015) who stated that when educators trust one another, collaboration becomes more meaningful, leading to shared decision-making and collective responsibility for student learning. Similarly, Adams and Forsyth (2025) revealed that trust enhances communication, reduces conflict and promotes a positive school climate where teachers feel empowered to lead beyond their classrooms. Furthermore, Altunay and Erol (2024) emphasized that trust in colleagues and administrators strengthens teachers’ professional identity and increases their willingness to engage in innovative practices that directly improve student outcomes.

Table 5 Perceived Level of Teachers' Leadership Practices in Terms of Expectations on Pupils' Academic Performance and Job Satisfaction

Items	Administrators		Teachers	
	AWV	D	AWV	D
1.The most important factor in the pupils' achievement is relationship with them.	4.12	A	4.18	A
2.The teachers are responsible for the success of the pupils in the classroom.	4.19	A	4.18	A
3.The teachers spend time thinking about what works and what doesn't work in the classroom and make changes to improve teaching.	4.09	A	4.18	A
4. The teachers make certain to translate the school's goals for improvement into one's own classroom practices.	4.04	A	4.17	A
5. The teachers derive satisfaction from work in the classroom and the relationships with the pupils.	4.06	A	4.18	A
Overall	4.13	A	4.18	A

AWV=Average Weighted Value D=Description as A=Always

Table 5 presents the data on the teachers' leadership practices in terms of expectations on pupils' academic performance and job satisfaction. The results show that the average weighted values fall within the range of 3.41 - 4.20 which is interpreted as "Agree" or "Always" manifested. This indicates that both teachers and administrators concur that teachers are highly focused on pupils' achievement. They firmly believe that establishing a positive and supportive relationship with pupils is the most critical factor in academic success. This aligns with the findings of Chen et al. (2022) and Losh et al. (2022) who emphasized that positive teacher-pupil relationships significantly enhance pupil engagement, motivation and overall academic performance. Such relationships serve as a secure foundation that encourages pupils to participate actively and persist in their studies. Furthermore, teachers demonstrate instructional leadership by constantly reflecting on their practices, evaluating what works best, and making necessary adjustments to improve learning outcomes. According to Ritonga et al. (2022) and Ashraf et al. (2016), reflective

teaching enables educators to become more adaptive, responsive to pupils' needs, and effective in delivering instruction. This process also helps them align their classroom

activities with the school's vision and goals, ensuring that instructional efforts are directed toward shared objectives. In addition, the data reveal that teachers derived great professional satisfaction from their work, particularly when they see positive results and maintain good rapport with their pupils. This sense of fulfillment is closely linked to their leadership roles as supported by Papadopoulos and Karagiannakis (2022) and Edemo et al. (2025) who found that teachers who feel valued and empowered in their practice tend to be more satisfied, committed and motivated to excel.

The overall picture indicates that teachers in Piñan District possess strong leadership potentials that are clearly manifested both inside and outside the classroom. Their leadership is exemplary, consistent, and deeply embedded in their daily practice--to the point that it has become a natural part of their professional identity. They do not find it difficult to exercise leadership because it is rooted in their genuine concern for pupil welfare and their dedication to the teaching profession.

2. Is there a significant difference in the teachers' and administrators' ratings on the perceived level of teachers' leadership practices?

Table 6 Test of Difference in the Teachers' and Administrators' Ratings on the Perceived Level of Teachers' Leadership Practices

Working w/ others	Mean	StDev	SE	Mean	t-value	p-value
Administrators	4.0200	0.0190	0.0077	5.06	0.001	
Teachers	4.0733	0.0175	0.0071			
Decision- Making						
Regarding Teaching	Mean	StDev	SE	Mean		
Administrators	4.0675	0.0538	0.027	0.64	0.551	
Teachers	4.0425	0.0568	0.028			
Working Outside Classroom						
Duties	Mean	StDev	SE	Mean		
Administrators	4.0629	0.0368	0.014	1.64	0.133	
Teachers	4.1043	0.0559	0.021			
Trust Among Others	Mean	StDev	SE	Mean		
Administrators	4.0800	0.0648	0.032	2.09	0.128	
Teachers	4.1525	0.0250	0.012			
Expectations on Pupils'	Mean	StDev	SE	Mean		
Academic Performance						
and Job Satisfaction						
Administrators	4.1000	0.0587	0.026	2.96	0.042	
Teachers	4.1780	0.00447	0.0020			

Table 6 discloses the test of difference between the teachers' and administrators' ratings on the perceived level of teachers' leadership practices. In terms of working with others, the computed t-value is 5.06 with a corresponding p-value of 0.001. Since the p-value is less than 0.05, the result is significant. This means that there is a statistical difference in how teachers and administrators perceive this aspect of leadership. Teachers rated themselves slightly higher than how administrators rated them indicating a variance in perception. This implies that while the teachers feel that they collaborate frequently, administrators may have a different standard or observation of how such collaboration is demonstrated in actual school settings. As regards decision-making regarding teaching, the

computed t-value is 0.64 and the p-value is 0.551, which is greater than 0.05. This indicates no significant difference between the ratings which suggests that both groups share the same view regarding how teachers make decisions about instruction. The administrators' assessment essentially confirms the teachers' self-evaluation, signifying a clear and observable manifestation of decision-making skills. Similarly, for working outside classroom duties, the t-value is 1.64 and the p-value 0.133 which is not significant. This implies that there is a strong agreement between the two groups. Teachers practice leadership beyond their regular classes, and this is clearly evident and witnessed by the administrators. For trust among others, the result shows a t-value of 2.09 and a p-value of 0.128 which is

not significant. This means that both parties perceive the level of trust and respect among faculty members in the same way, fostering a harmonious professional environment. However, in the aspect of expectations on pupils' academic performance and job satisfaction, the t-value is 2.96 and the p-value is 0.042 which is significant. This indicates that there is a difference in perception, particularly that teachers view themselves as highly responsible and focused on pupil success more than

how administrators perceive them. Despite this difference, the overall trend shows that for most areas, the ratings are congruent, signifying that teachers effectively demonstrate leadership practices as observed by both themselves and their superiors.

3. What is the level of pupils' academic performance in the five (5) areas in Piñan District during the school year 2013 – 2014?

Table 7 Level of Pupils' Academic Performance

Subjects	O	VG	G	F	P	Mean	D
English	123	162	246	413	200	2.64	G
Mathematics	89	145	183	410	317	2.37	F
Science	95	132	228	376	313	2.40	F
Filipino	211	189	313	221	210	2.97	G
Makabayan	203	200	302	214	225	2.95	G
Overall						2.67	G

Legend: 4.21-5.00=Outstanding, 3.41-4.20=Very Good, 2.62-3.40=Good, 1.81-2.60=Fair, 1.0-1.80=Poor

Table 7 exhibits the level of pupils' academic performance across the five learning areas. As gleaned from the data, English, Filipino, and Makabayan obtained mean scores of 2.64, 2.97 and 2.95 respectively, which are described as "Good". On the other hand, Science and Mathematics yielded lower means of 2.40 and 2.37 respectively categorized as "Fair". The overall mean performance of the pupils is 2.67, verbally interpreted as "Good". This implies that generally, the learners are meeting the basic competencies and standards required at their grade level. However, the results also indicate that while they perform well in language and social studies, they face greater challenges in the areas of Mathematics and Science. This finding is supported by Bandico (2002) who revealed that the academic performance of elementary pupils generally falls within the average level. Furthermore, this trend mirrors the findings from the international assessments such as the Trends in International Mathematics and Science Study {TIMSS} which consistently show that learners across various educational systems struggle with logical reasoning, analytical skills, and the application of concepts. According to TIMSS 2023 results, students typically perform better in recalling

facts but encounter significant difficulties when required to apply knowledge and engage in higher-order thinking. The difficulty in these subjects is often attributed to their abstract nature and cumulative structure. Unlike the subjects that deal with concrete or observable phenomena, Mathematics and Science require students to manipulate symbols, understand theoretical relationships, and build upon previously learned skills – gaps in which can quickly lead to further difficulties. Additionally, research indicates that limited instructional time, lack of hands-on activities, and lower student confidence also contribute to lower achievement in these areas. Therefore, although the general performance is acceptable, there is a need to strengthen pedagogical approaches specifically in Mathematics and Science.

This includes using more concrete examples, providing ample opportunities for practice and fostering a positive learning environment to improve mastery and competence among learners.

4. Is there a significant relationship between the level of teachers' leadership practices and the level of pupils' academic performance?

Table 8 Test of Relationship Between the Perceived Level of Teachers' Leadership Practice and the Level of Pupils' Academic Performance

Variables	Mean	SD	r-computed	t-computed	p-value
Teachers' Leadership Practices	4.08	3.211	0.132 Low correlation	4.75*	0.001
Pupils' Academic Performance	2.67	2.015			

Legend: $\alpha = 0.05$

c.v. = 1.96

* = significant

Table 8 presents the results of the test of relationship between the perceived level of teachers' leadership practices and the level of pupils' academic performance. The data revealed a computed r-value of 0.132 indicating a low positive correlation. However, when subjected to the t-test, the computed value of 4.75 exceeds the critical value of 1.96 with a corresponding value of 0.001, which is less than 0.05. This result leads to the rejection of the null hypothesis, signifying that there is a significant relationship between the teachers' leadership practices and pupils' academic performance. Although the correlation is statistically low, the relationship is meaningful and valid. This implies that when teachers demonstrate effective leadership-such as being good role models, establishing positive rapport, and showing responsibility- they create a learning environment where pupils feel safe, motivated and encouraged to perform better. This finding is supported by Hallinger and Heck (2016) and Nguyen et al. (2020) whose meta-analysis confirmed that teacher leadership has a positive and significant influence on pupil learning outcomes. They explained that teachers who lead influence achievement not only through instruction but also by fostering a culture of high expectations and collective responsibility. Similarly, Leithwood and Riehl (2020) emphasized that leadership practices contribute significantly to school success by establishing order, setting clear goals, and building trusting relationships. When teachers are responsible and dedicated, these qualities are mirrored in the attitude and performance of their pupils. As the saying goes "quality input yields quality output." Therefore, the leadership behaviors demonstrated by the teachers serve as vital inputs that directly shape the quality of learning and academic performance of the pupils.

VI. CONCLUSION

Based on the findings of this study, it was concluded that teachers demonstrate leadership potential inside and outside the classroom. However, the overall academic

performance remains a concern, particularly the low achievement levels in Mathematics and Science. Although there was a low correlation between the perceived level of teachers' leadership practices and the level of pupils' academic performance, there is still a need to continuously encouraged and support the teachers. It is recommended that the Curriculum Implementation Division (CID) Chief would provide the School Heads with concrete data on the teachers' leadership practices for proper monitoring. It is further recommended that the teachers would use these findings to enhance their instructional strategies especially in subjects where performance is low. Likewise, the pupils would use the results as basis for reflection to improve their learning engagement.

AUTHORS' CONTRIBUTION

Conceptualization, research methodology, data gathering, analysis and editing were done by all the authors.

CONFLICT OF INTEREST STATEMENT

All authors declare no conflict of interest.

ETHICAL REVIEW STATEMENT

The research was submitted to the Ethics and Review Board and was granted permission to proceed with the study. It has no human-sensitive issue.

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Fostering Entrepreneurship Through Vocational Education: A Study on Tribal Girl Students in India

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Abstract

The paper aims to explore the intricacies of the relationship between vocational education programs and the development of entrepreneurial capacity among tribal girl learners in selected regions of India. This paper adopts a mixed-methods approach, amalgamating quantitative survey research with 385 respondents and qualitative research through interviews with 52 vocational training learners and community stakeholders, to understand how the structural and pedagogical features of vocational training programs interact with socioeconomic factors to facilitate or discourage entrepreneurial intentions. The research findings demonstrate that under the circumstances of the introduction of culturally responsive, adequate infrastructure, and institutionally supportive systems, vocational education is a potent initiator of entrepreneurial intention. Besides, compliance with the National Education Policy 2020 and Sustainable Development Goal 5 on gender equality indicates that the existing paradigm requires conceptualisation on a broader level to incorporate intersectional vulnerabilities within tribal communities. The study will introduce certain factual data on the effectiveness of vocational education as a means of development and will identify certain critical gaps in its application that need some intervention in the form of a policy. The paper unravels the significance of using enterprise development modules, market connections and financial literacy in vocational training to make the most out of the previously sidelined population.

Keywords— vocational education, entrepreneurship, tribal girls, gender equality, inclusive development, India

I. INTRODUCTION

The structure of vocational education, gender equity, and entrepreneurial capacity building per se is a significant nexus in the contemporary discussion of education, particularly within the context of postcolonial nation-states who moderates the excessive globalisation and economic transformation. A structural

disparity of access to education, economic empowerment and social migrations has affected the tribal Indians, about 8.6 percent of the total population structure of the country, further compounded by economic vulnerability and which are unfamiliar to any traditional educational intervention efforts without intersectional barriers (Ministry of Tribal Affairs, 2023).¹ Vocational education, which is defined as the

¹ The framework of vocational education, gender equity, and entrepreneurial capacity development represents a major nexus in the modern discourse of education, particularly within postcolonial nation-states experiencing rapid

globalization and economic restructuring. Tribal populations in India, constituting approximately 8.6% of the total population, continue to experience persistent disparities in access to education, economic empowerment, and social

means of attaining skills and economic autonomy in vocational terms, presents a potentially game-changing process of rebuilding educational progressions and livelihood prospects of tribal girl learners. The questions that are posed in this study project are how vocational education programs nurture entrepreneurial consciousness, technical competency, and institutional agency among young tribally socially disadvantaged women and, at the same time, explore the policy infrastructure, how society perceives them, and the available resources that mediate these effects.

National Education Policy 2020 is a change of paradigm in the field of educational governance in India, as it considers multidisciplinary competencies, forms of learning based on experience, and the introduction of entrepreneurship at all levels of education. In the policy, vocational education is identified as one of the pillars of inclusive development and the aspect of introducing the elements of skill training into the standard educational process is implied to guarantee the creation of employment opportunities and enable self-employment (Ministry of Education, 2020). The reorientation of such a policy occurs against an international background that forms the framework of normative strategies that demand that educational systems be systematic in the eradication of gender-based inequalities and provide equal opportunities to skill advancement to all

demographic groups. The vocational education-gender equity nexus has developed some academic relevance because the acquisition of technical and entrepreneurial skills has persistently become a viable platform for empowering women economically in low- and middle-income contexts (Blackden et al., 2018). The empirical environment studying vocational education among tribal groups in India is one that is not even; scholarly research studies that have been developed extensively have been confined largely to the dominant caste or non-tribal. The absence of particular research that would address tribal girl students in particular is one of the significant epistemological gaps that obscure the exclusive issues, skills and opportunities provided by this population within this category. The existing policies of education applied to tribal communities are likely to reproduce homogenising schemes that do not take into account the heterogeneity of tribal communities, the significance of indigenous knowledge regimes, and the gendered nature of socio-economic disadvantage (Sukla, 2021). It is an empirical research study that seeks to address this research gap by developing research that is based on empirical research that tries to redefine vocational education programming to effectively meet the developmental needs of tribal girl students and, on the other hand, impart real entrepreneurial skills to the students.

Table 1: Demographic Profile of Research Participants (N=385)

Demographic Variable	Category	Frequency (n)	Percentage (%)
Age Group (Years)	15–18	148	38.4
	19–22	152	39.5
	Other age group(s)*	85	22.1
First-Generation Learner	Yes	267	69.4
	No	118	30.6
Place of Residence	Rural	312	81.0
	Urban	73	19.0

II. LITERATURE REVIEW

Vocational Education: Vocational education could be referred to as a tool of socioeconomic transformation.

Vocational education is nowadays rapidly becoming considered a notion that does not always mean one of the least attractive and least desirable and high-quality alternatives to more traditional academic paths but a

potentially valuable and even more high-quality means of accomplishing work-related skills and making oneself economically independent. (Kollmann et al., 2023; ²Robles et al., 2022). The pedagogical views of constructivist and experiential forms of learning have

mobility, further intensified by the feminization of poverty and intersectional vulnerabilities. These systemic inequalities remain inadequately addressed through conventional educational interventions.

² Kollmann, D., Christoph, V., & Ziegler, A. (2023). Entrepreneurial competencies and aspirations of vocational students: Gender differences and intersectionality. *Journal of Vocational Education & Training*, 75(2), 214-235.

shown³ that professional studies, with an appropriate application, offer deeper exposure to abstract conceptual knowledge in practical, problem-focused settings that may engage the students in professional desires at any given time. Despite criticism in the past, which noted that the Human Capital Theory has been considered to be reductionist insofar as issues of human development are concerned, it has provided a reasonable argument in the process of augmentation of individual earnings capacity based on investment in vocational skills training, and in the process of amassing aggregate productivity in the labour markets. (Becker, 2009).⁴

The models develop an essential distinction between the demand-pull vocational systems, which largely respond to the pressing workforce demands, and those systems able to advance skills like meta-cognitive abilities, adaptive capabilities and critical consciousness that enable individuals to bargain for changes in occupation in the rapidly evolving economic dynamics. (Marginson and Weir-Smith, 2018;⁵ Marginson, S., & Weir-Smith, G. (2018). South Asian comparative perspectives of skill development and the labour market. *International Journal of Educational Development*, 62, 89-104. Kumar and Rao 2023).⁶ The Indian case presents certain dilemmas. The accelerated technological change, rural change and the emergence of services-based economies provide the demand that has never been realised in reference to skilled labour, yet the many traditional occupational channels are being eliminated. Empirical research that has examined the effectiveness of the vocational policies in the South Asian environment suggests that there exists a high degree of heterogeneity in the quality of the programs, capacity of the institutions and the outcome of

employment, presupposing that the systemic components dominate the correlation between vocational enrolments and future economic patterns. (Azariadis and Stachurski, 2005)⁷.

Gender Issues of Vocational Education and Entrepreneurship.

The inclusion of women and girls in education has been a frank development agenda on the international policy front over the past 4 decades, with reference to the recognition of the fact that gender equity in access to education can be regarded as both an innate human right and the means of combating poverty, sustaining healthy populations, and social development. (UNDP, 2023; Joshi and Kumar, 2023)^{9,10} Nevertheless, the literature on vocational education still presents gendered discourse in vocational education, specialisation of programs, and labour market outcomes that sustain and affirm occupational division. (Livanos et al., 2020;¹¹ Sharma and Patel, 2022)¹². Occupations perceived to fit femininity the best offer very low occupational mobility and comparatively wage-redundant benefits, but those occupational programs offering more reward and occupational mobility are disproportionately male and frequently institutionally unfriendly to women who join them as well.

This ability of identifying, evaluating, and exploiting new economic prospects through either building new companies or re-planning the existing ones has been theorised as entrepreneurship, which has now been the most prominent policy tool of empowering women economically and enabling gender equality. (Singh and Desai, 2024)¹³. The educational conditions theorising entrepreneurship lie not only in the technical competencies of business but rather in psychological

³ Robles, M., Benavides, M., & Cisterna, D. (2022). Vocational education effectiveness: A systematic review of outcomes in Latin America and Asia. *International Journal of Educational Research Open*, 31, 100136.

⁴ Becker, G. S. (2009). *Human capital: A theoretical and empirical analysis with special reference to education* (3rd ed.). University of Chicago Press.

⁵ Blackden, C. M., Canagarajah, S., Klasen, S., & Lawson, D. (2018). Gender and growth in Sub-Saharan Africa: Issues and evidence. In G. Mavrotas & A. Shorrocks (Eds.), *Advancing development* (pp. 349-370). Palgrave Macmillan.

⁶ Marginson, S., & Weir-Smith, G. (2018). Skill development and the labour market: Comparative perspectives from South Asia. *International Journal of Educational Development*, 62, 89-104.

⁷ Kumar, R., & Rao, V. (2023). Skill development and labor market dynamics in India: A longitudinal analysis. *Economic Development and Cultural Change*, 71(3), 687-715.

⁸ Azariadis, C., & Stachurski, J. (2005). Poverty traps. In P. Aghion & S. N. Durlauf (Eds.), *Handbook of economic growth* (Vol. 1A, pp. 295-384). Elsevier.

⁹ Joshi, M., & Kumar, A. (2023). Gender equity in educational development: Global perspectives and South Asian challenges. *Educational Review*, 75(4), 512-528.

¹⁰ UNDP. (2023). *Human Development Report 2023: Rethinking development in an uncertain world*. United Nations Development Programme.

¹¹ Livanos, I., Pouliakas, K., & Zangelidis, A. (2020). Occupational segregation and gender wage gaps in Greece. *Journal of Labor Research*, 41(1), 45-68.

¹² Sharma, P., & Patel, S. (2022). Gender stereotyping in vocational education: Occupational segregation and career outcomes. *Gender and Education*, 34(4), 512-530.

¹³ Singh, N., & Desai, K. (2024). Gender-transformative approaches in entrepreneurship education: Evidence from South Asia. *Journal of Entrepreneurship Education*, 27(2), 1-18.

attributes (efficacy expectations, achievement motivation, and tolerance of ambiguity) that the literature has put forward as being instilled through pedagogical intervention. (Timmons and Spinelli,¹⁴ 2004, pp; Venkataraman et al., 2023,¹⁵ p. 24). The female entrepreneurs within the low- and middle-income environment are presented with a range of distinct problems, including insufficient access to finance, lack of social networks in the business circles, underdeveloped business infrastructures and the silence of the ideologies of cultural pedestals of the economic involvement of women. (Mahajan et al., 2024;¹⁶ Gupta and17 Joshi, M., & Kumar, A. (2023). Gender equity in educational development: Global perspectives and South Asian challenges. *Educational Review*, 75(4), 512-528.Sen, 2021)¹⁷.

Tribalists, Education Marginalisation, and Development Imperative.

The tribal population of India is a segment of the Indian people who historians have sidelined, where the chances to obtain school education and the quality of education, and future working prospects were significantly less in comparison with other groups of Indians. (Nayak and Mishra, 2023).¹⁸ Structural and historical factors that constitute inequities in education are: geographic inaccessibility of tribal communities, institutional fail tribal communities, lack of trained pedagogical personnel, cultural disjuncture between what is taught and practised in tribal communities, and socioeconomic issues that restrict school access (Singh & Bhattacharya, 2022; Dash, 2023). Intersectional studies reveal that tribal girls are the dispossessed of compounded disadvantages with concomitant margins in caste, tribe, gender, and socioeconomic status that demand the interventions of education answerable to expressly fulfilling such cross-sectional sources of structural challenges.

Policies that promote tribal disfavour are established on political agendas that recognise that educational transformation is a necessity that cannot be ignored in the present international commitments to the Sustainable Development Goals and the National

Education Policy 2020 (Menon & Kumar, 2024). SDG 4 is quite specific, and nations need to strive to ensure that all learners enjoy a fair quality education; it is especially focused on eliminating gender inequality and achieving inclusive education for marginalised communities. SDG 5 has the specific commitments of gender equality and female empowerment in recognition of the overlap of gender-based inequities with other forms of disadvantage to create mechanisms of marginalisation that perpetuate one another. (United Nations, 2023; World Economic Forum, 2024).¹⁹

III. GOVERNMENT SCHEMES AND POLICY FRAMEWORK

Vocational Education Initiatives.

The first scheme of skill development is the Pradhan Mantri Kaushal Vikas Yojana (PMKVY), which was piloted in 2015 by the Ministry of Education and is meant to provide unemployed and underemployed young people in the vocational sector with training in industry-relevant skills (Ministry of Education, 2023). The program aims to learn skills within a short period through training and occupational certification and placement linkages, with stipulations made to ensure fair access to the training by the economically disadvantaged groups. PMKVY operates through a network of Industrial Training Institutes (ITIs), outside training associates and skill councils in the sectors and offers training in many sectors, including construction, automobile, apparel, healthcare and information technology.

In 2015, the Skill India Mission was presented, providing a detailed scheme of the policy in the field of skill development, including the intention to skill 400 million people by 2022 and the establishment of particular National Skill Development Centres. By reducing the impediments to the attractiveness of the employer to the apprentices, the Apprenticeship Promotion Scheme subsidises the wages of the latter, while it seals the gap of constant disconnection between

¹⁴ Timmons, J. A., & Spinelli, S. (2004). *New venture creation: Entrepreneurship for the 21st century* (7th ed.). McGraw-Hill.

¹⁵ Venkataraman, S., Venkataraman, A., & Acs, Z. (2023). Nascent entrepreneurship and ecosystem development: Perspectives from theory and policy. *Small Business Economics*, 60(4), 1467-1485.

¹⁶ Mahajan, R., Damodaran, A., & Sharma, R. (2024). Female entrepreneurship in South Asia: Barriers, enablers, and policy implications. *Economic and Political Weekly*, 59(12), 28-37.

¹⁷ Gupta, A., & Sen, R. (2021). Women entrepreneurs in India: Structural barriers and supportive mechanisms. *Small Business Economics*, 57(3), 1189-1205.

¹⁸ Nayak, S., & Mishra, P. (2023). Educational equity in tribal contexts: Challenges and prospects. *Asia-Pacific Journal of Education*, 43(3), 412-428.

¹⁹ Ministry of Education. (2020). *National Education Policy 2020*. Government of India.

the school and the labour market (Ministry of Labour and Employment, 2023).

The Deen Dayal Upadhyaya Grameen Kaushalya Yojana (DDU-GKY) is a program that targets rural people specifically, where rural economically disadvantaged people are targeted during the training on skills and placement opportunities in the urban centres. The scheme especially focuses on the representation of women in the scheme, and the number of beneficiaries should have female learners at a minimum of 33 percent (Ministry of Rural Development, 2023).

Tribal Development Programs.

The Ministry of Tribal Affairs undertakes various programmes that have a direct target of increasing education rates and social rates among the tribal communities and reducing the burden on the tribal population with reference to economic opportunities. Post-Matric Scholarship Programme provides a concession of education to tribal students pursuing higher levels of education after secondary education. The model residential schools called Eklavya Residential Schools, which began in the tribal dominated districts, provide comprehensive secondary education in culturally appropriate learning environments in clear instructions of native systems of knowledge and tribal language systems in their curricula. (Tribal Affairs, 2023).²⁰

Van Dhan Vikas Yojana helps in developing sustainable livelihoods by collecting forest produce and value-adding them so that the tribal communities can receive organisational and entrepreneurial support to enter into forest-based business. These activities identify the unique needs of tribal groups but within the broad framework of the general development models.

Gender Equality and Education Programs for Girls.

The 2015 campaign, known as Beti Bachao Beti Padhao, has the theme of gender equity education, which involves the creation of awareness, institutionalisation, and delivery of resources to provide educational access, enrolment, and retention of girls. Sukanya Samriddhi Yojana provides financial stability for long-term levels, which is related to educational activities of girls, and creates structures of incentives to remain with the educational activities (Ministry of Women and Child Development, 2023).

The National Scholarship Scheme has some categories, which also provide a focus on the higher education of girls. More foundations of finance or fellowship provide for scholarship programmes for tribal girls.

Entrepreneurship Development Programs: These are programs initiated to offer entrepreneurship education to enhance the growth of economies.

The Prime Minister Employment Generation Programme (PMEGP) provides technical support and financial support to those entrepreneurs who form micro and small business ventures, with some being provided to female entrepreneurs. The scheme is a combination of credit subsidised by the participating banks with the help of the development agencies. Pradhan Mantri Mudra Yojana (PMMY) provides loans to establish small micro-enterprises. It helps to expand access to credit among women entrepreneurs.

The Stand-Up India, which specifically aims at increasing the rate of entrepreneurship among the scheduled tribes and women, also provides credit and incubation support services through specially selected banking partners. The Pradhan Mantri SVANidhi program is targeted at street vendors and to the majority women in the informal sector, where it makes available working capital credit and the assistance programme (Ministry of MSME, 2023).

IV. METHODOLOGY

This paper adopted an explanatory mixed-methodology that relied based on quantitative and qualitative data gathering and analysis as guided by the research questions that enquired how the tribal girl students acquire entrepreneurial potentials under the vocational educational programs, the specific processes through which this is achieved, the barriers and facilitators of this process, based on the institutional and societal circumstances, and the congruence of the current programming and the policy framework.

The quantitative type of data collection presupposed the application of the structured survey questionnaire that assessed demographic variables of the participants, their vocational educational experiences, entrepreneurial intentions, their self-efficacy, perceived barriers and facilitators, and their occupational expectations. The cognitive testing of the questionnaire was done on a sample of 35 individuals before the

²⁰ United Nations. (2023). Progress on the Sustainable Development Goals 2023: The leave no one behind report. UN Publications.

administration of the entire questionnaire. Sampling institutions. The response rate of sampled institutions was greater than 92 percent, resulting in a final analytical sample of 385 vocational students distributed in three Indian states with a high population of tribal people.

The qualitative data involved in its collection were the in-depth semi-structured interviews of 52 individuals, which covered vocational educators, parents or guardians of girls and leaders of the community. The interview processes were in the form of open-ended questions that were supposed to elicit the details regarding the perceptions of the participants towards the role of vocational education in the development of

girls and sociocultural factors influencing engagement in education.

The quantitative data were examined with the help of descriptive and inferential statistical procedures: frequency distribution, correlation analysis and multivariate regression analysis. Systematic codification procedures used in the qualitative data analysis were in the form of an iterative procedure of discovering emergent themes and conceptual categories.

V. ANALYSIS AND FINDINGS

Entrepreneurial Intent and Self-Efficacy Outcomes

Table 2: Entrepreneurial Intent and Self-Efficacy by Educational Exposure

Educational Variable	N	M (EI)	M (ESE)	r (sig)
Vocational with Entrepreneurship Module	174	4.18	4.26	.68**
Vocational without Entrepreneurship	211	2.91	3.04	.45**

Note: EI = Entrepreneurial Intent; ESE = Entrepreneurial Self-Efficacy; r = Pearson correlation; **p<.01

The entrepreneurial intent and self-efficacy of the student who has been exposed to integrated entrepreneurship courses in vocational programs are significantly higher when compared to those of the student who is enrolled in any vocational-related courses but not necessarily dealing with entrepreneurship issues. The average score of entrepreneurial intention of 4.18 in the integrated group versus 2.91 in the comparison students is also a significant boost that can be assumed to depict an

increase of approximately 43.6 percent in entrepreneurial intention. The validity of the relationship between entrepreneurial intent and self-efficacy scales suggests that the combined entrepreneurship courses present the individuals with actual confidence that they can easily establish and operate businesses.

Barriers and Facilitating Factors

Table 3: Frequency Distribution of Perceived Barriers to Entrepreneurial Pursuit

Barrier Type	Frequency	Percentage	Rank
Inadequate Access to Financial Capital	298	77.4%	1
Family Disapproval/Cultural Constraints	256	66.5%	2
Limited Business Acumen and Market Knowledge	241	62.6%	3
Gender-based Constraints and Stigma	219	56.9%	4
Deficient Infrastructure and Technology Access	187	48.6%	5

Quantitative investigation revealed 5 major types of barriers that restrained the pursuit of entrepreneurship among tribal girl students. The most common barrier that was identified was financial capital insufficiency and was reported by more than three-quarters of those who participated. Family-level disapproval and cultural restrictions (reported by about two-thirds) are signs of the still-present prevailing socio-cultural norms that

lessen the economic autonomy of women. Lack of business acumen, as confirmed by 62.6 percent implies that although vocational education offers technical skill

acquisition, there is limited curricular emphasis on entrepreneurship-specific skills.²¹

VI. DISCUSSION

The empirical data that guides this study is that vocational education, which is integrated with the elements of explicit entrepreneurial education development and that the modalities are aligned with the pillar of favourable policy environments, is a powerful process in developing entrepreneurial intent and confidence in the tribal girl students. The considerable difference between entrepreneurial performance among students who attended integrated entrepreneurship programs and strictly technical vocational programs suggests that entrepreneurial awareness and performance are developmental capabilities, which are sensitive to pedagogic interventions (Gupta et al., 2023).

The fact that the lack of financial capital had become the most notable stumbling block in that case is an indicator of the institutional inner-city seclusion and structural disadvantages of tribal people. The government schemes already underway, like PMMY and Stand-Up India, theoretically solve this hurdle with access to better credit and subsidised funds. However, qualitative data reveal that even though programs are generated on paper, tribal girls know nothing about them, and accessibility is hindered by documentation requirements and distance to banking centres (Patel and Sharma, 2023).

The intensity of opposition to the freedom of girls in the family is a reflection of the stereotypically ideologically entrenched and economic anxiety in the institutions of male-run families. To meet this intervention, it requires the involvement of families, which is founded on the enhancement of knowledge and implementation of community-based norm change programs to strengthen community awareness regarding women's economic participation in the economy. Such a multitude of cultural restraints presupposes the idea that vocational education, as the practice of a mandatory nature, requires complementary interventions

on its own (Devi & Rao, 2024).

The important gap in entrepreneurship-specific skills among vocational completers indicates that the modern curricula place greater emphasis on technical aptitude

and the overvaluation of business aptitude, financial literacy skills and strategic thinking, which are two core areas of entrepreneurship-specific skills. The redesign of vocational education should entail the entire range of entrepreneurship programs, which capture the financial management principles, market research methods and business plans. (Kapoor et al., 2024).²²

The insight that women entrepreneurs are likely to suffer in the spheres of commerce is comparable to the cultural myths and the market prejudices. These structural barriers that must be overcome should be addressed with the help of measures that cannot be attained by cultivating personal skills, but this should involve a community-based awareness campaign and active participation of the industry in motivating women entrepreneurs to start a business. The isolation of tribal girls into the gender-specific occupational fields of specialisation is a continuation of the general patterns in occupational segregation, perpetuating the pay gap and limited career mobility (Menon et al., 2023).

The gap in implementation between the ambitious vision of the National Education Policy 2020 and the realities in its working vocational institutions within the tribal serving institutions of higher learning points to the fact that more is needed than policy formulation to the high-level provision of resources and capacity building. The existing model of preparation of vocational educators should be highly improved to equip the educators with entrepreneurship pedagogies and gendered approaches of teaching. (Singh et al., 2024).

Authentic alignment with the Sustainable Development Goals presupposes the transition out of policy aspirations and the substantive change in the institutions. The equal aspirations and economic empowerment of women in SDG 5 are not due to the number of girls going to vocational institutions, but a qualitative transformation of the learning experiences and labour is the result. The SDG 4 quality education objective presupposes the need to make substantial investments in institutions, which are tribal in terms of application, and pedagogical innovation and

²¹ Ministry of Tribal Affairs. (2023). Eklavya Model Residential Schools: Implementation guidelines. Government of India.

²² Ministry of Women and Child Development. (2023). Beti Bachao Beti Padhao scheme: Progress report. Government of India.

infrastructural adequacy according to the non-tribal ones (World Bank, 2023).²³

VII. CONCLUSION

This paper demonstrates that vocational education is a significant yet underexplored undertaking of equipping entrepreneurial skills in the tribal girl students in India. The substantial promotion of entrepreneurial purpose and self-efficacy among the students who receive teaching on entrepreneurship provides the empirical basis for the success of the non-random educational assignment in the multiplication of entrepreneurial knowledge and skills. Still, to take advantage of the transformative potential of vocational education, the system needs to be restructured comprehensively, in terms of practices that would seal all the gaps in promotions within the system, scarcity of resources, and the policy implementation gaps of tribal girls in the process of attaining and obtaining quality education.

The essential recommendations that can be made out of this research are as follows: First, it is necessary to infuse vocational education programs with significant entrepreneurship education segments with clear emphasis on business planning, financial management, market analysis, and enterprise operation. Second, accessibility barriers to finances need to be better addressed and simpler access mechanisms of the existing schemes of government, with institutional innovations like vocational institution-based microfinance institutions. Third, the family and community outreach programs ought to clearly address family attitudes with respect to the economic role of girls. Fourth, vocational educators should undergo a considerable increase in their training to develop entrepreneurship pedagogical competencies. Fifth, the occupation desegregation activities should work hard to encourage girls to take up non-traditional occupational areas. Finally, the accountability tools and impact evaluation systems must also ensure that the policy undertakings lead to measurable transformations in the learning outcomes of girls and their career choices.

In the current research, there is the creation of empirically validated evidence on the discourse about the capacity of vocational education to make historically disadvantaged groups economically empowered in both scholarly and policy aspects. The research illuminates

the implementation issues and implementation schedules that necessitate a policy resolution. The additional studies based on a longitudinal design, where the emphasis will be placed on the separate forms of pedagogical strategies and the analysis of the consequences of the practice in various environments, will facilitate the addition to the future revision of the policy and the practice in the sphere of vocational education.

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Integrating and Delivering Vocational Education in Schools through a Scalable Curriculum Framework

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Abstract

The implementation of vocational education (VE) in primary and secondary schools is crucial for acquiring core employability and technical skills, but current approaches face challenges of scalability because of the significant infrastructure requirements, industry specificities, and shortage of instructors. This research introduces a new, scalable curriculum framework to fill the critical gap between lofty curriculum policy and implementation. Qualitative secondary analysis of literature and policy documents from 2019 to 2026 to identify systemic barriers and themes from pedagogical strategies. Results show that scalability is mostly limited by physical resource dependency and high level of contextual rigidity. The proposed framework addresses these challenges by adopting a modular micro-credentialing approach, digital virtual workshops, a core plus flex curriculum design, and a new model of facilitator teachers leading learning to enhance learning outcomes. The novelty of the study is that the term “scalability” is redefined as the standardisation of pedagogical delivery and skill modularisation, not mass-replicating physical trade programs in school-based environments. This can offer policy makers a blueprint that is sustainable and resource efficient rather than focused on a lot of capital spending, but rather on digital infrastructure and flexible industry partnerships. In the end it makes VE delivery equitable, flexible, and affordable to conduct in a variety of socioeconomic environments, and prepares students for the changing needs of the labor market in the current globalized world that is increasingly automated.

Keywords— Vocational education, curriculum integration, scalability, employability skills, qualitative analysis.

I. INTRODUCTION

In the current fast-changing global economy, education pathways need to be reconsidered with the impact of automation and digitalization. There is a growing emphasis on the need to introduce vocational education (VE) into primary and secondary schools, as this approach is seen as a key component of improving early employability, closing skills gaps, and promoting transitions from school to work (OECD, 2022). Today's policy advocates recognize the need to mainstream the delivery of VE to ensure that practical skills are gained

in addition to academic knowledge (Wheelahan & Moodie, 2021).

But there is a major implementation paradox. The delivery of VE is still limited, although policy calls for it. Traditional models of vocational education are local and resource-heavy, dependent on specialized physical facilities and regional industry connections and special training for teachers and instructors (Billett, 2020). Scaling such traditional models to a variety of socioeconomic settings can lead to significant misalignment and friction at the system level, potentially impacting

the quality of teaching and learning and reducing its relevance.

The real issue, therefore, is not the addition of vocational subjects, but rather the design of the scalable delivery of those subjects in architecture. The development of frameworks to ensure that the rigour of the education does not suffer as a result of being scaled up is essential (Grollman, 2021). This study proposes a new curriculum model for the implementation of VE in schools that assists in addressing this challenge. This work advances a promising and resource-light approach to mainstreaming VE in a variety of instructional settings by focusing on pedagogical mechanisms that are common across different types of VE.

II. LITERATURE REVIEW

The pedagogical design, funding, and alignment with the labor market are complex and interwoven aspects of the implementation of vocational education (VE) in mainstream education. A synthesis of these various strands of literature is necessary to provide understanding of the steps that may be taken to move from the fragmented pilot programs to national VE strategies.

The Shift toward Employability and Transversal Skills

Recent studies focus on the paradigm shift in the conception of the vocational education, from a narrow and trade-based approach to building a general employability and transversal skills. Given the temporality of today's labour market, Wheelahan and Moodie (2021) propose that education should focus on flexibility in learning and work while emphasising more complex problem-solving and socio-emotional skills rather than technical routines. Likewise, OECD (2022) emphasizes that embedding these core skills in the secondary school curriculum is essential to sustained labor market resilience and readiness for a more flexible work path than for narrowly targeted occupations.

Structural Barriers to Scaling Vocational Education

Even though there is agreement on the importance of school based VE, expansion of programs continues to be an obvious challenge. Billett (2020) points out that traditional vocational models are also localized and resource-consuming, and in need of specialized physical facilities and strong industry relations at the regional level. The scaling up of these models is often marred by serious bottlenecks in the educational systems. One of the main obstacles is the chronic lack of dual qualified

instructors, educators who have strong expertise in industry and formal pedagogical training (Grollman, 2021). This structural friction points to a foundational mismatch between the intent to achieve universal VE access and the distribution of educational resources, frequently leading to widespread deployments with low quality or contextual irrelevance, or both.

Digitalization as a catalyst for scalability

Recent scholarship has focused on digitalization of VE as a key driver of scalability as a way to lessen these physical and structural barriers. Grollman (2021) states that digital tools, Open Educational Resources (OER), and immersive technologies can help to separate vocational training from the need for a lot of physical infrastructure. Educational institutions can offer technical education that is widely accessible and standardised, without the high capital cost of physical workshops, by virtually recreating high cost or risk trades. In addition, digital platforms enable personalized and self-paced learning, and can be used as a pedagogical support tool and to alleviate the problem of teacher shortage.

III. LITERATURE GAP

The literature gap was identified by examining the available research and background information on the study.

The literature has been rich with the shift to employability skills, structural road blocks to scale up and the potential of digital tools, but there is a critical gap. These elements are mostly dealt with separately in the current research. There is a lack of overall coherent and theoretically-informed research on the way to integrate these digital, modular and employability-oriented aspects systematically into a coherent, scalable curriculum framework specifically for primary and secondary schools. Current scalable models are mostly geared towards post-secondary or corporate training settings, which do not consider the developmental, pedagogical and policy particularities of the school setting. The mainstreaming of VET is still under theorized, as is the way in which the mainstreaming can be made more scalable, through digital and modular approaches. This study seeks to fill that gap with a new conceptual approach that combines the modular design, digital delivery, and a flexible curriculum design to realize a true, context-appropriate scalability for school-based VE.

Research Objectives

To address the critical literature gap identified in the preceding section and to achieve the overarching aim of conceptualizing a scalable model for school-based vocational education, this study is guided by three specific research objectives:

1. To critically analyze the systemic barriers to scaling vocational education (VE) in schools and to conceptualize a novel, resource-efficient curriculum framework.
2. To evaluate the proposed framework's capacity to foster transversal employability skills alongside context-specific technical competencies.
3. To formulate actionable, evidence-based policy recommendations for educational stakeholders.

IV. RESEARCH METHODOLOGY

This study is designed as a qualitative secondary research, which uses systematic literature review to compile empirical, theoretical and policy data. This methodology is very useful for conceptual framework development and for determining macro level educational trends (Snyder, 2019). The sources of the data were high impact peer-reviewed journals, institutional repositories, and authoritative policy reports. Targeted boolean search combinations were used to search structuredly in Scopus, Web of Science and ERIC. To ensure the study was confined to the local level of vocational education integration, scalable curriculum design, and framework development, only English literature published from 2018 to 2026 and related to these topics was included. Each of the sources was thoroughly reviewed for methodological quality. Thematic analysis based on the six-phase reflexive approach of Braun and Clarke (2021) was used to analyse the selected literature. The main task of data extraction was to identify patterns with regard to scalability barriers, pedagogical innovations, and transversal employability skill development. Raw textual data was coded in an open and axial fashion into higher-order conceptual themes. The resulting synthesized themes directly guided the structure of the proposed scalable curriculum framework, contributing to the conceptual validity and theoretical underpinning of the framework (Page et al., 2021). Moreover, this secondary research was able to help triangulate different worldviews, which reduced the geographical constraints of primary research.

Data Analysis and Framework Design

The secondary data was thematically analysed and confirmed the presence of a uniform group of systemic barriers to scaling up vocational education (VE) in schools. Results from this was directly used to create the proposed Scalable Curriculum Framework's structural design.

Systemic Barriers to Scalability

There are three major barriers cited in the literature that are integrated with each other:

1. **Infrastructure Dependency:** Traditional VE models are based on specialized physical workshops, tools and machinery. It would be too costly for most national education systems to replicate this infrastructure in thousands of schools with diverse contexts, particularly in rural or under-resourced schools (Billett, 2020).
2. **Instructor Capacity Gap:** A dual qualified teaching workforce in the industry, capable of delivering a massive scale of VE training is needed. The struggle to recruit these qualified teachers is an extremely well-documented challenge impacting program quality and reach (Grollman, 2021).

National curricula are often very rigid and do not consider local economic facts. School curricula developed for an urban manufacturing cluster might have no relevance for a school in a rural farming community and may present difficulties for students to engage with and for the labour market to align with (OECD, 2022).

A "scalability paradox" exists: what is important and relevant to a VE program at a local level (specialized infrastructure, local industry connections) is also what makes it difficult to scale up.

Proposed Scalable Curriculum Framework

This research aims to address these challenges by presenting a novel four-pillar Scalable Curriculum Framework. The key innovation is the separation of vocational education from limitations of space and the standardization of delivery systems, not in the specific nature of the vocational education itself.

Pillar 1: modular and micro-credentialed design.

The curriculum is broken down into self-contained units of study based on the competencies taught (e.g., "Digital Literacy for Business," "Sustainable Resource Management"). The flexibility of the modularity means

schools can integrate VE into their current timetables without having to change the whole structure of the school (Bailey & Hughes, 2020). Students receive micro-credentials for each module completed to produce a portable, verifiable record of skills that is recognised to local industries (Wheelahan & Moodie, 2021).

Pillar 2: Digital "Virtual Workshop" Delivery.

The infrastructure dependency is addressed through the use of digital technologies in the framework as the main delivery vehicle. The creators of virtual reality (VR) and augmented reality (AR) can create simulated practical training for situations that are expensive, risky or space consuming (e.g., precision machining, electrical circuitry) in a conventional classroom using simple hardware. (Grollman, 2021) Centralized Open Educational Resources (OER) deliver high-quality, standardized theoretical content, creating a minimum base line of knowledge, no matter where a school is located or how many resources it has (UNESCO, 2022).

Pillar 3: The structure of the core and flex curriculum.

This is a structure that answers to both the need for standardization and for contextual relevance:

- 1. **The Core:** A nationally standardised component, limited to universal and

transversal employability skills (e.g. complex problem solving, team working, digital fluency). This ensures that the core skills that are required by the modern economy (OECD, 2022) are taught to all students, everywhere.

- 2. **The Flex:** It is a component that can be adapted and chosen by the school based on the regional industry requirements and partnerships being provided. This will keep the curriculum relevant and interesting to local communities.

Pillar 4: The "Facilitator" Teacher Model

The framework shifts the role of the educator from 'master tradesperson' to 'Learning Facilitator' rather than having all teachers become expert tradespersons. The facilitator oversees the classroom, directs the student through the digital modules, encourages student team projects and offers pastoral care. Technical instruction is provided through a digital platform, through guest industry experts (on video link) or standardized practical kits, thereby reducing the capacity gap of the instructor (Wheelahan & Moodie, 2021).

This integrated solution changes the scalability problem from replicating physical assets to implementing a flexible pedagogical architecture, one that is digitally-enabled.

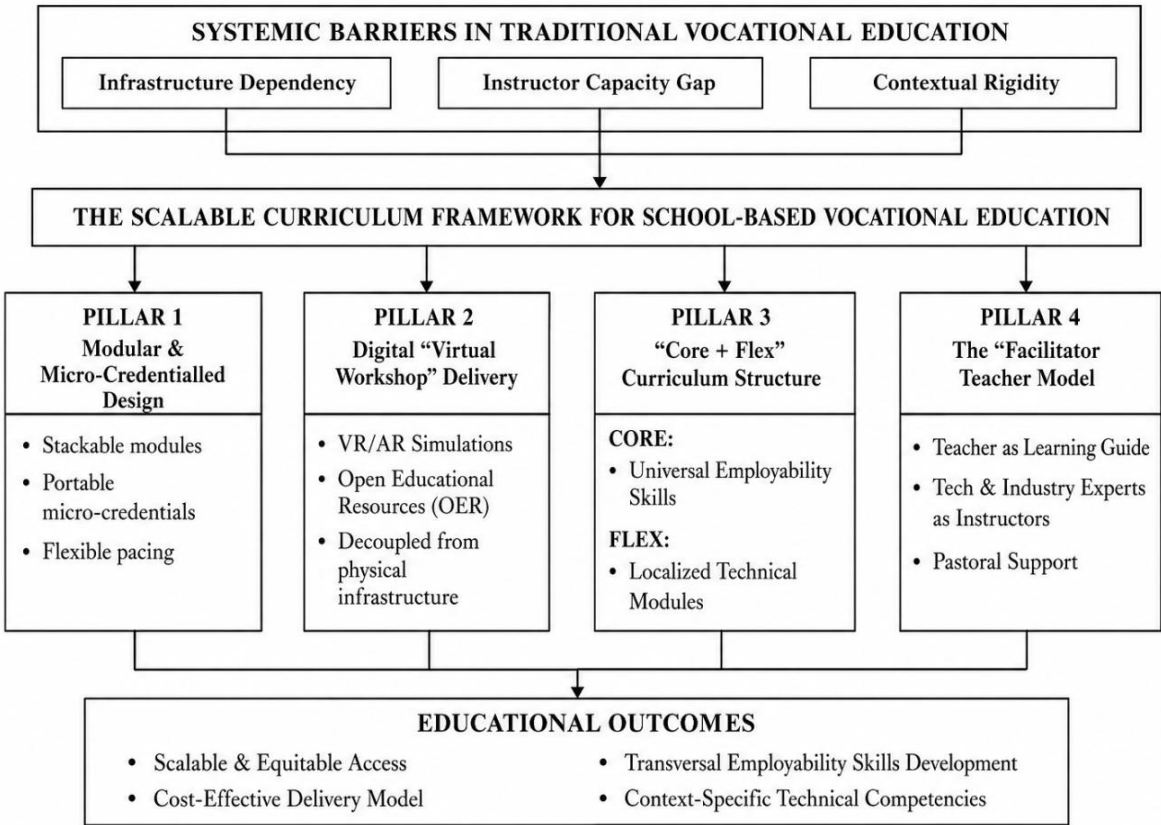


Fig.1. The Scalable Curriculum Framework.

V. DISCUSSION AND POLICY IMPLICATIONS

The proposed Scalable Curriculum Framework is a framework that fundamentally transforms the delivery of vocational education (VE), encouraging the development of transversal employability skills, and requiring strategic policy changes for successful national implementation.

Promoting the Transversal Employability Skills in the Framework

The framework has three different pathways to operationalising long-term labour market resilience. First, its modular, micro-credentialled design fosters the adaptability and cognitive flexibility needed in order to deal with the speed of technological disruption in the modern economy (Acemoglu & Restrepo, 2020; Jackson & Bridgstock, 2021). Second, it introduces the "Virtual Workshop" mechanism through digital technology, which uses VR and AR to develop advanced digital fluency, enabling students to have technological agility required by modern employers (UNESCO, 2022). Third, the new definition of the "Facilitator" teacher model facilitates the dynamic shift toward active and project-based learning, a learning approach that is very effective in building important socio-emotional skills such as teamwork, empathy, and complex problem-solving (Billett, 2020).

Agrodok Development Expertise for Scalable Implementation

Three areas of strategic change are needed to extend this approach to the national level. First, policy needs to shift funding from capital expenditures to physical workshops to operational expenditure to digital infrastructure and open educational resources, thus allowing for exponential, equitable scalability (UNESCO, 2022). Second, the educational system needs to evolve and adapt its assessment frameworks to include competency-based digital portfolios and ensure the outputs of these micro-credentials are formally recognised and have a solid labour market value (Jackson & Bridgstock, 2021). Third, government should encourage industry partnerships, both decentralised and through short-term micro-internships, by offering tax breaks or grants to better embed industry expertise in the school without adding additional strain to the school or local businesses (Bailey & Hughes, 2020).

Limitations and Future Research Directions

Although this study is well grounded, it is not without its limitations. It is a framework of qualitative secondary research analysis, which is derived from literature in

order to synthesize a framework, but has not been tested practically to see its efficacy in real schools. Future studies should thus focus on the design and implementation of pilot studies over different school districts and socio-economic contexts over time. These pilots will generate both quantitative and qualitative data, which will be key in validating the conceptual framework, to capture its direct effects on youth employment, and to inform context-specific nuances of implementation to meet the goal of sustainability in policy.

VI. CONCLUSION

The inclusion of vocational education in primary and secondary schools is an economic need, to reduce the unemployment rate among youth and the ever growing skills shortage problem around the world. Yet, traditional, resource-heavy approaches fail to scale equitably on a regular basis. This study sought to solve this paradox by introducing a new curriculum framework for implementing school-based vocational education that is scalable. The shift in focus from physical infrastructure replication to standardized pedagogical delivery has been effective in freeing up learning from common constraints. It makes contextual relevance and universal accessibility possible by means of modular micro-credentialing, digital virtual workshops, and a "Core + Flex" concept as well as a different model of the facilitator teacher. In essence it is not a mere trade training, but a systematic approach to developing transversal employability skills: skills that are required by the modern, automated labour market, such as socio-emotional resilience, digital fluency, and cognitive adaptability. Understanding that this model needs a strategic shift from large-scale capital investment in physical workshops to strategic investments in digital infrastructure and industry partnerships. The idea of scalability, which is redefined as the ability to deploy flexible architectures that are pedagogically adaptable, can allow more equitable access to high-quality vocational education and training. This paradigm shift ensures that all students will have access to the skills required for a future workforce, ensuring their equitable access to future-proof skills and giving a base frame to policymakers that will support effective educational reform today.

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Managing healthcare training activities in colleges using the CDIO approach

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Abstract

Training healthcare professionals at the college level needs innovation toward a competency-based approach that closely links theory and professional practice. The CDIO (Conceive – Design – Implement – Operate) approach has proven effective in engineering training, but its application to healthcare management is currently limited to confirming its philosophical suitability and has not yet been concretised into a framework of management content that can be directly applied in practice. Using a combination of document analysis and theoretical modelling, this study compares the characteristics of college-level healthcare training with the 12 CDIO standards. Based on this, a management framework consisting of six components is proposed: managing objectives and learning outcomes; managing the curriculum; managing teaching and clinical practice; managing faculty and practical guidance; managing facilities and the training environment; and managing the evaluation of training outcomes and linking training with human resource utilisation. The research results contribute to supplementing the theoretical basis of competency-based training management in the health sector, while also providing a reference tool for college principals to review, organise, and improve training management toward standardisation. The study also clarifies theoretical limitations and proposes directions for further empirical verification.

Keywords— training management, health sector, CDIO approach, college, learning outcomes.

I. PROBLEM STATEMENT

A well-trained and qualified healthcare workforce is a prerequisite for ensuring the quality of healthcare services and achieving sustainable health development goals (World Health Organisation [WHO], 2016). In Vietnam, colleges training in health-related fields such as nursing, midwifery, pharmacy, medical laboratory technology, medical imaging technology, rehabilitation technology, and general practitioners play a major role in providing most healthcare technicians for the primary healthcare system (Ministry of Labour, Invalids and Social Affairs, 2017). However, some domestic studies show that training management at these schools still leans towards administrative management, and the connection between theory and clinical practice is limited, leading to a gap between the

competence of graduates and the requirements of actual practice (Le Thi Mai Huong, 2018; Nguyen Van Tinh, 2016).

Internationally, reforms in healthcare workforce training towards integrating clinical competence, systems thinking, and professional skills have been strongly recommended since the beginning of the 21st century (Frenk et al., 2010). Simultaneously, competency-based education and outcome-based education have been established as common standards in modern medical training (Harden & Laidlaw, 2012). In this context, the CDIO approach – developed at the Massachusetts Institute of Technology for engineering education (Crawley et al., 2014) – has been noted by several studies as having the potential to be transferred to other highly practice-oriented training disciplines,

including the health sector, due to its focus on performance competence (Biggs & Tang, 2011; Zhou & Fagerholm, 2019).

However, existing studies on CDIO in medical education largely focus on confirming the philosophical suitability or conducting trials within a single course or a narrow discipline (Le Thi Phuong, 2019; Nguyen Minh Sang, 2022), while Zhou and Fagerholm (2019) simultaneously pointed out that CDIO, when applied to medical education, still faces barriers regarding the standardization of competency assessment and the organizational capacity of the teaching staff. To date, no work has developed a comprehensive content management framework that can be directly applied to managing training at the college level in the health sector in Vietnam. This is the research gap that this article aims to address.

The objective of this study is to develop a content framework for managing health-related training activities in colleges using the CDIO approach. To achieve this objective, the study answers two questions: (i) In what aspects is health-related college training compatible with the CDIO philosophy and standards? (ii) Based on this, what components should the content of training management activities be structured into to ensure both the logic of the CDIO cycle and suitability to the specific characteristics of medical training?

II. RESEARCH METHODOLOGY

The study employs a qualitative design, combining document analysis with theoretical modelling. The aim is to develop a management content framework at the initial stage of a broader research direction on health science education management using the CDIO approach.

The data consists of secondary documents, comprising three groups: current legal documents on vocational education and healthcare in Vietnam (Law on Vocational Education, National Assembly, 2014; Law on Medical Examination and Treatment, National Assembly, 2023; Decision No. 1982/QĐ-TTg, Government, 2016; Circular No. 09/2017/TT-BLĐTBXH, Ministry of Labour, Invalids and Social Affairs, 2017); original documents on CDIO, including the CDIO Syllabus and the system of 12 CDIO Standards (Crawley et al, 2014); and domestic and international research published between 2010 and 2024 related to CDIO and training management in the health sector. Documents were selected based on three criteria: being current legal documents or published scientific works;

Directly related to CDIO, competency-based education/output standards, or the characteristics of health science training; and prioritising publications from the last 10–15 years, with the addition of some classic literature as a theoretical foundation (Crawley et al., 2014; Frenk et al., 2010).

The analysis process consists of 3 steps: (1) systematizing the characteristics of college-level health science training (objectives, curriculum, practical proportion, professional ethics, facilities, evaluation) from regulatory documents and related studies; (2) deductive mapping of each characteristic with the 12 CDIO standards using content analysis techniques to determine the level of compatibility; (3) inductive synthesis of similar standard groups into management content components, cross-referencing with the 4 management functions (planning - organizing - directing - controlling) to ensure a complete and logical proposal framework.

This study is a conceptual framework-building step based on literature analysis, and has not undergone empirical surveys or expert consultations using Delphi techniques; therefore, the proposed framework needs to be validated for reliability and feasibility in subsequent studies before being recommended for widespread application, and its generalizability to medical training systems outside of Vietnam also needs careful consideration.

III. RESEARCH RESULTS - DISCUSSION

3.1. Theoretical basis

Training management is understood as the process of purposeful and planned influence by the management entity (principal, school management levels) on the components of training activities – objectives, curriculum, teaching organisation, staff, facilities, and assessment – in order to ensure the quality and effectiveness of training (Le Viet Chung, 2021). At the university and college level, training management is increasingly approached from a competency-oriented perspective, in which output standards play a central reference role for all management activities (Nguyen Quoc Chinh, 2021).

The CDIO (Conceive – Design – Implement – Operate) approach is an educational model developed by Crawley et al. (2014) to train learners to fully implement the entire cycle of ideation, design, implementation, and operation of a product, process, or system in a real-world professional context. This

approach is concretised through 12 CDIO standards, encompassing everything from the training context, learning outcomes, and curriculum design to teaching methods, assessment, and curriculum improvement.

College-level health science training in Vietnam comprises seven main fields (pharmacy, nursing, midwifery, general practitioner, medical laboratory technology, medical imaging technology, and rehabilitation technology), organised according to the List of College-Level Training Fields (Ministry of Labour, Invalids and Social Affairs, 2017), characterised by a dominant proportion of practical and internship components and high demands on professional ethics standards.

3.2. Compatibility between college-level health science education and the CDIO approach

The results of the document analysis using the inferential comparison process (section 2) show that college-level training in the health sector has a high degree of compatibility with the CDIO philosophy and standards in the following four aspects.

(1) Regarding training objectives: the output competency structure of the health sector – fundamental biomedical knowledge, clinical and paraclinical skills and professional attitudes and ethics – corresponds to the logic of competency formation according to the CDIO cycle, in which professional competencies are formed through the stages of problem identification, solution design, implementation and operation in the context of real profession (Crawley et al., 2014). Table 1 specifically compares the 4 stages of the CDIO cycle with the corresponding manifestations in training activities of the health sector.

Table 1. Comparison of the CDIO cycle with training activities in the health sector at the college level.

CDIO phase	Manifestations in health science training
Conceive (Idea Formation)	Identifying patient/community health problems based on fundamental biomedical knowledge.
Design	Selecting the appropriate technical procedures and care protocols based on the patient's condition.
Implement	Perform technical procedures and care interventions under professional supervision at the practice facility.

Operate	Monitor, evaluate care outcomes, and make adjustments in a hospital/community setting.
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Source: Compiled by the author from Crawley et al. (2014); Ministry of Health (2021).

(2) Regarding program structure: the college program in the health sector already integrates theory - practice - internship with a dominant proportion of practice, similar to the requirements for design-implement experiences in Standard 5 of CDIO (Crawley et al., 2014).

(3) Regarding the training environment: the system of practice rooms, simulation rooms and the network of hospital internship facilities correspond to the requirements for learning space supporting professional practice in Standard 6 of CDIO, and are in line with WHO recommendations (2016) on close links between training institutions, hospitals and the community in training medical personnel.

(4) Regarding professional ethics requirements: medical ethics standards in health science training correspond to the group of individual-interpersonal and social responsibility competencies in the CDIO competency structure, and also reflect the trend of considering professionalism as a core competency pillar alongside professional competence in international competency frameworks (Harden & Laidlaw, 2012).

Based on the four aspects of compatibility mentioned above, it can be affirmed that applying CDIO to the management of health science education does not require changing the fundamental nature of the current training model, but rather standardising and systematising existing elements within a consistent management framework that is scientifically and legally sound.

The above comparative results both build upon and expand upon previous studies: if Crawley et al. (2014) developed 12 CDIO standards for the context of engineering education, the analysis in the four aspects mentioned above shows that these standards can be fully adapted to the context of medical education without losing the essence of the Conceive – Design – Implement – Operate cycle, thereby concretizing the still generalized assessment of Zhou and Fagerholm (2019) on the potential application of CDIO in medical education.

3.3. Proposed framework for managing training activities in the health sector using the CDIO approach.

Based on the analysis results in section 3.2 and the inductive synthesis step according to the four

management functions (planning – organising – directing – controlling), the study proposes a content framework for managing training activities in the health sector using the CDIO approach, consisting of six closely related components operating in a closed cycle from goal setting to evaluation and improvement (Table 2).

Table 2. Content framework for managing training activities in the health sector according to the CDIO approach.

Management content	Implementation plan	CDIO Standard
<i>Managing goals and outcomes</i>	Specifically, the training objectives are defined according to the healthcare professional cycle; the learning outcomes are designed based on three competency groups: professional expertise, practical skills – communication, and professional attitude and ethics.	1, 2
<i>Training program management</i>	Organise the program using an integrated structure of foundational knowledge – specialised knowledge – practical training – internship; conduct periodic reviews with the participation of healthcare facilities.	3, 4
<i>Managing teaching and clinical practice</i>	Managing the simulation-semi-real-life-practice experience chain; building a coordination process between the school and the practical training facility.	5, 7, 8
<i>Managing the teaching staff and supervising practical sessions.</i>	Develop a team based on an integrated professional lecturer model; establish a mechanism for coordinating full-time lecturers with supervisors at the hospital.	9, 10
<i>Management of training facilities and environment</i>	Invest in and develop a system of skills training rooms and clinical simulation rooms linked to the network of training facilities.	6
<i>Managing and evaluating training outcomes and training-to-human resource utilisation.</i>	Develop a system for assessing performance competence (OSCE, practice assessment, documentation); coordinate three parties: schools, healthcare facilities, and regulatory agencies.	11, 12

3.3.1. Managing Objectives and Outputs

This content plays a guiding role in the entire training management system. Learning outcomes need to be developed according to the healthcare career cycle, while ensuring the three-component structure as per the Vietnamese National Qualifications Framework: knowledge, skills, and level of autonomy and responsibility (Government, 2016). Managing objectives and learning outcomes using the CDIO approach requires schools to publicly disclose, periodically review, and solicit feedback from employers to ensure that learning outcomes accurately reflect actual practice requirements and align with Standards 1 and 2 of the CDIO framework (Crawley et al., 2014).

3.3.2. Training Program Management

CDIO-based curriculum management focuses on horizontal and vertical integration between modules, avoiding fragmentation between theory and practice

(CDIO Standard 3). The development, evaluation, and updating of the curriculum should involve representatives from healthcare facilities to ensure it accurately reflects professional practice and meets the requirements of an early career orientation module for learners, as per Standard 4 (Crawley et al., 2014).

3.3.3. Management of teaching and clinical practice

This content covers the organisation of a learning experience sequence from simulation to semi-practical and practical training at healthcare facilities, according to Standard 5 and corresponding to the Implement and Operate phases of CDIO. A clear coordination process needs to be established between the school and the hospital/practical facility regarding the assignment of supervision, evaluation of the training process, ensuring the safety of learners and patients, and promoting active learning according to Standards 7 and 8 (Crawley et al., 2014).

3.3.4. Managing the teaching staff and practical training guidance

Full-time faculty and clinical instructors need to be managed according to an integrated professional faculty model, possessing both pedagogical competence and maintaining professional experience through rotation and regular training at healthcare facilities, in line with CDIO Standards 9 and 10. This also directly addresses the competency barrier pointed out by Zhou and Fagerholm (2019) when applying CDIO to medical education.

3.3.5. Management of facilities and training environment

CDIO-based facility management focuses not on changing infrastructure but on optimising the connection between the simulation space in the school and the actual clinical environment in the practice facility, following a series of increasing levels of complexity to ensure the safety of learners before direct contact with patients (Standard 6, CDIO).

3.3.6. Managing the evaluation of training results and linking training with human resource utilisation.

The assessment system needs to be designed to measure performance competence rather than just testing knowledge, through tools such as OSCE, structured practice assessments, and competency documentation, in line with CDIO Standard 11. Simultaneously, a coordination mechanism between schools, healthcare facilities, and regulatory bodies is necessary for assessment and recruitment, aiming to complete the management cycle according to the principle of continuous improvement as stipulated in Standard 12 (Crawley et al., 2014).

Compared to domestic studies such as Le Thi Phuong (2019) and Nguyen Minh Sang (2022) – which applied CDIO to a single activity (building a rubric for evaluating practice, designing a narrow specialised program) – the aforementioned six-component framework aims to encompass the entire training management cycle at the school level, from objectives, curriculum, teaching organisation, staff, facilities to outcome evaluation. This is the main difference between the proposed framework and previous studies, and also serves as a tool for principals to self-assess the operational level of each management component and identify weak areas.

3.4. Conditions for ensuring the implementation of management content

For the above-mentioned content management framework to operate effectively, several conditions

must be ensured simultaneously. On the part of the school, a development strategy clearly defining competency-based training, an internal quality assurance mechanism operating in a continuous improvement cycle, and a culture of safety and quality maintained consistently within the staff are necessary. On the external part, the system of policies governing vocational education and healthcare (National Assembly, 2014, 2023), professional standards for the health sector (Ministry of Health, 2021), and a stable network of practice facilities are crucial conditions for the successful implementation and operation of the stages in practice.

Overall, the above results reinforce the assertion of Frenk et al. (2010) that reforming healthcare workforce training needs to link clinical competence with systems thinking, and concretise this recommendation into operable management content and conditions at the school level, instead of stopping at macro-level policy orientation.

IV. CONCLUSION

The study systematised the compatibility between college-level health science training and the philosophy and standards of the CDIO approach in four aspects: training objectives, program structure, training environment, and professional ethical requirements. Based on this, the study proposed a management framework comprising six components: managing objectives and learning outcomes; managing training programs; managing teaching and clinical practice; managing faculty and practical guidance; managing facilities and the training environment; and managing the evaluation of training outcomes and the linkage between training and human resource utilisation. These six components operate in a closed cycle, with clear theoretical and legal foundations.

The research's contribution is evident in two aspects. Theoretically, the study contributes to supplementing and concretising the theory of competency-based training management in the field of college-level medical training, a field less studied than technical training. Practically, the management content framework serves as a systematic reference tool, helping principals of health-related colleges review and reorganise training management toward standardisation. It also serves as a reference document for state management agencies (Ministry of Labour, Invalids and Social Affairs, Ministry of Health) in developing and updating accreditation criteria for

health-related training programs based on output standards.

However, the research is currently at the theoretical level, based on document analysis, and has not been verified through surveys of the actual situation at schools or expert opinions; therefore, the suitability and feasibility of each component in the proposed framework need further testing. The next research direction should focus on: (i) surveying the current state of training management in the health sector according to the six proposed components at colleges in the Northern region; (ii) seeking expert opinions using the Delphi technique to refine and verify the reliability of the content framework; (iii) proposing and experimenting with specific management measures based on the validated framework, aiming to improve the effectiveness of medical workforce training using the CDIO approach.

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Integrating Indigenous Knowledge Systems into Global Knowledge Management Frameworks for Sustainable Futures: A Qualitative Study

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Abstract

The integration of Indigenous knowledge into global knowledge management frameworks is a key to ensuring sustainable futures. Indigenous knowledge is deeply grounded in local cultures and traditions, offers invaluable insights into ecology, governance, and community living. This paper explores the importance of a holistic approach to knowledge management that incorporates traditional wisdom and enriching global practices with time-honored insights. Qualitative multiple case study with document analysis used for this study. The study underscores the importance of indigenous knowledge management in addressing modern challenges such as sustainability, environmental management, and social equity.

Keywords— sustainable Future, Indigenous knowledge. Global knowledge management frameworks

I. INTRODUCTION

"May we be protected together; may we be nourished together; may we work together with great vigor; may our knowledge be full of light; may we not hate or dispute with each other". (Community cooperation and respect for one another, which is essential for sustainable development.) – Rig Veda

India is a land of rich in cultural diversity and traditional practices, integrating Indigenous knowledge into modern knowledge management systems is crucial for addressing contemporary challenges such as climate change, biodiversity loss, and food security etc. In recent years, the discourse surrounding sustainability has increasingly recognized the value of Indigenous knowledge systems. These systems, rooted in centuries of experience and cultural practices, offer unique insights into environmental stewardship and resource management. Vedas, Puranas and other sacred texts can significantly enhance contemporary

knowledge management practices by providing holistic solutions grounded in ecological balance and social responsibility. that integrating Indigenous knowledge into global knowledge management frameworks can enhance sustainability efforts and promote more equitable decision-making processes.

Indigenous Knowledge (IK) refers to the understanding and skills developed by local communities over generations, often encompassing ecological wisdom and sustainable practices..

The sacred texts like the Vedas, Puranas, Gita and other scriptures provide a philosophical foundation for integrating Indigenous knowledge into global knowledge management frameworks. They emphasize the sustainability, interconnectedness, and ethical stewardship of natural resources, which are essential for fostering a sustainable future in today's world. By incorporating these teachings into modern practices, organizations can create frameworks that respect

traditional wisdom while promoting holistic approaches to environmental management and social responsibility. Since indigenous knowledge systems are based on the historical experience and cultural traditions of communities, they provide practical knowledge regarding environmental protection, resource utilization, social cohesion, etc. The use of such knowledge in sustainable development models is also increasing in modern times.

II. THEORETICAL FRAMEWORK

Indigenous Knowledge Systems (IKS)

Indigenous knowledge systems include a deep understanding of local ecosystems, resource management practices, and community resilience that have been passed down through generations. Indigenous Knowledge Systems are characterized by their holistic understanding of the environment and sustainable practices. IKS encompasses various domains including agriculture, medicine, water management, and biodiversity conservation. These systems emphasize harmony with nature, resource conservation, and community well-being, which are critical for developing sustainable solutions in various sectors. Holistic understanding, sustainable practices, oral tradition, community centric and adaptability are the key features of indigenous knowledge.

Global Knowledge Management Frameworks (GKMF)

Global knowledge management frameworks typically prioritize scientific and technical knowledge derived from Western paradigms. These frameworks can benefit from incorporating insights from Indigenous knowledge systems. The GKMF serves as a structured approach to managing knowledge across global settings. Indigenous knowledge systems provide valuable perspectives on ethical governance, community engagement, and sustainable resource management. Integrating Indigenous knowledge into global knowledge management frameworks can enhance sustainability efforts by: providing alternative perspectives, promoting resilience and fostering collaboration.

Sustainable futures

Sustainable futures refers to the idea of creating a future that is resilient, equitable, and responsible, ensuring that the needs of the present generation are met without compromising the ability of future generations to meet their own needs. Environmental

sustainability, social sustainability and economic sustainability are the three main pillars of sustainable futures.

III. METHODOLOGY

This study employs a qualitative multiple case study with document analysis, where Indigenous knowledge has been successfully integrated into sustainable environmental management practices. Case studies were selected based on their successful integration of these ancient principles into modern frameworks. Data collection was done from secondary sources such as research articles, books, government reports, international organization publications, policy documents, and online databases. The collected data was examined through thematic analysis.

Case Studies

Menominee Tribe (USA)

The Menominee, sustainable forestry model is a successful example of Indigenous knowledge applied to modern resource management. Their approach involves a balance between timber production and conservation, ensuring that the forest ecosystem remains healthy over 150 years by blending Indigenous practices with modern forestry science (Pecore, 1992; Trostler, 2007).

Bad River Ojibwe Tribe (USA)

The Ojibwe people have long practiced sustainable wild rice harvesting and fishery management, using knowledge passed down through generations. Preserving the health of aquatic ecosystems, preventing overfishing, and ensuring the regeneration of wild rice beds etc. are the criteria of this holistic approach (Whyte, 2013; Hoover, 2017).

Maya Indigenous Peoples (Mexico and Guatemala)

The Maya have a deep respect for Mother Earth, which is reflected in their agricultural practices. One key practice is polyculture farming, including the "Three Sisters" method, where corn, beans, and squash are grown together. This technique maintains soil fertility, reduces pests, and increases crop resilience. Maya communities emphasize water conservation and traditional agro forestry, which help preserve biodiversity and adapt to changing climate conditions (Altieri & Toledo, 2011; Ford & Nigh, 2015).

San People (Southern Africa)

The San people have sustainable hunting and gathering practices. The San people's knowledge of medicinal

plants and wildlife conservation techniques supports biodiversity and helps mitigate environmental degradation in the arid regions where they live (Berkes, 2018; Chennells, 2007).

The Amazon Rainforest

Indigenous communities in the Amazon have employed traditional ecological practices for centuries. Their deep understanding of local ecosystems has proven invaluable in combating deforestation and promoting biodiversity (Posey, 2002; Levis et al., 2017).

North American Indigenous Fisheries Management

Collaborative fisheries management that includes Indigenous perspectives has resulted in sustainable fish populations and healthier aquatic ecosystems (Berkes, 2018; Wilson et al., 2020).

Australian Aboriginal Land Management

Aboriginal fire management techniques have been shown to reduce bushfire risks while enhancing biodiversity. Incorporating these practices into national fire management strategies has led to more effective outcomes (Bowman et al., 2020; Lewis et al., 2018).

The Kani tribe of Kerala and Jeevani medicine

The Kani community, an ancient tribal community in Kerala, is rich in traditional medicinal knowledge. Using the indigenous knowledge of the Kani tribe regarding the medicinal properties of the plant ArogyaPacha (*Trichopus Zeylanicus*), TBGRI, Thiruvananthapuram, developed a medicinal herb called Jeevani in 1995 (Pushpangadan, Rajassekharan & George, 2002).

Pokkali Rice Cultivation (Kerala)

Pokkali is a sustainable agricultural model that has been practiced in Kerala for centuries. It is a sustainable farming method that can withstand saltwater and climate change (Geethakutty & Narayanan, 2018).

Traditional water conservation system (Sikkim)

Traditional water conservation systems that are adapted to local conditions are beneficial for water security and water resource management. Such indigenous streams are integral to modern water resource management (Sharma et al., 2009, ICIMOD, 2017).

Sacred Groves (Kerala)

Home to rare plant and animal species, forests are a vital part of Kerala culture. Forests play a significant

role in maintaining biodiversity and ecological balance. Traditional environmental knowledge helps in sustainable development and resource conservation.

IV. DISCUSSION

Medicinal Knowledge

Traditional medicinal knowledge is passed down through generations. Modern society utilizes the medicinal value of plants and natural resources.

Water Management Practices

Ancient texts describe various water conservation techniques that align with sustainable practices today. For instance, traditional rainwater harvesting methods mentioned in the Puranas have been revived in several Indian states to combat water scarcity.

Agricultural Wisdom

The Vedic texts advocate for sustainable agricultural practices that promote biodiversity. Concepts such as crop rotation and organic farming resonate with modern sustainable agriculture movements.

Community Governance

The principles of Swaraj (self-rule) found in these texts emphasize local governance and community participation, which are critical for effective resource management today

Opportunities

Enhanced sustainability through traditional ecological practices.

Improved community resilience via participatory governance models.

Greater recognition of ethical considerations in resource management.

Challenges

The need for policy reforms that acknowledge Indigenous rights.

Bridging cultural differences between traditional practices and modern regulatory frameworks.

Ensuring equitable access to resources for Indigenous communities.

Recommendations

To effectively integrate Indigenous knowledge into global knowledge management frameworks, the following recommendations are proposed:

Governments should enact policies that recognize the value of Indigenous knowledge systems in environmental governance.

Training programs should be developed to enhance collaboration between Indigenous communities and policymakers.

Establish partnerships between academic institutions and Indigenous communities to document traditional practices.

Initiatives aimed at educating stakeholders about the relevance of ancient wisdom can foster greater appreciation for Indigenous contributions to sustainability.

V. CONCLUSION

Integrating Indigenous knowledge into global knowledge management frameworks is not only beneficial but necessary for achieving sustainable futures. The idea of a sustainable future through a global knowledge management framework highlights the importance of integrating diverse knowledge systems to address pressing global challenges.

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Academic Advising for University Students in the Digital Environment

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Abstract

Academic advising serves as the connective link between students, training programs, and the university, directly shaping learning outcomes and student engagement within credit-based training systems. Digital transformation, big data, and artificial intelligence are profoundly reshaping how this activity is delivered, shifting from traditional face-to-face advising toward e-advising systems, AI-driven chatbots, and predictive learning-analytics tools. Using a literature-review approach, this paper synthesizes domestic and international research on academic advising to clarify: (1) the nature and theoretical models of academic advising; (2) the impact of digital transformation on the role and modalities of academic advising in universities; (3) the categories of technological tools currently applied to support academic advising in the digital environment, including e-advising systems, AI chatbots, and learning analytics combined with recommender systems for predicting academic performance and advising on course selection; and (4) the data-ethics and algorithmic-fairness risks that must be managed when deploying these tools. The review finds that academic advising in the digital environment is shifting from an administrative role toward a personalised, developmental advising role, technology-enabled yet still requiring human judgment in consequential decisions; it also identifies a gap in integrating predictive-analytics tools into academic-advising workflows in Vietnam, as well as a gap in the corresponding data-governance framework. On this basis, the paper proposes directions for applying digital technology to academic advising at Vietnamese universities in line with a responsible-AI approach.

Keywords— academic advising, digital environment, digital transformation, artificial intelligence, recommender systems, data ethics, algorithmic fairness.

I. INTRODUCTION

Academic advising is the link connecting students, training programs, and the university, directly influencing learning outcomes within credit-based training (Tran Thi Minh Duc & Kim Anh Tuan, 2012). Digital transformation, big data, and artificial intelligence are profoundly changing how this activity is carried out, shifting from traditional face-to-face advising toward e-advising systems, AI chatbots, and predictive learning-analytics tools (Assiri et al., 2020; Brdesee & Alsaggaf, 2022). However, existing research on academic advising in the digital environment has

focused largely on electronic course-registration systems and information-support chatbots. In contrast, the potential to integrate learning analytics and educational data mining into the advising process to detect at-risk students early and recommend suitable courses remains insufficiently systematised, particularly in the Vietnamese context (Iatrellis et al., 2017).

The pressure to digitalise described above stems not only from within universities themselves but is also driven by top-level policy direction. Decision No. 131/QĐ-TTg dated 25 January 2022 of the Prime

Minister of Vietnam, approving the Scheme "Strengthening the Application of Information Technology and Digital Transformation in Education and Training for the Period 2022-2025, with a Vision to 2030," requires higher-education institutions to comprehensively digitalise management and student-support activities, of which academic advising is one of the most directly affected services. However, a top-down policy push does not automatically translate into genuine implementation capacity at the institutional level: the gap between policy targets and the actual state of data infrastructure, advisors' digital competence, and student readiness remains an open question, particularly given that most existing research on advising technology has been conducted in countries with more developed digital infrastructure than Vietnam. This is precisely why the present paper aims not merely to catalogue technological achievements but also to examine them critically.

Building on this gap, the paper synthesises and analyses domestic and international research to answer four questions: (i) How is academic advising conceptualised under existing theoretical models? (ii) How does digital transformation change the role and modalities of academic advising in universities? (iii) Which categories of technological tools are currently being applied to support academic advising in the digital environment? (iv) What ethical and fairness risks and limitations must be controlled for when applying digital tools, particularly predictive analytics, to the academic-advising process?

II. RESEARCH METHODS

The paper adopts a literature-review approach based on thematic synthesis. Sources fall into two groups: international works on academic-advising theory, digital transformation in higher education, and advising-support technology (mainly published in peer-reviewed journals between 1994 and 2025), and domestic studies on the status and models of academic advising at Vietnamese universities. Sources were retrieved through academic platforms (Google Scholar, domestic scientific journals) using the keywords "academic advising," "e-advising," "digital transformation higher education," "learning analytics ethics," "algorithmic bias education," and their Vietnamese equivalents combined with "digital transformation" and "artificial intelligence." Sources were selected according to three criteria: direct relevance to concepts, models, or technological tools in

academic advising; publication in a peer-reviewed journal, conference proceedings, or official documentation of a professional body (such as NACADA) or a state management agency; and theoretical or practical value for the higher-education context. The content of the selected sources was classified into five themes: concepts/theories of academic advising; digital transformation in academic advising; supporting technological tools (e-advising, AI chatbots, learning analytics, recommender systems); ethical and fairness issues related to the application of digital technology in academic advising; and academic-advising practice in Vietnam, which were then synthesised into the findings presented in Section 3.

III. FINDINGS

3.1. *Concept and theoretical models of academic advising*

Academic advising is defined by NACADA (2006) as a series of intentional interactions, grounded in the curriculum, pedagogy, and learning outcomes, that help students connect their educational experience to their own goals, capabilities, and life direction. Crookston (1994; originally published 1972) distinguishes two basic advising models: prescriptive advising, in which the advisor provides direct guidance on course selection and regulations, and developmental advising, in which the advisor acts as a companion who supports students in making their own decisions and developing critical-thinking and problem-solving abilities. In Vietnam, Tran Thi Minh Duc and Kim Anh Tuan (2012) show that academic advisors simultaneously perform class-management duties and act as advisors on study methods, research, and employment, reflecting a blend of the prescriptive and developmental models in Vietnamese practice.

Crookston's distinction between prescriptive and developmental advising, although highly influential, reveals its limits when applied as a rigid dichotomy. Later models, most notably proactive advising and appreciative advising, proposed by Bloom, Hutson, and He (2008), add an important dimension: rather than waiting for students to seek help once problems arise, advisors are expected to reach out proactively and early, while adopting a strengths-based approach rather than one focused solely on remedying deficits. This is arguably the most appropriate theoretical foundation for understanding the value of the predictive-analytics tools discussed in Section 3.3 because the "proactive, early-warning" nature that digital technology aims for is

not a purely technical innovation, but needs to be anchored in an advising model already validated in educational theory. Notably, most of the technology literature reviewed in this paper (Assiri et al., 2020; Brdesee & Alsaggaf, 2022; Ngo Van Thap et al., 2025) focuses almost exclusively on technical aspects—natural-language-processing performance, predictive accuracy—while lacking explicit engagement with these established advising-theory models. This theory-practice gap carries a real risk: if technology is designed and deployed without a clear underlying advising philosophy, the likely outcome is a digitised version of the prescriptive model—fast and convenient, but lacking depth in personal development—running counter to the shift toward developmental advising analysed in Section 3.2.

In terms of content, academic advising encompasses five main task categories: developing study plans under the credit-based system; advising on study methods; guiding scientific research; providing career and employment guidance; and helping students resolve psychological and academic difficulties. The quality of academic-advising services is assessed through criteria such as interaction frequency, timeliness, and the advisor's professional competence (Abernathy & Engelland, 2001), the very criteria that digital technology tools aim to improve, as discussed in Section 3.3.

3.2. Digital transformation and the changing role of academic advisors in universities

Digital transformation in higher education goes beyond digitising administrative processes; it also changes the fundamental nature of the interaction between the university and students, with academic advising being one of the services most visibly affected (Fernandez et al., 2023). A case study at King Abdulaziz University (Saudi Arabia) found that digitising the course-registration and academic-advising system significantly increased student satisfaction with the advising role, from 33.9% (agree and strongly agree) in 2018 to 51% in 2020, while also improving access to services regardless of time or location (Brdesee & Alsaggaf, 2022).

Pelletier and Hutt (2021) emphasise that digital transformation requires academic advisors not merely to adopt new tools but also to shift their mindset and professional skills to make effective use of student data in advising. In other words, technology does not replace the advisor's role. However, it reshapes it: reducing time spent on repetitive administrative tasks (course

registration, regulation lookups) to free up more time for in-depth, developmentally oriented advising interactions tailored to individual students. This trend aligns with the developmental-advising model discussed in Section 3.1, now operating with the support of digital technology.

The picture described above, while showing a positive trend, warrants caution on three grounds. First, the finding by Brdesee and Alsaggaf (2022) that student satisfaction with the advising role rose from 33.9% to 51% after digitization is a notable improvement, but it also means that fewer than half of the surveyed students were fully satisfied raising the question of whether digitizing registration and information-lookup processes genuinely improves the quality of advising content, or mainly improves the convenience of accessing the service. These are two distinct dimensions that should be disaggregated rather than collapsed into a single general satisfaction metric.

Second, Pelletier and Hutt's (2021) recommendation that advisors need to change their mindset and skills to exploit student data rests on a premise that may not yet hold in the Vietnamese context, where most academic advisors are faculty members serving in a part-time, concurrent capacity, without in-depth training in educational data analysis. A survey by Pham et al. (2021) of Vietnamese students during the COVID-19 pandemic found that students' readiness for digital transformation was uneven, depending on their awareness, attitudes, and self-directed-learning capacity a finding suggesting that the effectiveness of digital academic advising depends not only on the supply side (systems, advisors) but also on students' own digital competence, a dimension easily overlooked in studies focused on technology and operational processes.

Third, the distinction drawn by Fernandez et al. (2023) between digitising administrative processes (digitisation) and genuinely transforming the operating model (digital transformation) deserves greater emphasis in the Vietnamese context. If the push from Decision 131/QĐ-TTg (2022) results only in digitising existing advising processes without a parallel redesign toward the proactive, developmental model discussed in Section 3.1, the outcome will remain limited to administrative efficiency gains rather than the substantive shift in the advisor's role documented in the international literature.

3.3. Technology tools supporting academic advising in the digital environment

The literature review shows that advising-support technology has developed along three main

directions, presented in Table 1, each of which carries limitations or risks that should be made explicit rather than assessed solely from the standpoint of technical benefit.

Table 1. Categories of technology tools supporting academic advising in the digital environment and their limitations

Tool category	Characteristics and examples	Source	Limitations/risks to note
E-advising systems	Digitise course registration, curriculum lookup, and student-advisor connection via web portals or mobile devices	An et al. (2016); Brdesee & Alsaggaf (2022)	Improves administrative efficiency but does not automatically raise the quality of advising content unless processes are redesigned around a developmental model (Fernandez et al., 2023)
AI-integrated chatbots and virtual assistants	Use natural language processing (NLP), large language models (LLMs), and retrieval-augmented generation (RAG) to provide instant responses and reduce human advisors' workload	Assiri et al. (2020). Ngo Van Thap et al. (2025)	Hallucination risk; acceptance driven more by ease of use and social influence than by perceived usefulness (Bilquise et al., 2024)
Data-driven learning analytics and recommender systems	Apply educational data mining and regression, classification, or matrix-factorisation models to predict academic performance, detect at-risk students early, and recommend suitable courses.	Romero & Ventura (2010); Iatrellis et al. (2017)	Risk of predictive bias across demographic groups; ethical concerns over privacy, data consent, and "risk-labelling" effects (Slade & Prinsloo, 2013; Baker & Hawn, 2022; Lee & Kizilcec, 2020)

Specifically:

- Process-digitisation tools: focus on digitising course registration and information lookup, exemplified by mobile academic-advising support systems that let advisors access student information anytime, anywhere, and automate certain tasks to save time (An et al., 2016).

- Conversational-AI tools: Ngo Van Thap et al. (2025) propose a model for integrating an AI chatbot into the academic-advising system of a university in Hanoi, based on natural-language-processing technology and retrieval-augmented generation (RAG), pursuing three objectives: providing students with instant access to information; reducing the workload of academic advisors; and improving the overall quality of academic support.

Similar results are reported in the systematic review by Assiri et al. (2020), which finds that AI-integrated advising systems help address information overload and ensure consistency in advice, while also

raising challenges regarding personalisation and reliability when handling complex situations.

Building on this, a quantitative study by Bilquise, Ibrahim, and Salhieh (2024) of 207 students at two universities in the UAE yields a notable, somewhat counter-intuitive finding: the factors determining students' intention to use an academic-advising chatbot were ease of use and social influence (peer norms, the study environment), whereas perceived usefulness, autonomy, and trust in the system showed no statistically significant effect. This finding directly challenges an assumption often implicit in advising-technology research—that the more functionally useful a tool is, the more readily students will adopt it. In practice, students' adoption decisions may be driven more by convenience of use and peer influence than by a rational assessment of the advisory value received. The implication for designing academic-advising chatbots in Vietnam is that equal investment should go toward user experience and channels of social diffusion

(for example, dissemination through student networks or integration into class activities), rather than focusing solely on improving the technical accuracy of the language model.

Beyond technology acceptance, chatbots built on large language models also carry the risk of “hallucination”, generating inaccurate information with high apparent confidence. In the advising context, this risk is especially serious when it concerns academic regulations, course prerequisites, or registration deadlines areas where an incorrect answer can have direct consequences for a student's academic outcomes. This reinforces the argument made in Section 3.1: conversational technology should be designed as a support layer with built-in fact-verification mechanisms and cross-checks against human advisors for binding decisions, rather than operating as a fully autonomous, stand-alone advising channel.

- Learning-analytics and recommender-system tools: this category is especially significant for shifting academic advising from a reactive model (intervening only once a student runs into difficulty) to a proactive, early-warning model. Educational data mining is a research field that applies data-mining techniques to educational-system data to uncover latent information for improving teaching and learning quality (Romero & Ventura, 2010). Building on this foundation, recommender systems widely applied in e-commerce and entertainment have been studied for use in education to recommend learning resources, elective courses, or study pathways suited to each student's ability and interests, using collaborative filtering, content-based filtering, and hybrid-filtering techniques (Ricci et al., 2015). Predicting course-level academic performance by combining a student's learning-process data with course characteristics allows the system to recommend courses in which the student is likely to succeed, thereby supporting advisors in giving advice grounded in quantitative evidence rather than subjective experience alone. At the same time, early detection of students at risk of poor academic outcomes through classification or regression models allows advisors to intervene promptly, rather than only after a student has already received an academic warning.

However, the very tool category judged to hold the greatest potential is also the one carrying the most significant ethical and fairness risks, an aspect that existing reviews of academic advising in the digital environment, including in Vietnam, address only marginally. Slade and Prinsloo (2013), in a widely cited ethical framework for learning analytics, identify four

core issues: ownership and interpretation of learning data; consent and transparency toward students as the subjects of that data; the boundary between surveillance and care in monitoring learning behaviour; and how data is classified and retained over time. These issues are almost absent from the studies of advising technology in Vietnam reviewed above, which focus mainly on technical performance and user satisfaction.

More concerning still, predictive models are not technically neutral tools. Baker and Hawn's (2022) review of empirical evidence shows that predictive models in education tend to exhibit systematic bias by race/ethnicity, gender, nationality, and socio-economic status—meaning a model can achieve high overall accuracy while performing substantially worse for certain groups of students. Empirical evidence from Lee and Kizilcec (2020), based on a university's administrative data, reinforces this concern: the student-success prediction model they built showed gender and racial bias on two of the three fairness metrics examined, and adjusting the model to improve one fairness criterion could worsen another meaning there is no single technical solution that achieves “absolute fairness” across all criteria simultaneously; institutions must instead make deliberate, transparent choices about which fairness criteria to prioritize when deploying such systems.

Applied to the Vietnamese context, if a predictive-analytics system is trained predominantly on data from students in more advantaged areas, the model risks producing less reliable predictions for students from disadvantaged regions, working students, or students with distinct learning patterns precisely the groups that need the closest advising support, yet who risk receiving support based on the least accurate predictions. A further consequence is the phenomenon of “risk labelling”. Once a system flags a student as belonging to an “at-risk” group, that label can shape the expectations of both the advisor and the student in a negative direction, producing a self-fulfilling-prophecy effect rather than encouraging positive intervention. This reinforces the recommendation of Iatrellis et al. (2017) discussed below, and further suggests that this recommendation needs to be translated into concrete data-governance and fairness-monitoring principles when applied to academic-advising practice in Vietnam.

Iatrellis et al. (2017), through a systematic review of empirical studies on academic-advising systems from 2008 to 2017, identify three dominant, often overlapping, strands of research: pedagogy-oriented issues, learning analytics, and educational data mining.

The authors also caution that advising software, however advanced its analytical techniques, cannot and should not fully replace human advisors; instead, it should be designed to strengthen the relationship between students and advisors. This is a point deserving particular attention when applying technology to academic advising in Vietnam.

IV. CONCLUSION

Academic advising plays a central role in connecting students with the training program and the university. It is shifting from an administrative, prescriptive model toward a personalised, developmental model under the influence of digital transformation. Three categories of technology tools e-advising systems, AI chatbots, and learning analytics combined with recommender systems are reshaping how academic advising is delivered worldwide, with learning analytics and recommender systems holding the greatest potential for shifting advising from a reactive to a proactive, early-warning model, while also being the category that demands the most rigorous ethical and fairness governance.

The literature review shows that research and application in Vietnam remain concentrated in process-digitisation tools and AI chatbots (An et al., 2016; Ngo Van Thap et al., 2025), while learning-analytics and recommender-system tools for predicting academic performance, early warning, and course-selection advising remain at an early research stage and have not been widely integrated into actual advising workflows. On this basis, universities should pursue the following directions: (i) build a centralized learning-data infrastructure, interoperable between the training-management system and the academic-advising system, to underpin predictive-analytics models; (ii) pilot the integration of decision-support tools (predicting academic outcomes, recommending courses) into advisors' actual workflows, rather than confining them to the research stage; (iii) preserve the human role in consequential advising decisions, using technology as a support tool rather than a replacement for the academic advisor, in line with recommendations from the international literature; and (iv) establish internal regulations on data ethics and algorithmic fairness in academic advising, including a mechanism for obtaining student consent for the collection and use of learning data, and a periodic monitoring mechanism to detect predictive bias across different student groups.

More broadly, these directions can be generalized into a "responsible AI" framework for academic advising, built on four mutually reinforcing pillars: (1) algorithmic transparency students and advisors should be able to understand the basis of any recommendation or alert generated by the system, rather than receiving it as an opaque "black box"; (2) data consent and privacy upholding the principle that learning data belongs to students and may only be used for clearly disclosed learning-support purposes; (3) fairness monitoring across demographic and socio-economic groups, to detect and promptly correct predictive bias; and (4) preserving final human decision-making authority in situations with binding consequences for a student's academic pathway. These four pillars do not conflict with, but in fact reinforce, the digital-transformation objectives set out in Decision 131/QĐ-TTg (2022): technology can only generate sustainable value for academic advising when accompanied by a commensurate governance framework avoiding a situation of "superficial digital transformation," in which heavy investment in infrastructure and tools proceeds while questions of data ethics, advisors' digital competence, and equity of access to learning support remain unaddressed.

A limitation of this paper is that its findings are drawn from secondary literature, without empirical surveys at Vietnamese universities to verify the specific readiness and needs of advisors and students with respect to each category of technology tool, nor experimental data to assess the degree of predictive bias across different student groups in Vietnam. Future research should survey the actual state of digital-technology application in academic advising at Vietnamese universities, providing a basis for proposing and piloting an advising model that integrates predictive analytics and recommender systems suited to domestic conditions, while also testing the fairness of such predictive models across students from different backgrounds before any large-scale rollout.

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Epistemological Rupture in the Transition from Junior to Senior High School: An Analysis of Function Concept in Chinese Mathematics Curriculum

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Abstract

The function concept occupies a central position in school mathematics, yet its development across educational levels involves discontinuities that resist smooth cognitive progression. In the Chinese mathematics curriculum, the transition from junior to senior high school requires students to move from a "variable dependency" conception (biànlìang yīlài guān, 变量依赖观) to a "set correspondence" conception (jīhé duìyīng guān, 集合对应观). This paper argues that such a transition constitutes what Bachelard (1938) termed an epistemological rupture, a break in which previously adequate ways of knowing become obstacles to new knowledge. Through a theoretical analysis grounded in Bachelard's epistemological obstacle, Duval's theory of semiotic representation registers, and Sfard's reification framework, this study identifies three interrelated dimensions of the rupture: ontological (the shift from process to object), semiotic (the shift from natural-language descriptions to set-theoretic formalism), and cognitive (the demand for structural conception built on inadequate operational foundations). By examining textbook definitions, curriculum standards, and the mathematical structure of the concept itself, this paper traces the specific mechanisms through which prior knowledge becomes an impediment and proposes that recognizing this rupture as structurally necessary, rather than contingently problematic, can inform more coherent instructional design at the critical juncture between school levels.

Keywords— function concept, epistemological rupture, semiotic representation, reification, Chinese mathematics curriculum

I. INTRODUCTION

Few mathematical ideas carry the explanatory weight of the function. From the elementary recognition that one quantity determines another, to the abstract machinery of set theory and beyond, the function concept serves as both a unifying thread and a persistent source of difficulty in school mathematics. Students encounter functions repeatedly across grade levels, yet each encounter demands not merely an extension but, in certain respects, a reconstruction of what a function is understood to be.

In China's mathematics curriculum, this reconstruction takes a particularly sharp form. During the junior high school years (grades 7 to 9), students develop a conception of function centered on the idea of *variable dependency* (变量依赖): one quantity changes as another changes. The 2024 edition of the junior high mathematics textbook published by the People's Education Press (人教版 2024, hereafter PEP-JH) defines the function in these terms: in a changing process involving two variables, if every determined

value of one variable corresponds to a uniquely determined value of the other, then the second variable is called a function of the first (People's Education Press, 2024). Students at this level work with specific functions through formulas ($y = 2x$, $S = \pi r^2$), tables of values, and graphs, always anchored in concrete physical situations such as distance traveled at constant speed or the area of a circle given its radius.

When students enter senior high school (grade 10 onward), they encounter a fundamentally different definition. The senior high textbook (人教A版 2019, hereafter PEP-SH) states that given two non-empty sets of numbers A and B , if a definite correspondence relation f assigns to each element x in A a uniquely determined element $f(x)$ in B , then this correspondence $f: A \rightarrow B$ is called a mapping from A to B (People's Education Press, 2019). The function is now presented as a set correspondence between non-empty sets of numbers, with three essential components: the domain (定义域), the correspondence relation (对应关系), and the range (值域).

The gap between these two formulations is not merely a matter of increasing precision. The junior high conception treats functions as descriptions of covariation between measurable quantities: a car traveling at 60 km/h covers a distance $s = 60t$ as time t varies. The senior high conception treats functions as abstract mappings between sets, where the "varying" has been replaced by "belonging," and the physical process has been replaced by a formal assignment rule. A student who has spent three years understanding functions as processes of change must now understand them as objects defined by set-theoretic conditions.

This shift has been recognized in Chinese mathematics education research as a practical difficulty (Qu, 2016), yet it has rarely been subjected to systematic theoretical analysis using epistemological frameworks. Most discussions treat it as a pedagogical challenge to be managed through better bridging activities or review sessions. Such an approach, however well-intentioned, may underestimate the depth of the cognitive reorganization required.

This paper takes a different position. Drawing on Bachelard's (1938) concept of epistemological rupture, we argue that the transition from variable dependency to set correspondence is not a continuous deepening of understanding but a genuine rupture: a break in which the very knowledge that served the student well in junior high school becomes an obstacle

to learning at the senior high level. To analyze this rupture, we employ three complementary theoretical lenses: Bachelard's theory of epistemological obstacles (as developed in mathematics education by Brousseau, 1983, 1997), Duval's (1995, 2006) theory of semiotic representation registers, and Sfard's (1991, 2000) theory of reification. Together, these frameworks allow us to examine the rupture at multiple levels: the epistemological structure of the obstacle, the semiotic shift in representational systems, and the cognitive transformation from process to object.

The analysis proceeds as follows. Section 2 presents the three theoretical frameworks and explains how they converge to illuminate concept transitions. Section 3 describes the specific curricular context of function teaching in China, drawing on the most recent textbook editions and curriculum standards. Section 4 constitutes the core analysis, examining the epistemological rupture through three dimensions. Section 5 discusses the implications for teaching and curriculum design, and Section 6 offers concluding remarks.

II. THEORETICAL FRAMEWORK

2.1 Epistemological Obstacle and Rupture

Gaston Bachelard (1938) introduced the concept of *epistemological obstacle* (*obstacle épistémologique*) to describe a distinctive form of resistance in the development of scientific knowledge. Unlike external difficulties (such as the complexity of a problem or the limitations of instruments), an epistemological obstacle resides within knowledge itself: it is pre-existing knowledge that constitutes the obstacle to forming new knowledge (Bachelard, 1938/2002). The obstacle is not ignorance but rather a way of knowing that was once functional and appropriate but has become inadequate in a new context.

Bachelard identified several types of epistemological obstacles: the obstacle of first experience (generalization from limited instances), the verbal obstacle (confusion arising from language), the substantialist obstacle (the tendency to reify processes into substances), the pragmatic obstacle (the preference for what is useful over what is true), and the animist obstacle (the projection of life and intention onto inert matter). These obstacles are not errors to be eliminated but structural features of knowledge development. For Bachelard, knowing requires

rectifying one's knowledge (*connaître, c'est rectifier une connaissance*) (Bachelard, 1938/2002).

Guy Brousseau (1983, 1997) adapted Bachelard's concept to mathematics education, arguing that obstacles to learning mathematics are not merely the result of teaching deficiencies but arise from the very nature of mathematical knowledge. Brousseau distinguished between ontological obstacles (related to the nature of mathematical objects), instrumental obstacles (related to the means of approaching those objects), and epistemological obstacles (related to the ways of knowing the objects themselves). The key insight is that obstacles are inherent in the acquisition of knowledge and constitutive of knowledge itself (Brousseau, 1997). In this view, encountering and overcoming obstacles is not a detour from learning but an essential part of it.

Sierpinska (1992) applied this framework to the understanding of the function concept, demonstrating that students' difficulties are not arbitrary but follow predictable patterns rooted in the historical development of the concept and in the inherent tensions within the concept itself. She showed that the evolution from the Leibnizian notion of function (as a quantity associated with a curve) through the Eulerian notion (as an analytic expression) to the Dirichlet-Bourbaki notion (as a correspondence between sets) involved genuine epistemological ruptures at the level of the discipline, and that analogous ruptures appear in individual learning.

The concept of *epistemological rupture* (*rupture épistémologique*) is closely related to that of epistemological obstacle. Whereas the obstacle names the resistance encountered, the rupture names the break that must occur for knowledge to progress. In Bachelard's philosophy, the rupture is the moment of overcoming: the point at which prior knowledge is not discarded but fundamentally restructured. Bachelard insisted that all knowledge is a rectification of prior knowledge (Bachelard, 1938/2002), meaning that intellectual progress requires a negation of earlier modes of thought that were themselves necessary at an earlier stage. It is precisely this dual character, of being both necessary and insufficient, that makes the transition from junior to senior high school function concept a paradigmatic case of epistemological rupture.

2.2 Semiotic Representation Registers

Raymond Duval (1995, 2006) developed a theory of semiotic representation that provides tools

for analyzing how mathematical objects are accessed through different sign systems. The theory rests on a fundamental thesis: mathematical objects are never given directly but only through their representations (Duval, 2006). This means that understanding a mathematical concept requires the ability to move among different representational systems, or *registers*, such as natural language, algebraic notation, graphical displays, and tabular forms.

Duval distinguished three cognitive activities associated with representations: *formation* (producing a representation within a given register), *treatment* (transforming a representation within the same register, such as simplifying an algebraic expression), and *conversion* (transforming a representation from one register to another, such as converting an algebraic formula into a graph). Of these, conversion is the most cognitively demanding and the most essential for mathematical understanding. A student who can perform treatments within a single register but cannot convert between registers possesses only a partial understanding of the concept (Duval, 1995).

Duval also introduced the concept of *noesis*, the act of apprehending or conceptualizing a mathematical object through its representations, and distinguished it from the *semiosis*, the act of producing or manipulating representations. Understanding requires the coordination of noesis and semiosis: the student must recognize that different representations refer to the same underlying mathematical object. When this coordination fails, what Duval called a *rupture* occurs: the student treats different representations as referring to different objects, or treats a single representation as the object itself.

The notion of *congruence* is also relevant. Two representations in different registers are *congruent* when there is a one-to-one correspondence between their constituent elements. When congruence is low, conversion becomes more difficult. For instance, converting the algebraic expression $y = 2x + 3$ to a graph is relatively straightforward because the elements of the formula correspond clearly to visual features of the line. Converting a verbal description to a graph is less congruent because the relationship between the linguistic elements and the graphical features is not one-to-one.

2.3 Reification: From Process to Object

Anna Sfard (1991, 2000) developed a theory of mathematical concept formation that describes how learners progress from operational (process-based) to

structural (object-based) conceptions. Sfard argued that many mathematical concepts have a dual nature: they can be understood either as processes (dynamic operations) or as objects (static entities). The function concept is perhaps the paradigmatic example: one can think of $f(x) = 2x + 3$ as a procedure for computing an output from an input, or as an object, a function that can be manipulated, compared, and composed.

Sfard proposed three stages in the development of a mathematical concept:

Interiorization. The learner becomes familiar with a concept at the operational level, performing processes smoothly and efficiently. At this stage, the concept exists only as a set of actions or procedures. For the function concept, interiorization means being able to evaluate $f(x)$ for specific values, plot points on a graph, or trace the behavior of a formula.

Condensation. The learner begins to perceive the process as a whole, without needing to carry out each step. The process is "compressed" into a mental unit that can be manipulated without being executed step by step. At this stage, the student can think about the function $f(x) = 2x + 3$ without computing individual values, perhaps recognizing that it represents a linear relationship or that its graph is a straight line.

Reification. The learner suddenly becomes aware of the process as a manipulable object. This is the most difficult and most important stage, characterized by what Sfard called an "ontological shift." The concept is no longer something the student *does* but something the student *has*. The function becomes an object that can be an element of a set, a member of a function space, or an argument of another function (such as the derivative operator).

Sfard (1991, 2000) emphasized that reification is not a gradual process but a sudden restructuring: the concept is born when the process is suddenly seen as an object (Sfard, 1991). The difficulty of reification lies precisely in the fact that the operational conception, which was perfectly adequate at the earlier stage, now becomes an obstacle. The student who thinks of a function only as a computational procedure cannot easily grasp that the function itself can be treated as a single mathematical entity.

Sfard and Linchevski (1994) demonstrated this dynamic in the context of algebra, showing how students' operational conceptions of algebraic expressions blocked their ability to treat expressions as objects. Their analysis is directly applicable to the function concept, where a similar blockage occurs

when students must move from evaluating functions to manipulating functions as objects.

2.4 Convergence of the Three Frameworks

The three frameworks converge in their treatment of concept transitions. Bachelard's epistemological obstacle describes the *epistemological structure* of the difficulty: prior knowledge becomes an impediment. Duval's theory describes the *semiotic dimension*: the rupture involves a shift in representational systems that requires new cognitive operations. Sfard's theory describes the *cognitive mechanism*: the transition from process to object requires a reorganization of the learner's conception.

For the transition from junior high to senior high school function concept, these three perspectives yield a comprehensive analytical framework. The epistemological lens reveals why students' prior knowledge of variable dependency becomes an obstacle to set correspondence. The semiotic lens reveals the representational discontinuity between the registers used in the two school levels. The cognitive lens reveals the ontological shift from process to object that the transition demands. Together, they allow us to analyze the rupture not as a contingent pedagogical problem but as a structurally necessary break inherent in the mathematical nature of the function concept itself.

III. THE FUNCTION CONCEPT IN THE CHINESE MATHEMATICS CURRICULUM

3.1 Junior High School: The Variable Dependency Conception

In the Chinese mathematics curriculum, the function concept is first formally introduced in grade 8 (junior high year 2), within the "Number and Algebra" domain. The 2022 edition of the Compulsory Education Mathematics Curriculum Standards specifies that students should explore the relations and rules among quantities in concrete situations, understand the concept of function in real-world contexts, and be able to express functions using formulas, tables, and graphs (Ministry of Education, 2022).

The PEP-JH textbook (2024 edition, Volume 2, Chapter 22) presents the function concept through a sequence of concrete situations. The first situation involves a car traveling at constant speed, where the distance s is related to the time t by the formula $s = 60t$ (People's Education Press, 2024). Subsequent situations include the relationship between the side

length and area of a square ($S = x^2$), the relationship between water height and time in a filling tank, and others (People's Education Press, 2024). After presenting several such situations, the textbook abstracts a common pattern: in each situation, there are two variables, and when one variable takes a determined value, the other is uniquely determined. This relationship is called a function (函数). More precisely, in a changing process with two variables x and y , if every determined value of x corresponds to a uniquely determined value of y , then x is the independent variable (自变量) and y is a function of x (因变量) (People's Education Press, 2024).

This definition emphasizes several features. First, the function is understood through *process*: it exists "in a changing process" (在一个变化过程中). Second, the emphasis is on *dependence*: one quantity varies as another varies. Third, the uniqueness condition ("uniquely determined value") is stated, but it is embedded in a dynamic, quasi-physical context. The student's understanding at this level can be characterized as *variable dependency*: y is a function of x means that y depends on x in a specific, deterministic way.

During grades 8 and 9, students study three families of specific functions: linear functions ($y = kx + b$, $k \neq 0$), inverse proportional functions ($y = k/x$, $k \neq 0$), and quadratic functions ($y = ax^2 + bx + c$, $a \neq 0$) (Ministry of Education, 2022; People's Education Press, 2024). For each family, they learn to derive properties from formulas, sketch graphs, and apply functions to solve problems. Throughout, the emphasis remains on the dynamic relationship between variables: students trace how y changes as x changes, observe the resulting patterns in graphs, and solve equations and inequalities by reading values from these graphs.

The cognitive achievement at the end of junior high school is substantial. Students can evaluate functions, plot and interpret graphs, determine domains from contexts, and solve problems using function properties. Yet this achievement rests entirely on the variable dependency conception. The function is a process of covariation, anchored in physical situations, expressed through formulas and graphs, and understood primarily through its dynamic behavior. As Tall and Vinner (1981) observed, a learner's *concept image*, the total cognitive structure associated with a concept, may diverge significantly from the formal concept definition. At the junior high level, the concept

image of function is built from processes and physical contexts, creating a structure that will prove difficult to reconcile with the set-theoretic definition encountered later.

3.2 Senior High School: The Set Correspondence Conception

When students enter senior high school (grade 10), the function concept undergoes a fundamental redefinition. The PEP-SH textbook (2019 edition, Compulsory Volume 1, Chapter 3) begins by revisiting the junior high conception only to supersede it:

The textbook notes that the junior high conception of function, studied from the perspective of variable dependency, captures the essential feature of functions but is limited in scope, and that the language of sets allows a more general and rigorous definition (People's Education Press, 2019).

The new definition is then stated:

The definition states that given two non-empty sets of numbers A and B , if a definite correspondence relation f assigns to each element x in A a uniquely determined element $f(x)$ in B , then $f: A \rightarrow B$ is called a function from A to B , written $y = f(x)$, $x \in A$ (People's Education Press, 2019).

This formulation differs from the junior high definition in several respects that bear careful analysis.

First, the ontological status of the function has changed. Instead of a relationship between *variables* that vary in a process, the function is now a correspondence between *sets* of numbers. The variables x and y are no longer quantities that change but elements that *belong* to sets. The phrase "in a changing process" has disappeared; in its place stands "let A and B be two non-empty sets of numbers." The function is no longer something that happens but something that exists, a mathematical object characterized by three components: the domain A , the correspondence relation f , and the range $\{f(x) \mid x \in A\} \subseteq B$.

Second, the language has shifted from the informal register of variable dependency to the formal register of set theory. Terms such as "set" (集合), "element" (元素), "correspondence" (对应), and "mapping" (映射) replace the language of "changing process," "variable," and "dependence." This represents not merely a change of vocabulary but also a change in the representational system: the mathematical objects

are now conceived within a different theoretical framework.

Third, the scope of the definition has expanded. The junior high conception, tied to physical processes, naturally encompasses only functions that can be expressed by formulas relating measurable quantities. The set-theoretic conception, by contrast, allows functions that have no simple formula: for instance, the Dirichlet function (which equals 1 for rational inputs and 0 for irrational inputs), piecewise-defined functions with complex structures, and functions defined by tables without any discernible pattern (People's Education Press, 2019).

During the first year of senior high school, students study function properties (monotonicity, odd/even symmetry, maximum/minimum values) within this set-theoretic framework (People's Education Press, 2019). They learn to determine domains rigorously using inequalities on sets, to compose and invert functions using the correspondence structure, and to prove properties using the formal definition. The emphasis shifts from *tracing how quantities change* to *analyzing the structural properties of a mathematical object*.

3.3 The Curricular Gap

The two curriculum documents that govern function teaching at each level make the discontinuity explicit. The Compulsory Education Mathematics Curriculum Standards (2022 edition) requires students to explore simple numerical changes and functional relationships in concrete situations (Ministry of Education, 2022), emphasizing intuitive understanding and practical application. The Senior High School Mathematics Curriculum Standards (2017 edition, revised 2020) requires students to establish the function concept using set theory and correspondence language, understand function properties, and use function concepts and methods to solve problems (Ministry of Education, 2020), emphasizing formal definition and abstract reasoning.

Between these two documents lies a content gap (内容断层): the junior high curriculum cultivates a dynamic, contextually grounded understanding, while the senior high curriculum demands a static, formally grounded understanding. The gap is not a matter of degree (more depth, more complexity) but of kind: the very conception of what a function *is* must be restructured.

This is the rupture we analyze in the following section.

IV. ANALYSIS OF THE EPISTEMOLOGICAL RUPTURE

4.1 The Ontological Rupture: From Process to Object

The most fundamental dimension of the rupture is ontological. At the junior high level, the function is a *process*: a description of how one quantity varies with another. The textbook's language makes this clear: "In a changing process" (在一个变化过程中), y depends on x . The function is not an object that exists independently of this process; it is the process itself, or rather, the regularity governing the process. When a student says " $y = 2x + 3$ is a function," what is meant is that a certain process of doubling and adding is occurring.

At the senior high level, the function is an *object*: a correspondence $f: A \rightarrow B$ defined by three components. It is no longer something that *happens* but something that *is*. The student is expected to treat the function as a mathematical entity that can be an element of a set (for instance, the set of all continuous functions on $[0, 1]$), an argument of an operation (for instance, the derivative operator applied to f), or the subject of a proposition (" f is continuous," " f is increasing").

This shift maps directly onto Sfard's (1991) framework. The junior high student has achieved *interiorization*: they can perform the processes of evaluating functions, plotting points, and reading values from graphs. Some students have reached *condensation*: they can perceive a function as a whole (for instance, recognizing that $y = 2x + 3$ represents a straight line with slope 2 without computing individual points). But the senior high curriculum demands *reification*: the function must become a structural object that can be manipulated independently of the process it encodes.

The difficulty of this reification can be analyzed more precisely using Sfard's observation that the reified concept is not a negation of the operational one but subsumes it (Sfard, 1991). The student must not abandon their process conception but must recognize it as one aspect of a more general object conception. The problem is that the junior high curriculum provides almost no opportunity for this recognition. Students work exclusively with functions

as processes of covariation, in physical contexts, expressed through formulas and graphs. They never encounter a function as an object in its own right.

Consider a concrete illustration, drawn from the respective textbook exercises (People's Education Press, 2024; People's Education Press, 2019). At the junior high level, the question "Is y a function of x ?" is answered by checking whether each value of x yields a unique value of y in a given formula or table. At the senior high level, the same question requires checking whether a given *correspondence* satisfies the condition that every element of set A is mapped to a unique element of set B . The difference is not merely one of formality. In the first case, the student is verifying a process: does this formula produce a unique output for each input? In the second case, the student is verifying a property of an object: does this correspondence satisfy the defining condition of a function? The cognitive operation is fundamentally different.

This ontological rupture generates what Bachelard would call a *substantialist obstacle*. The student, accustomed to thinking of a function as a process, encounters the demand to treat it as a substance, an entity with fixed properties. This is analogous to the historical rupture in mathematics itself: it took centuries for mathematicians to move from the Newtonian conception of function (as a quantity varying in time) through the Eulerian conception (as an analytic expression) to the Dirichlet-Bourbaki conception (as a set-theoretic correspondence). At each historical stage, the previous conception served as an obstacle to the next. The student recapitulates this history, and the obstacles are structurally similar.

The ontological rupture can also be described in terms of Tall's (1991) concept of *procept*: a mathematical entity that is simultaneously a process and a concept (object). The function $f(x) = 2x + 3$ is a procept: it denotes both the process of "doubling and adding three" and the object "the function with formula $2x + 3$." At the junior high level, the process pole dominates; the student thinks of the function as something to *do*. At the senior high level, the object pole must dominate; the student must think of the function as something to *think about*. The difficulty lies precisely in the fact that the proceptual nature of the function, which was barely visible at the junior high level, must now become the central focus of attention.

4.2 The Semiotic Rupture: From Natural Language to Set-Theoretic Formalism

The ontological shift is accompanied by, and in some sense constituted by, a semiotic rupture. Duval's (1995, 2006) framework allows us to describe this rupture with precision.

At the junior high level, the function concept is expressed through four main semiotic registers:

1. **Natural language:** descriptions such as the distance s increasing as the time t increases, or y changing as x changes.
2. **Algebraic formulas:** $s = 60t$, $y = 2x + 3$, $S = \pi r^2$.
3. **Graphical representations:** Plots of specific functions on coordinate axes.
4. **Numerical tables:** Tables of corresponding x and y values.

Throughout the junior high curriculum, the natural-language register plays a dominant role. The textbook introduces the function concept through verbal descriptions of physical situations, and the definition itself uses natural language, stating that for every determined value of x , there is a uniquely determined value of y . The formulas are always linked to specific situations, and the graphs are always interpreted as descriptions of physical processes. Conversions between registers are guided by the physical context: the student converts a word problem to a formula, evaluates the formula to produce a table, and plots the table to produce a graph, always anchored in the original situation.

At the senior high level, a new register appears and quickly becomes dominant: the **set-theoretic formal language**. The function is now written $f: A \rightarrow B$, with explicit reference to domain A , codomain B , and correspondence rule f . Properties are stated using set notation, such as specifying the domain as the set $\{x \mid x > 0\}$ or stating that the function is increasing on the interval $(0, +\infty)$ (People's Education Press, 2019). The correspondence relation is described not as a formula but as an abstract mapping: $x \mapsto f(x)$.

The discontinuity between these two semiotic regimes can be analyzed using Duval's concept of *congruence*. At the junior high level, the congruence between registers is relatively high. The formula $s = 60t$ corresponds directly to the verbal description "distance equals speed times time," and the graph of this formula corresponds directly to the picture of a car traveling at constant speed. The elements of each register map transparently onto the physical situation that grounds them all.

At the senior high level, the congruence drops sharply. The set-theoretic notation $f: A \rightarrow B$ has no direct counterpart in natural language. The expression "correspondence relation" (对应关系) is not equivalent to "rule" or "formula"; it is a new term that refers to an abstract structural relationship between sets. The domain A is not simply "the values of x " but a set defined by membership conditions. Converting between the set-theoretic register and the algebraic register, or between the set-theoretic register and the graphical register, requires operations that are *non-congruent*: there is no one-to-one correspondence between the elements of the notation $f: A \rightarrow B$ and the elements of a graph or a formula.

This non-congruence has a concrete consequence. At the junior high level, conversions between registers are *transparent*: the student can see that the formula, the graph, and the verbal description all refer to the same situation because they are all grounded in the physical context. At the senior high level, conversions become *opaque*: the student must recognize that $f: \{1, 2, 3\} \rightarrow \{4, 6, 8\}$ with $f(x) = 2x$, the set of ordered pairs $\{(1, 4), (2, 6), (3, 8)\}$, and the arrow diagram with arrows from 1 to 4, 2 to 6, and 3 to 8 all represent the same function (People's Education Press, 2019). The common referent is no longer a physical situation but an abstract mathematical object, and the student must coordinate multiple representations of this object without the support of physical intuition.

Duval (1995) argued that the ability to convert between non-congruent representations is the hallmark of genuine mathematical understanding. When conversion fails, the student may possess representations in each register separately but lacks the coordination that constitutes the concept. This is precisely the situation that arises at the junior-to-senior-high transition. Students arrive with well-developed abilities to work with functions in the natural-language, algebraic, graphical, and tabular registers. But when the set-theoretic register is introduced, their existing conversion abilities are inadequate. They may be able to read a graph or manipulate a formula, but they cannot convert between these representations and the set-theoretic notation. The result is what Duval would call a *rupture in semiosis*: the semiotic activity at the senior high level is disconnected from the semiotic activity at the junior high level, and the noetic activity (the apprehension of the mathematical object) is correspondingly disrupted.

4.3 The Cognitive Rupture: The Variable Dependency Conception as Epistemological Obstacle

The ontological and semiotic ruptures described above converge at the cognitive level. The variable dependency conception, which was a genuine cognitive achievement at the junior high level, becomes an *epistemological obstacle* at the senior high level. We can identify several specific mechanisms through which this occurs.

Obstacle 1: The process conception blocks the object conception.

The junior high student understands a function as a process of covariation: y changes as x changes. This conception supports a wide range of mathematical activity, from evaluating formulas to interpreting graphs. But when the senior high curriculum requires the student to treat a function as an object (for instance, to determine whether two functions are identical by comparing their domains and correspondence relations), the process conception becomes an impediment. The student who thinks of $f(x) = x^2$ as "squaring the input" cannot easily see that $f = g$ if and only if f and g have the same domain and the same correspondence rule, because the process conception does not provide the categories "domain" and "correspondence rule" as components of the function-object.

A typical manifestation, found in both textbooks and standardized assessments (People's Education Press, 2019): a student is asked whether $f(x) = x$ and $g(x) = x^2/x$ are the same function. Using the process conception, both functions "give back x ," so they should be the same. But using the set-theoretic conception, they have different domains (g is undefined at 0), so they are different functions. The variable dependency conception, which attends only to what the function *does*, cannot resolve this question because it has no category for the domain as a component of the function-object.

Obstacle 2: The context-dependence blocks abstraction.

At the junior high level, every function is introduced through a physical context: distance and time, area and radius, cost and quantity. This context provides meaning and motivation, but it also constrains the student's conception. The function is *about* something: it describes a relationship in the physical world. The idea of a function that has no physical

referent, or whose domain is an arbitrary set of numbers, is alien to the junior high conception.

When the senior high textbook presents a function such as $f: \{1, 2, 3, 4, 5\} \rightarrow \{2, 4, 6, 8, 10\}$ with $f(x) = 2x$ (People's Education Press, 2019), the student seeks a physical situation that this function describes. If none is forthcoming, the student experiences confusion. The set-theoretic conception requires the student to accept that a function is defined purely by its domain, its correspondence rule, and its range, without reference to any physical situation. This abstraction represents what Bachelard (1938/2002) called a *rupture with the concrete*: the break from immediate experience that is necessary for scientific thought.

Obstacle 3: The uniqueness criterion is reinterpreted.

Both the junior high and senior high definitions include a uniqueness condition: for every value of x , there is a unique value of y . But the role of this condition differs between the two levels. At the junior high level, uniqueness is verified through the physical context: given a time t , there is only one distance s at that instant. The criterion is grounded in physical determinism. At the senior high level, uniqueness is a formal condition on the correspondence: each element of A is mapped to exactly one element of B . The criterion is now a structural property of the mapping, independent of any physical interpretation.

Students often carry the junior high interpretation into the senior high context, attempting to verify uniqueness by imagining a physical process rather than analyzing the formal structure of the correspondence. This generates errors when the function has no natural physical interpretation, or when the domain and range are abstract sets of numbers.

Obstacle 4: The graphical interpretation is disrupted.

At the junior high level, the graph of a function is understood as a picture of the process: the curve *rises* because y is *increasing*, it *falls* because y is *decreasing*. The graphical representation is read as a narrative of change. At the senior high level, the graph must be understood as a set of ordered pairs $\{(x, f(x)) \mid x \in A\}$, and properties such as monotonicity must be defined using set-theoretic language (People's Education Press, 2019): f is increasing on interval I if for any $x_1, x_2 \in I$ with $x_1 < x_2$, we have $f(x_1) < f(x_2)$.

The senior high definition of monotonicity is not simply a more precise version of the junior high understanding. It represents a fundamentally different way of seeing the graph: not as a picture of motion but as a set of points satisfying a universal condition. The student who reads monotonicity off the graph visually ("the curve goes up") must learn to prove it using the formal definition, which requires a different relationship to the graphical register entirely. The graph is no longer an illustration of a process but a representation of a set-theoretic structure.

Obstacle 5: The variable itself is reconceptualized.

In the junior high conception, variables are quantities that vary: x is a number that changes, and y changes in response. At the senior high level, x is an element of a set: a fixed but arbitrary member of the domain. The shift from "variable" (*biànlìàng*, literally "changing quantity") to "element of a set" (*shùjǐ de yuánsù*) is subtle but fundamental. The variable is no longer something that *moves* through a range of values but something that *ranges over* a set. This is an instance of what Bachelard called the transition from the "substantialist" to the "formal" mode of thought: the variable is no longer a substance with dynamic properties but a placeholder in a formal structure.

The term "variable" (*biànlìàng*) itself becomes an obstacle. Its Chinese name, meaning "changing quantity," carries the implication of process and motion. When the senior high textbook asks the student to treat x as an element of a set, the student must suppress the dynamic connotations of the term and replace them with a static, set-theoretic understanding. This suppression is not a matter of simple substitution; the old meaning persists as an undercurrent, distorting the student's engagement with the new formalism.

4.4 The Rupture as Structurally Necessary

The analysis above reveals that the transition from variable dependency to set correspondence is not a smooth deepening of understanding but a genuine rupture involving multiple dimensions. This raises a question: is this rupture a contingent feature of the Chinese curriculum, or does it reflect a deeper structural necessity?

We argue for the latter. The function concept, as it has developed in the history of mathematics, necessarily involves these ruptures. Bachelard (1938/2002) argued that the development of scientific concepts follows a pattern of rupture and rectification:

each stage of knowledge contains the seeds of its own overcoming. The function concept illustrates this pattern. The Leibnizian conception (function as a quantity associated with a curve) was overcome by the Eulerian conception (function as an analytic expression), which was in turn overcome by the Dirichlet-Bourbaki conception (function as a set-theoretic correspondence). Each rupture was not an arbitrary change but a rectification of the preceding knowledge, motivated by internal demands of mathematical development.

The student's cognitive development recapitulates this historical sequence, not by coincidence but because the logical structure of the concept demands the same sequence of ruptures. The variable dependency conception is the student's "Leibnizian" stage: functions are understood through their manifestations in specific curves and processes. The set correspondence conception is the "Dirichlet-Bourbaki" stage: functions are understood as abstract correspondences between sets. Between these stages lies a rupture that is not optional but structurally required by the mathematical content itself.

This does not mean that the rupture is insurmountable or that curriculum design is irrelevant. On the contrary, recognizing the rupture as structurally necessary allows educators to design instructional interventions that address its specific dimensions. If the rupture is merely a contingent gap, it can be bridged by review or acceleration. If it is a structural necessity, it requires a pedagogical approach that acknowledges the cognitive reorganization and provides appropriate support for the ontological shift.

V. DISCUSSION

5.1 Implications for Teaching

The analysis presented in Section 4 carries several implications for the teaching of the function concept at the junior-to-senior-high transition.

First, the ontological dimension of the rupture suggests that simply presenting the set-theoretic definition and moving on is insufficient. The student must undergo a genuine cognitive restructuring, not merely acquire new information. Sfard (1991) noted that reification is typically preceded by a period of difficulty and confusion during which the learner struggles to reconcile the new structural conception with the old operational one. Teachers should anticipate this period and provide tasks that explicitly

require the structural conception. For instance, tasks that ask students to compare functions not by their formulas but by their domains and correspondence relations force the student to attend to the function as an object rather than as a process.

Second, the semiotic dimension of the rupture suggests that the transition between representational systems requires explicit instructional attention. Duval (1995) argued that conversion between non-congruent representations is the most demanding cognitive activity in mathematics learning. At the transition point, students must learn to convert between the natural-language and algebraic registers of junior high school and the set-theoretic register of senior high school. Teachers can support this by providing tasks that require such conversions explicitly: for instance, translating between the formal statement that for every x in A there exists a unique $f(x)$ in B and the arrow diagram representing the same correspondence, or between the set-builder notation for the domain and the verbal description of the conditions on x .

Third, the epistemological dimension of the rupture suggests that teachers should acknowledge the difficulty explicitly rather than treating it as a matter of students "not trying hard enough" or "not reviewing enough." Brousseau (1997) emphasized that epistemological obstacles are constitutive of knowledge itself, and that the teacher's role is not to remove obstacles but to create conditions under which students can overcome them. In the context of the function concept, this means creating tasks that force students to confront the inadequacy of their variable dependency conception. A well-designed task might present a correspondence that satisfies the set-theoretic definition of function but has no obvious physical interpretation (such as a function defined by a lookup table with no discernible pattern) and ask students to determine whether it is a function. Such a task forces the student to abandon the search for physical meaning and to engage with the formal definition directly.

5.2 Implications for Curriculum Design

The analysis also has implications for curriculum design at both the junior high and senior high levels.

At the junior high level, the variable dependency conception could be enriched with elements that anticipate the set-theoretic conception without requiring full reification. For instance, teachers could introduce the idea that a function has a *domain*

(the set of allowable inputs) and a *range* (the set of possible outputs) even within the variable dependency framework. The 2024 PEP-JH textbook already mentions domain in the context of physical constraints (for instance, the radius of a circle must be positive; People's Education Press, 2024), but this notion could be developed more systematically as a component of the function concept rather than merely a contextual constraint. Similarly, the idea of a *correspondence* could be introduced through simple mapping diagrams (arrow diagrams) that show how elements of one set correspond to elements of another, without yet using set-theoretic language.

At the senior high level, the curriculum could acknowledge the rupture explicitly and provide a transitional period in which the variable dependency and set correspondence conceptions coexist. Rather than presenting the set-theoretic definition as a replacement for the junior high conception, the curriculum could present it as a *generalization* that encompasses the junior high conception as a special case. The historical development of the function concept provides a natural narrative for this: Leibniz → Euler → Dirichlet → Bourbaki, each stage generalizing the preceding one. By situating the student's own transition within this historical sequence, the curriculum can help the student understand that the rupture is not a failure of their junior high learning but a natural step in the development of mathematical knowledge.

5.3 Implications for Research

This paper has offered a theoretical analysis of the epistemological rupture in the function concept transition. The analysis generates several questions for future empirical research:

1. How do students actually work through the transition from variable dependency to set correspondence? Do they exhibit the patterns of obstacle and rupture predicted by the theoretical framework?
2. What specific instructional interventions are most effective in supporting students through the rupture? Can task sequences designed with the three dimensions of the rupture in mind improve student outcomes? Recent methodological advances in tracing learning through combined process-object theories and individual learning trajectories (Bednorz et al., 2026) offer promising tools for such empirical investigations.

3. How does the rupture manifest in different curriculum systems? The Chinese curriculum provides a particularly sharp case, but analogous transitions exist in other educational systems (for instance, the transition from covariation to correspondence approaches in many Western curricula).

4. How do teachers' own conceptions of function influence their treatment of the transition? Research on teachers' analogies for function (Hatisaru, 2024) suggests that teachers' conceptions may privilege either the correspondence or the covariation perspective, and this may affect how they mediate the transition for students.

5.4 Limitations

This study is a theoretical analysis, not an empirical investigation. The claims about student cognition are based on theoretical reasoning and on the analysis of textbooks and curriculum standards, not on direct observation of student learning. The identification of specific obstacles is derived from the theoretical frameworks rather than from systematic data collection. Future empirical research is needed to test and refine the theoretical claims made here.

Additionally, this analysis focuses on the function concept as defined in two specific textbook series (PEP-JH 2024 and PEP-SH 2019). Other textbook series may present the transition differently, and the analysis may not generalize to all Chinese mathematics classrooms. The role of teachers as mediators of the curriculum is also not addressed, although it is likely to be significant in practice.

VI. CONCLUSION

The transition from junior high to senior high school in the Chinese mathematics curriculum requires students to reconstruct their understanding of the function concept from a variable dependency conception to a set correspondence conception. This paper has argued, using Bachelard's concept of epistemological rupture together with Duval's theory of semiotic representation and Sfard's theory of reification, that this transition is not a smooth progression but a genuine rupture involving three interrelated dimensions:

The *ontological* dimension: the function must be reconceived from a process of covariation to an object defined by set-theoretic conditions. This shift

requires what Sfard (1991) called reification, the sudden restructuring of a process into an object.

The *semiotic* dimension: the student must learn to work in a new representational system (set-theoretic formalism) that is not congruent with the registers used at the junior high level (natural language, formulas, graphs, tables). The non-congruence between the old and new registers creates additional cognitive demands that go beyond the ontological shift alone.

The *cognitive* dimension: the variable dependency conception, which was a genuine achievement at the junior high level, becomes an epistemological obstacle at the senior high level. Specific mechanisms of this obstacle include: the process conception blocking the object conception, context-dependence blocking abstraction, the reinterpretation of the uniqueness criterion, the disruption of graphical interpretation, and the reconceptualization of the variable itself.

These three dimensions are not independent. The ontological shift is made more difficult by the semiotic rupture (the new language makes the new conception harder to access), and both are intensified by the cognitive obstacle (the old conception persists and distorts engagement with the new material). Together, they constitute a rupture that is structurally necessary given the mathematical nature of the function concept itself.

The practical implication is clear: the transition cannot be managed by simply presenting the new definition and expecting students to adapt. It requires deliberate instructional design that addresses each dimension of the rupture. Teachers and curriculum designers should anticipate the obstacle, support the semiotic conversion, and create conditions for the ontological shift to occur. The historical development of the function concept, from Leibniz through Dirichlet to Bourbaki, provides both a justification for the difficulty and a narrative that can help students understand their own cognitive journey as part of the broader development of mathematical thought.

Bachelard (1938/2002) observed that science unquestionably progresses, but it does not progress continuously. The development of the function concept in school mathematics, we have argued, follows this same pattern of discontinuous progress. Recognizing the rupture as a feature of mathematical cognition,

rather than a bug, is the first step toward designing more effective instruction at this critical juncture.

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