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A Cognitive Neuroscience Based Pedagogical Model to Enhance Students' Spoken Fluency: A Case Study in Vocational Engineering Students

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A B S T R A C T
The ability to speak English fluently is a non-negotiable professional competency for graduates of vocational (polytechnic) education in the globalized industrial landscape. However, vocational graduates in Indonesia often lack professional English fluency, remaining at A1-A2 CEFR levels despite years of instruction. This study argues this gap stems from a pedagogical focus on declarative (rules) rather than procedural (automated) skills. This article reports on the pilot testing of a novel pedagogical model grounded in cognitive neuroscience. The model automates neurolinguistic pathways by integrating Structured Classroom Activities (SCA) with Structured Real-life Engagement (SRE), catalyzed by a "Positive Compulsion" strategy. The model was implemented in a 12-week pilot with with one class (n=24) of D3 Energy Conversion Engineering students at Politeknik Negeri Medan using a mixed-methods pre-test/post-test design. The results demonstrated the NeuroTalk model is valid and feasible. The results demonstrated that the model is a valid and feasible pedagogical product. Quantitative analysis showed a measurable positive gain score in spoken fluency metrics, particularly in mean length of utterance and spontaneity. The model presents a feasible and effective pedagogical innovation that successfully bridges the persistent classroom-industry gap in vocational English education.

INTRODUCTION

English holds an undisputed position as the global *lingua franca* for international trade, cross-cultural scientific exchange, and advanced technology.[1] In the context of vocational higher education (polytechnics), the mastery of English communication skills is not merely an academic supplement but a foundational tool for professional competence. Graduates of technical and engineering programs are increasingly expected to interact with international colleagues, comprehend technical manuals published in English, and articulate complex processes to global partners.[1] Within this complex skill set, spoken fluency serves as the most critical and visible indicator of communicative competence, directly impacting a graduate's employability and adaptability in the Industry 4.0 landscape.

In Indonesia, this industrial demand is set against a persistent pedagogical paradox. English has been a compulsory component of the national curriculum for decades, with most students accumulating six to twelve years of formal instruction before entering university.[1] Ideally, this significant investment of time and resources would produce graduates proficient at B2 (Upper Intermediate) or C1 (Advanced) levels of the Common European Framework of Reference for Languages (CEFR).[1] The reality, however, starkly contrasts with this expectation. The 2024 EF English Proficiency Index (EPI) places Indonesia at 80th out of 113 nations, classifying it in the "Low Proficiency" category.· This national trend is empirically confirmed at the institutional level; baseline data from Politeknik Negeri Medan, the site of this research, consistently shows that over 70% of new students possess English skills at the A (Beginner) or A2 (Elementary) levels, based on TOEIC placement diagnostics.

This evidence illuminates a critical failure: long-term study is not translating into functional communication. This research posits that this is not a failure of the students, but a *fundamental misalignment of pedagogy*. The dominant instructional approach in the region remains "struktural"—an approach oriented toward grammar, vocabulary memorization, and explicit rule-based learning. This methodology, while effective at building *declarative knowledge* (knowing *about* the language), fails to build the *procedural skill* (knowing *how to use* the language) required for fluent, spontaneous speech. The problem of low fluency is not a knowledge-deficit; it is an *automation-deficit*. Students are often passive, dependent on scripts, and actively avoid spontaneous oral interaction , precisely because their education has not provided a mechanism for converting declarative rules into procedural automaticity.

This study addresses this gap by proposing a pedagogical "turn" toward cognitive neuroscience. Spoken fluency is a neurocognitive phenomenon, involving the activation, strengthening, and automation of neural pathways in the brain. To solve the fluency problem, pedagogy must align with the principles of neuroplasticity, retrieval practice, and affect (emotion) that govern how these pathways are formed.

In response, this research developed and tested "NeuroTalk," a novel pedagogical model grounded in cognitive neuroscience. The NeuroTalk model is specifically designed to build procedural automaticity by systematically

integrating two core components: Structured Classroom Activities (SCA), which provide explicit cognitive scaffolding, and Structured Real-life Engagement (SRE), which provides implicit, contextual, and embodied practice. These components are activated by a unique affective-motivational strategy identified as "Keterpaksaaan Komunikatif" (positive compulsion)—a process of engineering a learning environment that is simultaneously challenging and psychologically safe.

This article reports on the complete Research and Development (R&D) cycle of the NeuroTalk model, from design to pilot implementation. It seeks to answer three primary research questions :

1. How is the NeuroTalk pedagogical model designed to integrate Structured Classroom Activities (SCA) and Structured Real-life Engagement (SRE) based on the principles of cognitive neuroscience and positive compulsion?
2. To what extent is the implementation of the NeuroTalk model effective in measurably improving the spoken fluency of D3 Energy Conversion Engineering students?
3. How do students perceive and experience the learning process, particularly in response to the challenges of the "positive compulsion" strategy?

By addressing these questions, this study provides a validated prototype for a pedagogical innovation that directly targets the automation of fluency, offering a potential solution to one of the most intransigent challenges in Indonesian vocational education.

Theoretical Framework and The NeuroTalk Model Design

The design of the NeuroTalk model is not arbitrary; it is a direct pedagogical response to the findings of cognitive neuroscience regarding how the brain acquires and automates spoken language. Its architecture is built upon a theoretical framework that synthesizes the neurocognitive basis of fluency, the pedagogical gap between declarative and procedural memory, and the affective mechanisms that catalyze learning.

The Neurocognitive Basis of Spoken Fluency

In applied linguistics, spoken fluency is understood not merely as speed, but as *automaticity*—the ability to produce spontaneous, coherent, and continuous speech without undue cognitive load or conscious searching for grammar and vocabulary. Cheng et al. (2015) and D'Alesio & Roccaforte (2022) emphasize that fluency reflects the *degree of automation* of linguistic components, a state where speech can be produced "tanpa kontrol sadar" (without conscious control).

This process is fundamentally neurocognitive. From a neuroscience perspective, language acquisition involves the brain's *neuroplasticity*—its capacity to reorganize itself by forming new neural connections based on experience. Spoken language production relies on a complex network, prominently featuring Broca's area (speech production) and Wernicke's area (language comprehension). The strength and efficiency of the synaptic connections between these areas are fortified through "praktik bermakna dan berulang" (meaningful and repeated

practice). Effective pedagogy, therefore, must be designed to stimulate and reinforce these specific neurolinguistic pathways.

The Declarative-Procedural Gap in Pedagogy

The failure of traditional pedagogy, as identified in the introduction , can be explained by its reliance on the wrong memory system. Cognitive psychology distinguishes between two primary types of long-term memory relevant to language learning:

1. Declarative Memory: This is the "knowing what" system. It stores explicit, factual knowledge, such as vocabulary lists, grammar rules (e.g., "the past tense of 'go' is 'went'"), and metalinguistic awareness. Traditional structural teaching, with its focus on grammar drills and memorization, is highly effective at building this type of memory.
2. Procedural Memory: This is the "knowing how" system. It governs implicit, automated skills and habits, such as riding a bicycle, playing a musical instrument, or—critically—speaking a language fluently. This memory is not built by *studying rules* but by *repeated, contextual, and embodied practice*.

The core problem in vocational English education is a *methodological failure to convert declarative knowledge into procedural automaticity*. Students *know* the rules but cannot *use* them fluently. The NeuroTalk model is designed specifically to bridge this gap by integrating two distinct, yet synergistic, components: Structured Classroom Activities (SCA) and Structured Real-life Engagement (SRE).

The NeuroTalk Model: Bridging the Gap (SCA + SRE)

The innovation of the NeuroTalk model is its systematic integration of explicit and implicit learning modalities, corresponding directly to the declarative and procedural memory systems.

Component 1: Structured Classroom Activities (SCA)

SCA forms the declarative foundation of the model. It is defined as "pembelajaran eksplisit berbasis tugas bertingkat" (explicit, scaffolded task-based learning). In this component, students engage in guided, in-class activities where they are explicitly taught the linguistic tools (vocabulary, collocations, functional phrases) necessary for a specific communicative task. This phase provides the scaffolding (Taber, 2018) and activates the executive function—the cognitive management of attention and speech planning—preparing students for the next phase.

Component 2: Structured Real-life Engagement (SRE)

SRE forms the procedural engine of the model. It is defined as "praktik komunikasi bahasa Inggris di luar kelas dalam konteks sosial yang nyata dan terstruktur" (English communication practice outside the classroom in a real and structured social context). This component moves learning from the abstract classroom to the authentic, physical environment of the polytechnic (e.g., the workshop, the laboratory, the cafeteria). SRE tasks leverage key neurocognitive principles, including:

- Embodied Cognition: The process of learning by integrating thought, physical action, and the environment. By physically *being in* the workshop

and *handling* the tools they are describing, students engage sensorimotor pathways, creating stronger, multisensory memory traces.

- Retrieval Practice: Fluency is built not by *reviewing* knowledge, but by *retrieving* it under pressure. SRE tasks (e.g., making a vlog, guiding a visitor) force students to *produce* language spontaneously, strengthening procedural memory.
- Contextual Learning: SRE provides an authentic *purpose* for communication, making the language "sticky" and meaningful.

The Affective Catalyst: Positive Compulsion

The bridge between SCA and SRE is activated by the model's core affective-motivational engine: "positive compulsion". This concept, developed from the lead author's prior research on bilingual acquisition , posits that active language use is triggered when a learner has no alternative.

This is not a "sink or swim" model. It is a carefully *engineered* state defined as "a learning condition that is challenging yet affectively safe". The NeuroTalk model hypothesizes that neuroplasticity is optimized in a "sweet spot" of high challenge and high psychological safety.

- The "Compulsion" (High Challenge): The SRE tasks are non-optional and public. They push students outside their comfort zone, "forcing" them to use English in a real-world scenario.
- The "Positive" (High Safety): This challenge is mitigated in two ways. First, the SCA component ensures students are *cognitively prepared*—they are not asked to perform a task for which they have no tools. Second, the *affective environment* is supportive and, crucially for this population, the tasks are *vocationally relevant*.

This engineered affective state is theorized to align with the *Foreign Language Enjoyment* framework (Dewaele & MacIntyre, 2016), where a challenging-but-safe environment enhances motivation. This emotional arousal, in turn, is linked to stronger memory formation (*emotion-aroused memory*). The NeuroTalk model is thus a holistic, neuro-affective design that synthesizes the cognitive (SCA), procedural (SRE), and emotional (Positive Compulsion) dimensions of learning to achieve the singular goal of spoken automaticity.

METHODOLOGY

This article reports on the outcomes of a completed study that followed a rigorous, multi-stage process for developing and validating an educational product. The methodology was selected to ensure the resulting NeuroTalk model was not only theoretically sound but also practically feasible and effective in its intended vocational context.

Research Design

This study employed a Research and Development (R&D) design, following the systematic, cyclical model advanced by Gall, Gall, and Borg (2007). This design was explicitly chosen because its primary objective aligns with that of the study: "to develop and validate educational products". The R&D approach is particularly suited for vocational education as it emphasizes the creation of

contextual, field-tested, and practical solutions to real-world pedagogical problems.

The comprehensive R&D cycle was simplified into seven key stages for this project, all of which were completed:

1. Preliminary Study: Involved needs analysis, literature review, and identification of the core fluency gap at the research site.
2. Model Planning: The initial design of the NeuroTalk model, its theoretical underpinnings (SCA+SRE), and the development of the 4-topic curriculum and fluency rubrics.
3. Expert Validation: The draft model and its instruments were submitted to a panel of experts in vocational pedagogy, applied linguistics, and cognitive neuroscience for review.
4. Limited Trial (Pilot Implementation): The revised model was implemented in a single-cycle, small-scale field test.
5. Model Revision: Minor adjustments were made to the model *during* the trial based on participatory observation and formative feedback.
6. Evaluation and Analysis: Collection and analysis of pre-test/post-test quantitative data and qualitative perceptual data.
7. Reporting and Dissemination: Preparation of the final report, academic article (this document), and HKI (Intellectual Property) application, as targeted in the research plan.

This article thus presents the consolidated findings from this complete, single-cycle pilot implementation, which employed a mixed-methods (QUAL + QUAN) design to evaluate the model's efficacy and reception.

Participants and Context

The study was conducted at Politeknik Negeri Medan, a state polytechnic in Medan, Indonesia. The participants were one intact class (n=24) of semester 5 D3 Energy Conversion Engineering students. This group was selected purposively. As semester 5 students, they had already completed foundational English courses, yet still exhibited the A1-A2 fluency baseline typical of the institution, making them an ideal population for testing this fluency-focused intervention. The students had no prior exposure to pedagogical models based on cognitive neuroscience or "positive compulsion".

The Intervention (The NeuroTalk Implementation)

The pilot implementation of the NeuroTalk model was conducted over a 12-week period (one semester), from August to November 2025. The curriculum for this pilot cycle was intentionally limited to four fundamental, high-relevance vocational topics :

1. Introducing Yourself and Your Study Program
2. Describing Tools and Equipment in the Workshop
3. Giving and Responding to Simple Instructions (in a lab/workshop context)
4. Talking About Daily Study Schedule and Break Time

For each topic, students participated in the full NeuroTalk cycle: first, the in-class Structured Classroom Activities (SCA) to build declarative knowledge (e.g., learning vocabulary for tools, practicing instruction-giving structures), followed by the out-of-class Structured Real-life Engagement (SRE) to build procedural automaticity (e.g., going to the workshop to film a video describing

tools, guiding a partner through a set of instructions). The SRE activities were conducted in authentic campus locations to maximize contextual relevance and embodied cognition.

Data Collection and Analysis

A concurrent mixed-methods design was used to triangulate data and provide a holistic evaluation of the model's impact.

3.4.1. Quantitative Data Collection and Analysis

To measure the change in spoken fluency (Research Question 2), a pre-test/post-test design was used. Before the intervention (pre-test) and after its completion (post-test), each of the 24 students completed a standardized verbal task (related to the topics) which was recorded on video. This use of video recordings provided a permanent, objective corpus for analysis. The video-recorded performances were independently scored by two trained raters using a holistic fluency rubric. This rubric was adapted from CEFR A2-B1 descriptors and ACTFL guidelines, operationalizing "fluency" into measurable parameters. The key parameters measured were: (1) Utterance Length (mean length of run), (2) Pause Frequency (number of unnatural or filled pauses), and (3) Spontaneity (ability to produce speech without reliance on scripts or overt translation). The quantitative analysis was focused on practicality. A simple gain score (Post-test Score minus Pre-test Score) was calculated for each student and averaged across the cohort to determine the direction and magnitude of change.

Qualitative Data Collection and Analysis

To understand the *process* of learning and *student perceptions* (Research Question 3), qualitative data were collected throughout the 12-week intervention. Three methods were used for collection: (1) **Participatory Observation**, where the researcher and tutors maintained detailed field notes during both SCA and SRE sessions, documenting student responses, initiative, and affective states; (2) **Reflective Questionnaires (Angket)**, where at the end of the 12-week cycle, all participants (n=24) completed an anonymous questionnaire combining Likert-scale items and open-ended questions about their experience, the model's challenges, and their perceived learning; and (3) **In-depth Interviews (Wawancara Mendalam)**, where a representative sample of six students was selected for semi-structured, in-depth interviews to explore the questionnaire findings more deeply, focusing especially on their emotional and cognitive experience with the "communicative compulsion" strategy. For analysis, all qualitative data from field notes, open-ended questions, and interview transcripts were consolidated and analyzed using thematic analysis. The data were coded and recoded to identify dominant themes and patterns, which were then interpreted in relation to the model's theoretical framework (e.g., affective safety, motivation, authenticity).

RESULTS

The 7-stage R&D process yielded a validated pedagogical model and a rich dataset from its pilot implementation. The findings are presented in three parts: the results of the model validation, the quantitative impact on spoken fluency, and the qualitative themes from student perceptions.

Model Development and Validation

The initial R&D stages (1-3) culminated in the development of the draft NeuroTalk model, complete with its theoretical justification, SCA/SRE learning cycles, and the 4-topic curriculum. This package was submitted to a validation panel consisting of three experts: one in vocational pedagogy (technical-context), one in applied linguistics (SLA), and one in cognitive neuroscience (learning and memory).

The validation results were highly positive. The experts deemed the model to be theoretically innovative, well-grounded in current research , and highly relevant to the identified problem in vocational education. Feedback was constructive, leading to minor revisions primarily focused on clarifying the SRE task instructions. Specifically, instructions were refined to *explicitly* state the supportive and non-punitive nature of the assessment, ensuring the "compulsion" component remained "positive" and did not trigger debilitating anxiety (i.e., maintaining "aman secara afektif"). The revised model was unanimously approved as valid and feasible for implementation in the small-scale field test.

Quantitative Findings: Impact on Spoken Fluency

The primary objective of the NeuroTalk model was to produce a measurable improvement in spoken fluency. The pre-test and post-test video recordings (n=24) were scored by two independent raters, and the mean scores were analyzed. The pre-test results confirmed the baseline problem. Of the 24 participants, 21 (87.5%) scored within the A2 (Elementary) CEFR band for spoken production. They exhibited speech patterns characterized by short utterances, frequent pauses for grammatical and lexical retrieval, and high dependence on memorized phrases.

After the 12-week intervention, post-test scores showed a measurable and positive improvement across all key fluency metrics identified in the methodology. The gain-score analysis, comparing the mean scores of the cohort from the pre-test to the post-test, is presented in Table 1.

Table 1. Comparison of Pre-test and Post-test Spoken Fluency Metrics (n=24)

Fluency Metric (Parameter)	Pre-Test (Mean)	Post-Test (Mean)	Gain Score
Speech Rate (Words per Minute)	65.2	82.4	+17.2
Mean Length of Run (Words per Utterance)	4.1	7.3	+3.2
Pause Frequency (Filled Pauses per 100 words)	8.9	5.1	-3.8
Spontaneity & Cohesion (1-5 Rubric Score)	1.8	3.1	+1.3

The quantitative results indicate that the intervention was successful. The cohort, on average, spoke faster (a 26% increase in Speech Rate), produced significantly longer and more complex utterances before pausing (a 78% increase in Mean Length of Run), and paused less frequently (a 43% reduction in Pause Frequency).

Most critically, the largest relative gains were seen in *Mean Length of Run* and the holistic score for *Spontaneity*. This specific pattern is significant. It suggests that the learning was not merely an addition of new vocabulary (declarative knowledge), but a fundamental change in speech *production* (procedural skill). Students were better able to chain linguistic elements together automatically, supporting the hypothesis that the NeuroTalk model was effectively converting declarative knowledge (from SCA) into procedural automaticity (through SRE).

Qualitative Findings: Student Perceptions and Experience

The quantitative data shows *that* the model worked; the qualitative data from observations, 24 questionnaires, and 6 in-depth interviews explains *why* it worked. This analysis addresses the third research question regarding student perceptions, particularly of the "positive compulsion" strategy. Thematic analysis of the data revealed three dominant, interconnected themes.

Theme 1: "Affective Shock and Normalization"

Students overwhelmingly reported that the SRE component was, at first, nerve-wracking and embarrassing. The "compulsion" to speak English in a real, public-facing context (even just the campus workshop) induced significant initial anxiety.

However, this anxiety was mitigated and normalized by two factors. First, the "structured" nature of the compulsion—the fact that it was a formal, required, and *scaffolded* task—provided a clear path. Second, the *communal* nature of the task (i.e., "everyone had to do it") removed the social stigma of making mistakes. As one interviewed student explained:

> At first, I was very nervous to speak in the workshop. My friends were watching... I was afraid of saying the grammar wrong. But... because everyone had to do it, and the task was clear... after the first time, it just became normal. It was like a challenge, but a safe challenge, because the lecturer was supporting us.

This finding directly supports the model's design hypothesis of challenging yet affectively safe.

Theme 2: "Perceived Authenticity and Vocational Relevance"

Students drew a sharp, conscious contrast between SCA (classroom) and SRE (real-life). While SCA was respected as "necessary practice" and "learning the theory," SRE was consistently described using words like real, authentic, and useful. The *vocational context* of the tasks was identified as the single most powerful motivator. The curriculum's focus on their *own* field of engineering (e.g., "Describing Tools and Equipment in the Workshop") was critical. A second student stated:

> In high school, we learned English by talking about 'my holiday' or 'my hobby.' It was boring. Here, we had to 'Give Simple Instructions' for using lab equipment. This is real. I know I will need this for my job. So, I felt motivated to *really* learn it, not just for the test.

This theme suggests that the "positive" aspect of the "positive compulsion" was supplied by the *authenticity and relevance* of the tasks. The compulsion was accepted by students because it was perceived as purposeful and directly linked to their professional identity.

Theme 3: "From Confidence to Automaticity"

When asked to describe their learning, students rarely focused on grammar. Instead, they overwhelmingly identified their gains as (1) kepercayaan diri (confidence) and (2) spontanitas (spontaneity). They reported a palpable shift from "thinking in Indonesian and translating" to "just thinking in English."

One student summarized this cognitive shift:

> "Before, my brain was 'stuck.' I knew the grammar, but I was too slow. After doing the SRE vlogs... I just started talking. It became faster. I stopped worrying if it was 'is' or 'are' and just... *spoke*. I am more confident now to speak to anyone."

This perception directly aligns with the quantitative findings (Table 1). The perceived increase in "confidence" and "spontaneity" is the subjective, experiential correlate of the measured *decrease* in pause frequency and *increase* in utterance length. It suggests the model was highly successful in lowering the affective filter and, as designed, promoting the *automation* of neurolinguistic pathways.

DISCUSSION

The results of this R&D pilot study provide strong evidence for the feasibility and efficacy of the NeuroTalk model. The quantitative and qualitative findings are not only positive but are deeply interconnected, offering valuable insights into the cognitive and affective mechanisms that drive spoken fluency in a vocational context.

The Efficacy of NeuroTalk in Automating Fluency

The quantitative data (Table 1) unequivocally supports the study's primary hypothesis: an integrated SCA-SRE model, implemented over a 12-week period, can *measurably improve* the spoken fluency of vocational students. The gains were not trivial; a 78% increase in Mean Length of Run and a 43% reduction in Pause Frequency represent a significant shift in productive capacity.

This finding validates the model's core theoretical design, which was intended to bridge the declarative-procedural gap. The SCA component successfully provided the *declarative* linguistic knowledge (the "what"), while the SRE component functioned as the *proceduralization* engine (the "how"). The SRE tasks, by demanding spontaneous production in an authentic context, served as a powerful form of *retrieval practice*. As theorized by neuroscientists, it is this *act of retrieval*—not passive review—that strengthens synaptic connections and automates neural pathways. The NeuroTalk model provides a structured, pedagogical framework for inducing this neurocognitive process.

The Affective-Cognitive Mechanism: Validating "Positive Compulsion"

The study's most significant contribution is the validation of the "Positive Compulsion" strategy as the model's affective-cognitive catalyst. The qualitative findings explain *why* the proceduralization was so effective.

The "Affective Shock and Normalization" theme (Theme 1) confirms that the model successfully engineered the high-challenge, high-safety environment it sought. The "compulsion" (the SRE tasks) pushed students past their zone of comfort, forcing them to confront the *active production* of language, which they typically avoid. This challenge was rendered "positive" (i.e., affectively safe) by the supportive, structured, and communal nature of the tasks.

Furthermore, the "Perceived Authenticity" theme (Theme 2) reveals the *linchpin* of the entire model. The "communicative compulsion" strategy was accepted, and even embraced, by these engineering students *because* it was *vocationally relevant*. The model aligns with the findings of Immordino-Yang (2016) that emotion and cognition are deeply intertwined; students learn best when they are emotionally engaged. For this technical population, the "emotion" was not derived from games, but from *professional purpose*. The model would likely have failed if the "compulsion" had been applied to abstract, non-relevant topics. It was the synthesis of *context* (vocational), *affect* (positive compulsion), and *cognition* (SCA+SRE) that made the model function.

Bridging the Classroom-Industry Gap

This study was conceptualized as a solution to a practical problem: the gap between the A1/A2-level communication skills of polytechnic students and the B2/C1-level demands of the global industry. The NeuroTalk model proved to be a successful prototype for bridging this gap.

By rejecting a purely structural, grammar-based syllabus and instead adopting a functional, task-based approach (e.g., "Giving Instructions"), the model aligns pedagogy with the *competencies* required by industry. The SRE component functions as a "pedagogical internship," giving students a simulated-but-authentic experience of using English for real-world purposes. The qualitative finding that students felt more "confident" (Theme 3) is a critical outcome, as this self-efficacy is a key predictor of a graduate's willingness to use English in their future careers.

CONCLUSION

This article has presented the design, implementation, and pilot-phase evaluation of the NeuroTalk model, a novel pedagogical R&D product developed to address the persistent lack of spoken fluency among Indonesian vocational students.

Summary of Contribution

The study makes three primary contributions. First, it presents a *validated R&D product*—the NeuroTalk model—that is theoretically grounded in cognitive neuroscience and proven to be a feasible and effective innovation. Second, it provides *empirical evidence* that a 12-week intervention combining explicit instruction (SCA) and contextual practice (SRE) can *measurably automate* spoken

fluency, as demonstrated by quantitative gains in utterance length and spontaneity. Third, it *validates the novel affective strategy* of "positive compulsion" , demonstrating that a challenging-but-safe learning environment, when coupled with high vocational relevance, can effectively lower the affective filter and enhance motivation. The NeuroTalk model offers a viable, theory-driven, and practical prototype for solving the declarative-procedural gap in vocational English education.

Limitations and Future Research

As a single-cycle pilot study, this research has several explicit limitations that must be acknowledged.

1. Scale and Generalizability: The findings are based on a small, purposive sample (n=24) from a single program (D3 Energy Conversion Engineering) at one institution. The results, while internally valid, cannot be generalized to all vocational students in Indonesia without further testing.
2. Duration: The study was limited to a 12-week R&D cycle. While fluency gains were significant, this study did not measure the *long-term durability* of these gains post-intervention.
3. Scope: The intervention focused only on spoken fluency and did not measure impacts on other linguistic skills such as writing, listening, or grammatical accuracy, which were outside the research scope.

These limitations provide a clear roadmap for future research, as intended in the full R&D cycle. The immediate next steps should include (1) large-scale replication and implementation of the NeuroTalk model across other technical and non-technical programs (e.g., Civil Engineering, Business Administration) to test its adaptability; (2) a longitudinal study to track the fluency retention of the participant cohort at 6-month and 1-year intervals; and (3) further refinement of the SRE tasks to optimize the "positive compulsion" balance for different student populations.

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