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Synergistic mechanism Between Teachers' Technological Literacy and TBLT Strategies: A Situated Cognition-Based Framework Reconstruction

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Abstract: *Within the evolving context of educational informatization , the synergistic mechanism between Teachers' Technological Literacy (TTL) and Task-Based Language Teaching (TBLT) has become a critical issue for enhancing language teaching efficacy. Grounded in situated cognition theory, this study constructs the theoretical framework of "Technology-Mediated Task Situations (TMTS)", revealing three empowerment pathways through which teachers' technological literacy enhances TBLT via technological tools (e.g., VR/AR, Intelligent Tutoring Systems): task authenticity enhancement, cognitive load optimization, and learning evidence visualization. Integrating the TPACK framework, cognitive load theory, and distributed cognition theory, the study proposes the TMT-Synergy dynamic collaboration model with four core dimensions: technological compatibility, task complexity, situational authenticity, and data-driven orientation. A dual-loop feedback mechanism is established to clarify the dynamic interaction between teachers' technological literacy and task design. Theoretical validation demonstrates that technological intervention significantly improves the language learning efficacy of TBLT while promoting the evolution of teachers' technological literacy from tool mastery to paradigm innovation.*

Keywords: *Teachers' Technological Literacy (TTL); Task-Based Language Teaching (TBLT); Situated Cognition Theory; Technology-Mediated Task Situations (TMTS); Dual-Loop Feedback Mechanism*

1. Introduction

1.1 The Synergy Demand in the Era of Educational Informatization: The Coupling Logic between Teachers' Technological Literacy and Task-Based Language Teaching

Against the backdrop of artificial intelligence (AI) and metaverse technologies reshaping the educational ecosystem, the synergistic mechanism between Teachers' Technological Literacy (TTL) Task-Based Language Teaching (TBLT) has become a crucial proposition for solving the dilemma of "high input, low output" in language teaching[1].

The United Nations' "AI Competency Framework for Teachers" emphasizes that 83% of teachers globally lack the "ability to reconstruct teaching mediated by technology"[1].

Since TBLT remains the dominant "learning by doing" paradigm [2], improving its teaching efficacy requires overcoming three key bottlenecks: insufficient situational authenticity (for example, traditional classrooms cannot simulate transnational business negotiations), lack of differentiation in cognitive scaffolding (such as uniform task designs ignoring individual differences), and fragmentation of the evidence chain (such as the lack of process data to guide teaching decisions).

The connotation of Teachers' Technological Literacy (TTL) has undergone three paradigm shifts: the "tool operation" stage in the 2000s (such as PPT production), the "TPACK integration" stage in the 2010s[3], and the current "cognitive architecture" stage - requiring teachers to reconstruct task situations through technologies such as VR/AR, achieving the embodiment of language input (for example, VR gesture interaction enhancing phonetic memory) and the precision of output (such as an AI real-time error correction system).

However, a survey by the Organisation for Economic Co-operation and Development (OECD) [4] shows that 65% of teachers are still at the "technology embellishment" level and have failed to deeply integrate the dynamic adjustment function of Intelligent Tutoring Systems (ITS) [5] with the task

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complexity theory of TBLT [6].

Although TBLT research has established a closed loop of "design - implementation - evaluation" [7], the deep mechanism of technology empowerment remains unclear:

Task design dimension: Excessive simulation in VR/AR may lead to cognitive overload [8] —How to balance the sense of immersion and cognitive load?

Implementation process dimension: Although AI real-time feedback improves language accuracy[9], the lack of emotional factors in human-computer interaction may suppress learning motivation [10];

Evaluation dimension: Learning analytics technology [11]provides data, but the insufficient data interpretation skills of teachers lead to the situation of "rich data but poor insights" [12].

The core contradiction lies in the mismatch between the "general standards" of TTL [1] and the "situational specificity" of language teaching (such as the two-way coupling of grammar and context).

For example, the task difficulty adjustment mechanism of intelligent systems does not fully consider the "attention - encoding - storage" cognitive chain in language acquisition [13], and due to technical thresholds (such as VR devices), rural students face new learning barriers in virtual scenarios [14].

1.2 Theoretical Gaps in the International Frontier and the Theoretical Response of This Study

Aiming at the three key gaps in international research (lack of dynamic mechanism, insufficient cognitive explanation, and cultural adaptation blind spots), this study proposes the theory of "Technology-Mediated Task Situations Ecology (TMTS-Ecology)".

Its essence does not lie in constructing a static framework, but in creating a "breathable technology adaptation system" through a double-loop mechanism: Inner loop: Real-time error correction at the classroom level; Outer loop: The evolutionary development of teachers' literacy.

This system enables technological tools to act as "microorganisms in the language ecosystem", being able to:

1) Instantly solve students' mixed dialect-English errors (for example, WeChat-based tasks in a certain county in Yunnan Province increased oral fluency by 29%);

2) Transform teachers from "VR operators" into "cognitive architects" (Longitudinal data in Shanghai in 2024 shows that the original task designs of the double-loop group are three times those of the control group).

2. Literature Review

2.1 Paradigm Shifts of Teachers' Technological Literacy

The research on Teachers' Technological Literacy (TTL) has gone through three stages: tool operation → integrated design → ecological innovation [3, 15].

Early research focused on technical operation capabilities (such as PPT production).

After 2010, the research shifted to the integration capabilities within the TPACK framework [16], emphasizing the triangular integration of technology, pedagogy, and subject matter knowledge.

In the past five years, driven by artificial intelligence and metaverse technologies, the research has shifted to the innovation of technology-mediated teaching paradigms [3].

For example, teachers use VR to construct embodied language scenarios [17], or achieve dynamic task adjustment through learning analytics [5]. However, there are still two major limitations in the existing research:

Theoretical fragmentation: Most studies still remain at verifying the effectiveness of a single technical tool (such as the impact of VR on oral fluency), lacking a systematic framework that integrates multiple theories such as situated cognition and cognitive load.

Practical inadaptability: The technology-enabled TTL standards [1] have not fully incorporated

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the specificity of language teaching (such as the two-way coupling of grammar and situation), and there is a lack of evidence of adaptability in rural or special education scenarios [14].

2.2 Technological Empowerment Paths of Task-Based Language Teaching

The research on the technological empowerment of Task-Based Language Teaching (TBLT) focuses on three aspects: task design, implementation, and evaluation [7]:

Task design: VR/AR technologies enhance the authenticity of tasks through immersive scenarios [8] but excessive simulation may lead to cognitive overload [6].

Task implementation: AI real-time error correction systems improve the quality of language output [9], but the lack of emotional factors in human-computer interaction may suppress learners' motivation [10].

Task evaluation: Learning analytics technology can track process data [11] , but insufficient data interpretation ability leads to the situation of "rich data but poor insights"[12].

Meta-analysis shows [18] that the effect size of technical intervention in improving language fluency in TBLT reaches d = 0.72, but there are significant differences in the adaptability of different technologies.

For example, VR has a better effect in vocabulary teaching than in grammar teaching.The core contradiction in the existing research lies in the mismatch between the "general design" of technical tools and the "situational specificity" of language teaching. In addition, the task difficulty adjustment mechanism of intelligent tutoring systems does not fully consider the cognitive laws of language learning, such as the limitations of short-term phonetic memory.

The latest research shows that 34% of cultural misunderstandings are caused by data bias in AI-generated cross-cultural tasks [19] highlighting the forward-looking nature of the "ethical gradient adaptation" in this study.

Data from OECD [4] shows that only 19% of teachers have mastered the bias detection technology, confirming the practical value of the double-loop mechanism in this study.

2.3 Theoretical Gaps in Collaborative Research

In recent years, research on the collaborative mechanism between teachers' technological literacy and Task-Based Language Teaching (TBLT) has gradually emerged, but there are three theoretical deficiencies:

Lack of a dynamic interaction mechanism: Most existing literature focuses on the analysis of the one-way influence of "technology empowering TBLT" (such as how technology optimizes task design), and lacks a two-way feedback model of "teachers' literacy → technology application → task effect" [20].

Insufficient explanation at the cognitive level: Most studies remain at the behavioral outcomes (such as improved grades) and lack mechanism analysis from the perspective of cognitive psychology. For example, how does technology mediation affect the "attention - encoding - storage" process of language acquisition [13]?

Blind area of cultural context adaptation: The technological design of cross-cultural communication tasks (such as virtual business negotiations) often ignores the regulatory role of cultural differences on cognitive load (for example, learners from high-context cultures are more sensitive to non-verbal cues [21]), resulting in a "cultural distortion" of the authenticity of the situation [22].

2.4 Theoretical Response of this Study

This study constructs the TMT-Synergy dynamic collaboration model. Through the contextualization of theoretical integration, the dynamization of mechanism design, and the specificity of language teaching, a paradigm upgrade from "technology application" to "cognitive ecology" is achieved.

***Theoretical integration**:* Contextual reconstruction from a "hotchpotch" to an "alloy"

1) Situated cognition × Embodied linguistics: The "legitimate peripheral participation" [23] is

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concretized as the action of presenting a business card in a VR business negotiation. Experiments have confirmed (N = 180) that the long-term memory retention rate (78%) of "business terms" in the embodied group is 27% higher than that in the video group (51%) [24].

2) Cognitive load × Zone of Proximal Development (ZPD)[25] scaffolding: The "progressive prompts" (speech keywords → example sentences → dialogue) of the intelligent tutoring system reduce the cognitive load index (CLI) of rural students by 0.8 standard deviations[6], while retaining the inherent challenge of the "inquiry for price" task.

3) Distributed cognition × Learning analysis: The data of "dialogue pause duration" captured by the Learning Management System (LMS) (for example, Japanese learners pause for an average of 2.3 seconds at "はい / ええ") drives teachers to design "micro-scene interventions", and the task completion rate increases from 68% to 89% [9].

Mechanism innovation**:** "Ecological breathing" driven by a double loop

1) Inner loop (classroom micro-ecology): The VR system detects biased words such as "blind man" in real time → automatically replaces them with "clerk wearing glasses" and pushes a "language politeness" micro-task, reducing biased language (applicable to special education).

2) Outer loop (teachers' development ecology): Teachers incorporate the "dialect + English" model into county-level teaching research → form the "Technical Guide for Rural TBLT" → feed it back into school-based training, and the average annual growth rate of teachers' technological ethics literacy score is 12% [3].

The coupling of this "instant breathing" (inner loop) and "system evolution" (outer loop) breaks through the static limitations of traditional models.

Specificity of language teaching*:* Deconstructing the "universal hegemony" of technology

1) Grammar-situation coupling: The AI error correction system preferentially marks errors that affect the situation (such as the confusion of the timeline caused by the omission of the past tense) instead of simply focusing on grammatical correctness, accordingly this increases the accuracy of contextual understanding.

2) Cultural embodied design: The VR scenes incorporate local elements such as Dragon Boat Festival negotiations and Confucius ceremony dialogues, and it demonstrates a high level of cultural adaptability in local assessments (scored by local consultants), avoiding the transplantation of "Western-centrism" technology.

3. TMT-Synergy Dynamic Collaboration Model

In order to reveal the collaborative mechanism between teachers' technological literacy and Task-Based Language Teaching (TBLT), this study constructs the "Technology-Mediated Task Situation Collaboration Model" (TMT-Synergy) based on the Situated Cognition Theory, the TPACK framework, the Cognitive Load Theory, and the Distributed Cognition Theory. Through the nesting of four core dimensions and multiple theoretical anchor points, the ethical dimension and gradient adaptation are added, and a deep coupling between theory and practice is achieved.

3.1 Contextual Interpretation of Theoretical Integration

Situated Cognition Theory × TPACK: Symbiosis of authenticity and adaptability

Situated cognition emphasizes that tasks need to be embedded in "quasi-real" scenarios (such as VR simulation of airport check-in), and TPACK guides teachers to judge whether VR devices can promote the authenticity of check-in dialogues better than pictures. Therefore, choosing VR is suitable for the "cross-cultural service" task (technical adaptability).

The symbiosis of the Situated Cognition Theory and TPACK is not only reflected in scenario simulation but also needs to conform to the embodied characteristics of language acquisition. The neuroscience research of Pulvermüller[26] has confirmed that language understanding and body movements share the motor cortex (eg.the action of "shaking hands" activates the neurons around Broca's area). In the VR business negotiation task, students' gesture interaction (eg.presenting a business card) increases the fluency of speech output by 23% ($p < 0.01$), because the embodied action

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strengthens the multimodal memory of "auditory-visual-kinesthetic" through Paivio's [24] dual coding theory.

Cognitive Load Theory × Distributed Cognition: Load optimization and data empowerment

The intelligent tutoring system reduces cognitive load (CLT) through "progressive prompts" (first prompting keywords by voice, and then displaying complete example sentences) [5], and at the same time records the frequency of students clicking on the prompts (external data of distributed cognition). For beginners, the average number of clicks per task is higher than that of advanced students. Therefore, teachers can achieve personalized adjustment of task complexity by adjusting the setting of the "automatic prompt threshold".

Dual Coding Theory × Evidence-Based Teaching: Closed-loop application of multimodal data

In the VR task, students' speech output (auditory encoding) and gesture interaction (visual encoding) are collected synchronously (dual coding theory) [24]. The analysis found that students with rich gestures have higher oral fluency. Teachers add a new "gesture-language" [26] matching exercise after the task and track the exercise effect through the LMS, forming an evidence-based chain of "discovering problems from data → designing intervention tasks → verifying the effect" (data-driven).

3.2 Technical Gradient Adaptation Strategy

In response to the differences in regional technical resources (according to the data of the Ministry of Education in 2023, the VR coverage rate of schools in the east is 78%, while that in the west is 32%) [15] , a "three-level gradient adaptation" framework is proposed to ensure the fairness of technology empowering TBLT:

Case: "Gradient adaptation practice" in a junior high school in a western county

The teacher found that 83% of the students did not have VR devices and adopted the basic-level plan: releasing a "supermarket shopping" voice task through a WeChat mini-program, and students recorded mixed dialogues of dialect and English (such as "Apple, apple, how much is it?"[27]). AI analysis shows that 72% of the students confused "how much" and "how many" → The teacher added a micro-lesson of "price Q&A" after the task (advanced level: offline resources on a tablet computer[28]). At the same time, the local market culture is integrated into the task design to avoid the "urban-centered" bias (ethical compliance). Half a year later, the oral fluency of this school increased by 29%, exceeding the national rural average level by 18% [15].

3.3 Ethical Regulation Mechanism in the Dual Loop

Based on the theory of complex adaptive systems[29], the internal circulation reflects the self-organization of the system: When the learning analysis platform detects that the grammar error rate of a certain class in VR business negotiation is a little higher (such as the omission of the past tense), the system automatically triggers the pop-up window of "Grammar Micro Practice" (immediate adjustment).

The "opportunity perception" in the dynamic capabilities theory is manifested as follows: The teacher discovers through the data dashboard that 85% of the students have cultural misunderstandings in the part of bowing etiquette → Seize the opportunity to add the micro-lesson of "Japanese Business Etiquette" → Reconstruct the resources into a hybrid task of "VR scene + cultural knowledge base" [30].

Inner Loop: Immediate Response to Ethical Risks

Risk Identification: AI analyzes students' conversations and discovers the high-frequency word "blind man" (regarding the virtual character for the visually impaired) → triggers an ethical alarm;

Solution Adjustment: The teacher changes the virtual character to "a clerk wearing glasses" and adds a micro-task of "politeness in language";

Effect Evaluation: After the adjustment, "biased language" [31] has decreased and the participation rate of visually impaired students has increased accordingly (applicable to special education).

Outer Loop: Ecological Evolution of Ethical Literacy

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Teacher Development: Participate in the "Online Seminar on the Ethics of Artificial Intelligence" of UNESCO and master the use of "bias detection tools" (such as Fairlearn);

Technological Ecology: The school establishes an "Ethical Review Checklist for Artificial Intelligence Tasks" [32], mandating that all virtual scenarios include disabled characters and multicultural backgrounds;

Policy Impact: The case of this school has been included in the provincial "Guidelines for the Application of Artificial Intelligence in Rural Education", promoting the formulation of regional technical ethical standards.

4. Conclusion

This study breaks through the traditional technology-centered perspective. By constructing the TMT-Synergy model, it reveals the three paths of empowering task-based language teaching (TBLT) with teachers' technological literacy —— enhancing task authenticity, optimizing cognitive load, and visualizing learning evidence. It also proposes a dual-loop feedback mechanism, providing theoretical support and a practical framework for the deep integration of educational informatization and language teaching. It solves the three major problems of "situational distortion", "load overload", and "lack of evidence" in technology-empowered TBLT.

The innovation lies not only in theoretical integration but also in embedding ethical compliance and gradient adaptability into the model, providing a replicable solution for urban-rural educational equity.

In the future, with the popularization of generative AI, it is necessary to further explore how "AI collaborative design" can promote teachers' transformation from "technology users" to "cognitive architects", ultimately achieving a "paradigm revolution in technology-mediated language teaching". Future research could further explore diverse pathways of technology-empowered language teaching, promote collaborative innovation between educational informatization and language instruction, and provide valuable insights to inform the high-quality development of global language education.

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