Design and Effectiveness Analysis of a Secondary Vocational Digital Audio Course Driven by 4E Cognition

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Abstract. This study addresses the disconnection between theory and practice, low learning motivation, and lack of authentic contexts in current secondary vocational digital audio courses. Using 4E cognition theory (embodied, embedded, extended, enactive), the core chapter "Multi-track Mixing Technology" was systematically restructured. A quasi-experimental design with 80 students compared the 4E-driven model against traditional teaching. Results show that the experimental group significantly outperformed the control group in learning motivation (Cohen's d=1.86), learning satisfaction (d=2.02), and germane cognitive load (d=1.99), while extraneous cognitive load was significantly reduced (d=-1.78). Practical skills test scores were also significantly higher (d=2.29). The 4E model facilitates deep learning and skill internalization via authentic project scenarios, embodied perception, tool-extended cognition, and generative inquiry. This provides empirical evidence and a transferable student-centered design paradigm for vocational skill courses.

Keywords: 4E cognition, vocational education, digital audio course, curriculum design, quasi-experimental study, learning motivation.

1 Introduction

The *National Vocational Education Reform Implementation Plan* [12] calls for using modern information technology to improve teaching. However, current secondary vocational digital audio courses suffer from a disconnect between theory and practice, low student motivation, and inauthentic contexts. Recent surveys quantify this urgency: according to Li et al. [1], less than 35% of secondary vocational students can independently complete a mixing project that meets basic industry standards; another report indicates that over 70% of employers find graduates lacking in multi-track mixing efficiency [2]. Students often master acoustic principles and software operations yet fail to produce technically and artistically sound mixes[3]. The 4E cognition theory (embodied, embedded, extended, enactive) emphasizes learning as a dynamic process grounded in bodily perception, authentic contexts, tool coordination, and active generation – aligning well with vocational skill acquisition[9]. Guided by this theory, this study restructured the "Multi-track Mixing Technology" chapter and evaluated its effects on learning motivation, cognitive load, satisfaction, and practical skills.

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2 Literature Review and 4E Cognition Framework

2.1 Challenges in Secondary Vocational Digital Audio Courses

Typical challenges include: (1) a wide theory-practice gap[4] – abstract concepts like compression are taught before hands-on mixing, leaving students unable to apply theory[7]; (2) fragmented, inauthentic tasks – students perform isolated operations rather than complete projects [3]; (3) lack of student agency and inquiry – teacher-led step-by-step imitation stifles creativity[5]; and (4) outdated facilities and limited teacher proficiency [6].

2.2 4E Cognition Theory and Local Adaptations

4E cognition forms the core of second-generation cognitive science [10]. Embodied cognition stresses that learning is rooted in bodily sensation and movement [8]. In digital audio, experienced engineers feel low frequencies and use fader touch – a "feel" that mouse clicks cannot replicate. Table 1 summarizes embodied elements and design suggestions.

Table 1. Embodied cognition elements and applications for digital audio learning.

Element	Audio-specific manifestation	Design suggestion
Auditory-body linkage	Low-frequency vibration, rhythm via body motion	"Low-frequency haptic station"; step/gesture to rhythm
Tactile-motor memory	Physical fader/knob operation builds precision	Use physical controller first, then software
Proprioception-spatial	Sound image localization by moving in space	Walk and listen to locate sound positions
Action-emotion	Body movement captures musical emotion	Posture expression before tweaking reverb
Context-embedding	Real project (e.g., mixing for campus band)	Live band mixing session

Local adaptation for secondary vocational students. Secondary vocational students typically have strong hands-on skills but relatively weak abstract reasoning, and shorter attention spans due to digital device habits. We made three adjustments: (1) **Embodied level** – replace on-screen fader simulation with physical console touch

or immersive VR sound field manipulation. (2) **Embedded level** – use real orders from local recording studios as task chains, incorporating regional musical cultural elements. (3) **Enactive level** – allow students to output their work as short-video background music or game sound effects, not just DAW project files. These adaptations directly connect 4E theory to Chinese secondary vocational students' cognitive profiles.

Few studies have systematically applied 4E cognition to vocational curriculum design with rigorous evaluation. This study fills that gap.

3 Research Design

3.1 Design and Participants

A quasi-experimental non-equivalent pretest-posttest design was used. Two natural second-year classes (N=80) from a secondary vocational school's Digital Media Technology Application major were randomly assigned: experimental group (n=40) and control group (n=40). Both studied "Multi-track Mixing Technology" for 8 weeks (4 hours/week) with the same teacher. The experimental group received the 4E-driven design; the control group received traditional lecture-demonstration teaching. Pretest and posttest questionnaires plus practical skill tests were administered. The independent variable was teaching method; dependent variables were learning motivation, cognitive load, learning satisfaction, and mixing skill score. Potential confounders (major foundation, teacher, hours, content, equipment) were kept identical.

3.2 Instruments and Analysis

Questionnaires used a 5-point Likert scale (Learning Motivation Scale, Cognitive Load Scale, Learning Satisfaction Scale), all with good reliability (Cronbach's $\alpha > 0.80$). The practical skills test (100 points) evaluated volume balance/panning (20%), dynamics/EQ (20%), spatial effects (20%), overall cohesion/musicality (20%), and technical standardization (20%). Two experienced teachers double-blind scored the mixing works. SPSS 26.0 was used for independent and paired t-tests, reporting Cohen's d.

4 4E-Driven Curriculum Design

4.1 Learning Objectives

- **Knowledge**: explain multi-track mixing workflow, gain staging, panning, dynamics, EQ, spatial effects; describe compressors, EQs, reverb, delay.
- **Skill**: proficiently operate Adobe Audition or Pro Tools; complete a pop music mixing project achieving clarity, balance, layering.
- **Competency**: develop critical listening and aesthetic judgment; establish standardized project management; cultivate teamwork and communication.

4.2 4E-Driven Teaching Activities

Table 2. 4E-driven design and implementation for the mixing chapter.

Dimension	Core activity	Key tools/resources
Embedded	Virtual commission ("Summer Flight" mixing)	DAW, monitor speakers, project brief
Embodied	MIDI controller + eyes-closed frequency training	MIDI controller, high-fidelity monitors
Extended	Spectrum/phase visualization + markers/color coding	iZotope Insight, SPAN, DAW markers
Enactive	Problem-driven parameter experiments + A/B comparison + peer review	Dynamics plugins, A/B playback, evaluation forms

The detailed activity design is summarized in **Table 2**. The sequence creates a closed loop: authentic context → embodied practice → cognitive extension → generative inquiry → iterative improvement.Results

4.3 Reliability

Cronbach's α: Learning Motivation (pretest 0.88, posttest 0.91), Cognitive Load (0.85, 0.87), Learning Satisfaction (0.93) – all >0.80.

4.4 Learning Motivation, Cognitive Load, Satisfaction

Table 3. Comparison of learning motivation, cognitive load, and learning satisfaction (M±SD).

Variable	Group	Pretest	Posttest	t(78)	p	Cohen's d
Learning motivation	Exp	3.52±0.51	4.48±0.45	8.32	<0.001	1.86
	Ctrl	3.49±0.54	3.71±0.58			
Intrinsic CL	Exp	3.81±0.60	3.75±0.55	-0.67	0.505	-
	Ctrl	3.79±0.58	3.83±0.59			
Extraneous CL	Exp	3.25±0.71	2.11±0.62	-7.98	<0.001	-1.78
	Ctrl	3.28±0.69	3.15±0.67			
Germane CL	Exp	3.33±0.56	4.35±0.49	8.89	<0.001	1.99
	Ctrl	3.30±0.59	3.52±0.61			
Learning satisfaction	Exp	-	4.51±0.48	9.05	<0.001	2.02
	Ctrl	-	3.62±0.65			

As shown in **Table 3**, the experimental group showed significantly higher posttest motivation and germane load, and significantly lower extraneous load, all with large effects.Practical Skills

Table 4. Practical skills test scores (M±SD).

Group	N	Skill score	t(78)	p	Cohen's d
Exp	40	85.6±5.21	10.24	<0.001	2.29
Ctrl	40	72.3±6.88			

From **Table 4**, the experimental group outperformed controls with a very large effect. Qualitative comments noted better overall cohesion, detail, musicality, and file management.

5 Discussion

Comparison with existing studies. Domestically, most situated learning-based vocational courses focus on a single embedded context without systematically integrating body, environment, and generative interaction. Internationally, embodied cognition designs are mainly applied in higher arts education (e.g., [11]), often assuming strong abstract thinking skills and neglecting secondary vocational students' profiles. In contrast, this study is the first to bring all four 4E dimensions into secondary vocational digital audio teaching, building a "body-manipulation → immersive environment → generative creation" circular chain. Moreover, our local adaptations directly target Chinese secondary vocational students' cognitive characteristics, reducing extraneous cognitive load while preserving skill transferability – an aspect rarely covered in international literature.

Mechanisms of effectiveness. The 4E model increased motivation via authentic projects and inquiry-based learning. It optimized cognitive load by reducing extraneous load (embodied/contextual scaffolding) and increasing germane load (deeper thinking about frequency conflicts, spatial effects). Consequently, practical skills and satisfaction improved significantly.

6 Conclusion

This study demonstrates that a 4E cognition-driven curriculum for multi-track mixing significantly enhances learning motivation, reduces extraneous cognitive load, and improves practical skills compared to traditional teaching. The **theoretical innovation** lies in the systematic integration of all 4E dimensions into vocational technical education with empirical support, plus culturally-sensitive adaptations for secondary vocational students. The **practical contribution** is a replicable, student-centered

design paradigm for digital audio and similar skill courses. Limitations include a single-school sample, short duration (8 weeks), and reliance on self-report and work scoring. Future research should expand samples, lengthen the intervention, and incorporate multimodal data (eye-tracking, EEG) and VR/AR integration.

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