

Metacognitive Calibration Deficits and Formative Assessment Uptake in Secondary-Level STEM Classrooms: An Empirical Analysis Across Socioeconomically Stratified Schools in Urban South Korea

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Abstract. This study empirically examines the relationship between metacognitive calibration accuracy and the effective uptake of formative assessment feedback among secondary-level STEM learners in socioeconomically stratified urban schools in South Korea. Employing a mixed-methods design across 14 schools ($n = 1,247$ students, Grades 9–11), the research integrates the Metacognitive Awareness Inventory (MAI), classroom observation protocols, and multilevel regression modelling to identify calibration deficit patterns that systematically undermine feedback integration. Findings indicate that learners exhibiting overconfidence-based miscalibration demonstrate significantly lower formative feedback uptake ($\beta = -0.41$, $p < .001$), an effect amplified in low-SES school cohorts. Teacher assessment literacy emerged as a robust moderating variable. The study concludes with actionable pedagogical recommendations for calibration-targeted instructional scaffolding within differentiated STEM curricula.

Keywords: metacognitive calibration, formative assessment feedback uptake, STEM secondary education, assessment literacy, socioeconomic stratification, multilevel regression modelling, instructional scaffolding, overconfidence bias in learning, mixed-methods educational research

Introduction

The intersection of metacognition and formative assessment represents one of the most consequential frontiers in contemporary educational research. As competency-based curricula and data-driven instructional models expand across secondary education systems globally, the capacity of students to accurately self-appraise their knowledge states—a process formally termed metacognitive calibration—has emerged as a decisive determinant of academic achievement trajectories. Miscalibration, defined as the systematic divergence between a learner's confidence in their performance and their actual performance outcome, constitutes a particularly insidious barrier to formative assessment effectiveness, as it prevents learners from meaningfully interpreting, internalising, and acting upon diagnostic feedback provided by educators. The urgency of this problem has intensified in the post-pandemic educational landscape of 2024–2026, wherein disrupted schooling continuity has produced heterogeneous cohorts with compounded metacognitive deficits, particularly in STEM subjects where conceptual prerequisite chains are especially sensitive to gaps in self-regulated learning. South Korea, despite its internationally recognised scholastic performance metrics, presents a paradoxical context: structurally high academic achievement coexists with documented affective and metacognitive rigidities, including performative compliance with feedback rituals that mask genuine cognitive integration failures. Socioeconomic stratification further complicates this landscape, as resource-disparate schools differ markedly in the assessment cultures and teacher professional development infrastructures that support calibration-aware pedagogy. Existing literature has established robust links between metacognitive awareness and academic self-regulation (Hattie & Timperley, 2007; Pintrich, 2002; Zimmerman, 2013), and separate bodies of work have addressed the efficacy of formative assessment feedback under varied classroom conditions (Black & Wiliam, 1998; Shute, 2008). However, the specific mechanistic pathway through which calibration deficits constrain the uptake—rather than the mere receipt—of formative feedback remains insufficiently theorised and empirically underdeveloped, particularly within stratified real-world school settings as opposed to controlled laboratory paradigms. Furthermore, the moderating role of teacher assessment literacy in buffering or exacerbating these calibration-uptake dynamics has not been systematically examined in the East Asian secondary schooling context. This paper addresses these lacunae through a rigorously designed mixed-methods empirical study conducted across 14 secondary schools in metropolitan Seoul and Incheon, South Korea, spanning the 2023–2024 academic year. The investigation proceeds as follows: Section 2 provides a critical synthesis of the theoretical frameworks underpinning metacognitive calibration and formative feedback uptake. Section 3 details the methodological architecture, including sampling strategy, instrumentation, and analytic procedures. Section 4 presents quantitative findings from multilevel regression modelling alongside qualitative thematic analyses of classroom observation data. Section 5 discusses the implications of these findings for instructional design, teacher professional development, and education policy within stratified schooling systems. Section 6 concludes with limitations and directions for future cross-national replication studies.

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