

A Survey Study on the Current State of Quantity Sense Instruction in Primary School Mathematics from an Embodied Cognition Perspective

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Abstract: This study employs questionnaire surveys to conduct empirical research on the current state of quantitative sense teaching in primary mathematics, grounded in embodied cognition theory. Statistical analysis of collected questionnaire data reveals: pupils demonstrate a strong demand for embodied learning, expressing a desire to construct quantitative sense through multisensory engagement and practical operations; however, teaching provision exhibits significant shortcomings, while teachers acknowledge the value of embodied teaching in theory, a structural disconnect exists in its practical implementation, manifesting as formulaic scenario creation and superficial hands-on activities; instructional design suffers from insufficient cognitive engagement, with the absence of operational experience severely limiting spatial sense development; evaluation systems exhibit pronounced uniformity, over-relying on paper-and-pencil tests that fail to support embodied teaching development. Addressing these issues, this study proposes a systematic improvement pathway: constructing a learning environment centred on bodily experience, establishing an operational closed loop of "experience-estimation-measurement-reflection"; building a bridge between theory and practice by providing a transferable repository of embodied teaching activity paradigms; deepening the cognitive quality of activity design through problem chain design to achieve deep integration of operation and thought; constructing a multi-dimensional developmental assessment system incorporating estimation ability and operational processes as core evaluation dimensions. This research provides empirical evidence and practical guidance for advancing quantitative sense teaching reform in primary mathematics, offering significant implications for implementing subject-specific core competencies.

Keywords: Embodied cognition theory, primary mathematics, sense of quantity, teaching practices.

1. Introduction

The 2022 Edition of the Compulsory Education Mathematics Curriculum Standards first designated "quantitative sense" as a core competency in primary mathematics, emphasising its foundational role in cultivating students' abstract thinking and mathematical application awareness [1]. However, traditional quantitative sense instruction in primary mathematics has to some extent fallen into the predicament of "overemphasising unit memorisation while neglecting perceptual construction, and prioritising computational drills over practical application," hindering students' development of profound and accurate measurement concepts [2]. Embodied cognition theory, with its core tenets that "cognition originates from the body, is rooted in the environment, and serves action," offers a novel theoretical perspective to overcome this pedagogical bottleneck [3]. It suggests that the formation of quantitative sense does not stem from abstract symbol indoctrination but relies on the subject's bodily experiences and sensory operations within authentic activities. Although this concept has garnered significant attention, the current state of quantity sense instruction in primary mathematics classrooms within the embodied cognition framework—its manifestations, achievements, and practical challenges—remains under-researched and requires in-depth empirical investigation. This study therefore aims to systematically examine the status of quantity sense teaching in primary mathematics through methods such as questionnaire surveys, thereby providing empirical evidence and practical guidance for optimising teaching practices and effectively cultivating students' quantity sense.

2. Research Design

2.1. Research Participants

This investigation employed a questionnaire approach. Given that younger primary pupils may struggle to fully comprehend questionnaire content, upper primary pupils were selected as the representative sample for this study.

The questionnaire was administered to upper primary pupils at J Primary School in J City, where the author undertook teaching practice. One class was randomly selected from each of Years 3, 4, 5, and 6 (totalling four classes) to ensure consistency in the pupils' background characteristics. To guarantee data validity, questionnaires were distributed by class and completed under the supervision of each class's mathematics teacher. A total of 208 questionnaires were distributed and 208 were returned, with 203 valid responses yielding an effective return rate of 97.6%. Basic information statistics for the survey subjects are as follows:

Table 1. Statistical Summary of Survey Participants

Name	Option	Frequency	Percentage (%)
Gender	Male	104	51.2
	Female	99	48.8
Year group	Year 3	53	26.1
	Year 4	51	25.1
	Year 5	48	23.6
	Year 6	51	25.1
Achievement	Excellent	23	11.3
	Good	80	39.4
	Average	72	35.5
	Poor	28	13.8
Total		203	100

2.2. Questionnaire Design and Implementation

The student questionnaire for this study was developed based on the embodied cognition theory and systems theory mentioned earlier, incorporating requirements from the New Curriculum Standards. It draws upon the questionnaire design dimensions for core concepts proposed by Xu Meng, Cui Jiwen, and Li Jinlian [4], as well as elements from Li Chen's work [5]. This composite questionnaire comprises 22 single-choice questions and 3 multiple-choice questions. Among the single-choice questions, 20 employ a five-point Likert scale, with response options rated as "Strongly Agree", "Agree", "Neutral", "Disagree", and "Strongly Disagree", scored sequentially from 1 to 5. The questionnaire is structured across five dimensions: Interest and Attitude, Teaching Methods, Learning Activities, Learning Approaches, and Evaluation and Reflection. The specific categorisation is detailed in Table 2 below:

Table 2. Distribution of Content Dimensions

Questionnaire Dimensions	Corresponding Question Number	Sample Size
Interest and Attitude	1-5	203
Teaching Methods	6-10	203
Learning Activities	11-15	203
Learning Methods	16-19	203
Assessment and Reflection	20-25	203

This study primarily employed Cronbach's Alpha (α) coefficient as the reliability assessment method. The questionnaire's α coefficient was 0.821, indicating high reliability and effectively ensuring the validity of statistical results. The most commonly employed KMO test and Bartlett's sphericity test were utilised in this study. Valid scale data from the questionnaire were sequentially input into IBM SPSS 26.0, yielding a KMO value of 0.818 (exceeding 0.7) and a Bartlett's Sig value <0.05 . This indicates the questionnaire exhibits sound design-level correlation. Conducting confirmatory factor analysis on the questionnaire yielded eigenvalues exceeding 1 for the top five factors, aligning with the five hypothesised dimensions. After extracting these five factors and performing rotation, the cumulative variance explained reached 80.680%, indicating the questionnaire possesses relatively complete construct validity.

2.3. Survey Findings

(I) Interest and Attitude

Data indicates that the vast majority of students exhibit strong interest in mathematics lessons centred on the "measurement" theme, with 78.8% selecting positive responses of "somewhat agree" or "strongly agree". Notably, the proportion selecting "strongly agree" significantly exceeds those choosing "somewhat agree", suggesting students' preference is not merely a reluctant attitude but rather a clear and strong inclination, laying a solid affective foundation for subsequent learning. Furthermore, students' confidence levels are notably high, with 83.8% expressing strong confidence in mastering measurement concepts. However, 16.2% still lack sufficient confidence, and teachers should enhance this group's assurance through positive feedback and encouragement. Regarding the statement "Solving real-life problems related to measurement (e.g., weighing items while shopping, calculating room dimensions) is very useful," 74.9% of students selected the positive options "somewhat agree" and "strongly agree." This indicates that the vast majority of students recognise the practical utility of measurement knowledge in daily life, which serves as one of the intrinsic motivations driving their learning. Regarding the statement "Would you proactively explore and reflect on measurement-related problems encountered in daily life?", 73.9% of students selected the affirmative options "Somewhat agree" or "Strongly agree". This indicates that the vast majority recognise the practical value of measurement knowledge in everyday life, serving as an intrinsic motivator for learning as they perceive the knowledge's utility. This indicates that students not only passively absorb knowledge but also develop a tendency towards active application. The 'fully agree' rate for this question was the lowest among the four, while the 'somewhat agree' option had the highest proportion. This suggests a diminishing return from 'interest' and 'confidence' towards 'active application', representing an area for pedagogical improvement.

To gain deeper insight into the preferred formats for mathematics course delivery, the author included a multiple-choice question in the survey. Multiple response analysis was conducted using SPSS 26 software, with specific case percentages summarised in Table 3 below:

The results are presented in Table 3 below:

Table 3. Statistical Summary of Preferred Mathematics Lesson Formats (Multiple-Choice Question)

Question	Option	Number of Cases	Percentage	Percentage of Cases
5. In what forms do you prefer mathematics lessons related to 'measurement' to be conducted?	A. Presented through engaging, real-life scenarios	146	31.4%	71.9%
	B. Games or challenge tasks	107	23.0%	52.7%
	C. Lessons feature numerous hands-on activities and experiential opportunities	129	27.7%	63.5%
	D. Teacher-led instruction predominates	30	6.5%	14.8%
	E. Group collaboration and discussion-based	53	11.4%	26.1%
Total		465	100.0%	229.1%

The survey findings reveal that 71.9% of pupils explicitly expressed a preference for engaging, real-life scenarios. This perfectly explains why 74.9% of pupils in Question 3 deemed measurement knowledge "useful". Integrating knowledge closely with everyday contexts remains the most effective approach to sparking pupils' interest and fostering a sense of relevance. Furthermore, 63.5% of pupils enjoy lessons

offering ample hands-on activities and experiential opportunities, aligning strongly with the inherent characteristics of the measurement subject. Over half of the students favour lessons incorporating games or challenges. This format enhances learning enjoyment, competitiveness, and immersion, proving a powerful driver for active student participation and engagement. Approximately a quarter of

students prefer group collaboration. Though not the largest proportion, this remains a significant teaching approach. It helps cultivate students' communication and teamwork skills and proves highly effective when undertaking complex measurement tasks, such as measuring playground areas. Less than 15% of pupils selected teacher-led lectures as their preferred method. This sends a clear signal: traditional, teacher-centred 'lecture-style' lessons hold little appeal for most pupils when teaching measurement. Pupils yearn to be active participants in the classroom rather than passive listeners. A comprehensive analysis of the survey findings reveals that purely teacher-led lecture formats struggle to meet contemporary students' learning needs and preferences.

The most favoured classroom model is one that is "real-life oriented, activity-based, and gamified". Students desire lessons that are engaging, hands-on, and relevant to their everyday lives.

2.3.1. Teaching Methods

Investigating teachers' instructional approaches is essential. Teachers can use survey findings to precisely align teaching with learning objectives, diagnose instructional effectiveness, and identify actionable improvement directions. This fosters self-reflection and professional growth. Survey results are presented in Figure 1:

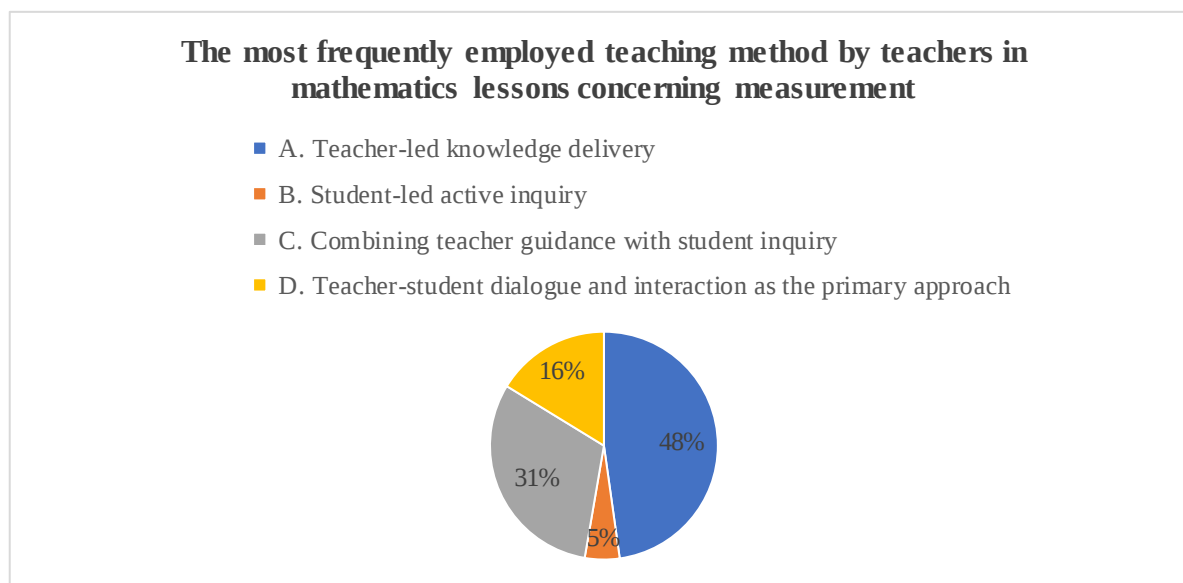


Figure 1. Teaching methods most frequently employed by teachers in mathematics lessons related to measurement

As illustrated in Figure 1, the "teacher-led knowledge transmission" approach accounted for 48%, followed by the "teacher-guided student inquiry" approach at 31%. This indicates that in primary education, teachers predominantly assume the traditional role of knowledge disseminators, with teacher-dominated instruction remaining prevalent. However, teaching methods are diversifying, with conscious emphasis on student inquiry components.

Survey findings reveal that 35.9% of pupils explicitly stated teachers rarely organise embodied practical activities, while only 30.6% held a positive view, indicating negative assessments outweigh positive ones. This stands in stark contrast to Question 5, where 63.5% of pupils expressed a preference for hands-on activities. A significant gap of approximately 33 percentage points exists between pupils' desires and their actual classroom experiences, suggesting their practical learning needs remain largely unmet. 76.8% of students acknowledged that teachers frequently utilise everyday teaching aids, with only a negligible proportion expressing disagreement. This strength aligns perfectly with the 71.9% of students in Question 5 who preferred "real-life scenarios". Teachers' effective practices have successfully met student expectations. 68.4% of students believe real-world scenarios are frequently introduced in lessons, significantly outnumbering those who disagree. This approach is a direct factor behind 74.9% of students in Question 3 finding measurement knowledge "highly useful" – it connects mathematical concepts to the real world, lending purpose and meaning to learning. However, a significant 75.9% of students reported that teachers rarely designed games or

competitive activities, with only 11.3% affirming such practices. This suggests classrooms may predominantly feature relatively formal, traditional lecturing and exercises, lacking light-hearted, engaging, challenging, and competitive elements. The data indicates teachers perform well in utilising life-like teaching aids and scenarios but exhibit shortcomings in embodied operations and gamified instruction.

2.3.2. Learning Activities

Over three-quarters of students cognitively believe that engaging physical senses—visual, auditory, tactile—effectively aids learning measurement. This demonstrates the deep psychological foundation of the embodied learning concept among students. Combined with Question 5 data, it reveals students not only "emotionally prefer" hands-on activities but also "rationally recognise" their value. This provides robust theoretical grounding and student endorsement for teachers designing multi-sensory teaching activities. Nearly 85% of students believe integrating real-life contexts aids measurement learning, demonstrating a profound understanding of mathematics' practical value. This correlates with Questions 8 and 9, where teachers effectively employed everyday teaching aids and real-world examples in practice, creating a virtuous cycle of "teachers doing well – students acknowledging it". The data from Question 13 presents a striking contrast to Question 11. Although 77.3% of students endorse embodied learning, a significant 58.1% explicitly state that teachers rarely organise hands-on activities, with only 17.7% reporting frequent occurrence. This clearly indicates that the "lack of hands-on activities" represents the most significant shortcoming in current

classroom teaching. There exists a serious disconnect between teachers' classroom design and students' preferred learning methods. This represents the most critical area for improvement. There must be an increase in design-based and experiential practical tasks to transform students' "cognitive agreement" into "learning practice". In Question 14, over sixty per cent of students indicated they collaborate with peers when completing learning tasks, suggesting cooperative learning is implemented to some extent in classrooms. However, nearly twenty per cent of students rarely participate in collaboration, indicating room for improvement in both the coverage and depth of cooperative learning. Efforts must ensure every student can participate effectively. Compared to the "hands-on activities" in Question 13, Question 15 shows a slightly higher frequency of students using specific tools. Nevertheless, nearly half of students still report being "unable to meet requirements" or "only partially able". This suggests that even when hands-on activities are provided, not all students may have the opportunity to practise personally, or the activity design may fail to guarantee sufficient tools and time for each student. Teaching must not only design hands-on activities but also ensure their inclusivity and effectiveness, enabling every student to engage fully with measurement tools.

The data reveals a stark contrast between students' cognitive preferences in 'measurement' learning and classroom realities. While pupils strongly endorse the effectiveness of multi-sensory learning and real-life contexts, classroom practice falls far short of meeting their needs and expectations. Concurrently, cooperative learning is somewhat reflected in classroom settings.

2.3.3. Learning Approach

Over seventy per cent of pupils actively associate abstract units of measurement (such as 1 square metre or 1 kilogram) with familiar everyday objects (like a door or a bottle of water) to develop a concrete 'sense of quantity'. This finding directly correlates with the teaching characteristic observed in Question 8, where teachers adeptly employed everyday teaching aids. It demonstrates that the teachers' approach successfully cultivated this learning method among pupils. Over half of pupils employ sketching diagrams or gesturing to aid problem-solving, representing a crucial mathematical strategy (the integration of numbers and shapes). However, nearly 30% rarely utilise this approach, potentially relying more on abstract reasoning or formula memorisation – a disadvantage when tackling complex problems. Teachers should continue demonstrating and emphasising the importance of visual representation to enhance overall problem-solving capabilities. The habit of constructing knowledge networks represents a weak link in students' thinking patterns. Only approximately one-third of pupils demonstrate proficiency in identifying connections and forming networks. The largest cohort (43.3%) exhibits an ambiguous attitude, remaining at a "moderate" level, suggesting they may occasionally recognise links but have not developed a conscious, systematic learning habit. This indicates learning may be fragmented rather than interconnected. Teachers should consciously guide students to organise knowledge during unit summaries or revision phases. Utilising tools such as mind maps and concept comparison tables can help students connect fragmented knowledge points into coherent systems, thereby deepening and structuring their thinking. In Question 19, a significant 58.2% of students rarely proactively consider mathematics'

practical applications in daily life or attempt to apply it. Only 16.7% possess this habit. This reveals a deep-seated issue in current teaching: while students acknowledge knowledge's utility, they fail to translate this recognition into proactive application awareness and practice. Learning remains largely about "completing tasks" rather than "solving real-world problems."

The above data illuminates the learning strategies and cognitive habits students employ in 'measurement' learning. Collectively, the findings indicate that while students demonstrate relative strength in establishing real-world connections and utilising mental imagery tools, they exhibit significant deficiencies in constructing knowledge networks and actively applying knowledge. This reflects that current learning predominantly remains at the levels of association and imitation, failing to progress to the higher-order domains of systematic construction and active transfer.

2.3.4. Evaluation and Reflection

Over forty per cent of students explicitly stated that teachers' assessments primarily focused on whether answers were correct, rather than the process of hands-on operation. This aligns closely with the data from Question 13 indicating that "teachers rarely conduct hands-on activities," collectively pointing to a fundamental issue: even when operational activities are present, the assessment methods fail to align with them. When assessment prioritises outcomes over process, hands-on activities risk becoming superficial – mere 'operations for operations' – depriving students of meaningful feedback on their investigative methods, procedural standards, and problem-solving approaches. This undermines the educational value of such activities. Over sixty per cent of students reported that teachers frequently encourage them to share strategies and thought processes. This is a positive indicator that educators are consciously focusing not only on 'how to do' but also on 'how to think'. Encouraging sharing makes implicit thought processes explicit, enabling both the sharer to organise their reasoning and other students to learn diverse problem-solving strategies, thereby fostering intellectual exchange. This constitutes a highly significant pedagogical strategy. Approximately sixty per cent of students confirmed that teachers guide them in post-learning reflection and assign extension tasks. This indicates teachers consciously extend learning beyond the classroom, striving to cultivate students' reflective habits and ability to apply knowledge. This finding contrasts with the result from Question 19, where only 16.7% of students actively applied knowledge. This suggests that despite teacher guidance, the proportion of students internalising this into conscious habits remains low. Future efforts could design more engaging and challenging extension tasks to stimulate student initiative.

This data set reveals teachers' practices across three areas: assessment methods, encouraging visible thinking, and post-class extension. Findings indicate teachers perform relatively well in encouraging students to share thought processes and organising post-class reflection and extension activities. However, there are notable shortcomings in employing formative assessment, with evaluation methods remaining rather limited.

Table 4 indicates that 80.8% of students selected "homework and exercises" as their primary assessment method, with the vast majority being evaluated and consolidating knowledge through such assignments. Additionally, 75.4% chose "examinations and tests," collectively forming a traditional assessment system centred

on "paper-and-pencil testing." Over two-thirds of students perceive classroom observation and questioning by teachers as an assessment method, indicating educators' attention to students' immediate responses during daily instruction. The current assessment framework is overwhelmingly dominated by these three traditional methods – homework/exercises, examinations/tests, and classroom observation – covering the vast majority of students. This demonstrates that assessment remains fundamentally centred on knowledge acquisition and

immediate performance. Only 13.3% of students selected 'portfolios' as an assessment method. This extremely low adoption rate (13.3%) aligns precisely with the view expressed in Question 21 that '41.8% of students believe teachers do not assess through the operational process'. Together, these findings confirm that the current assessment system severely lacks focus on the learning process, with the emphasis clearly skewed towards learning outcomes.

Table 4. Statistical Overview of Assessment Method Utilisation (Multiple-choice question)

\$E20 Frequency				
		Response		Percentage of Cases
		Number of Cases	Percentage	
20. What assessment methods are generally used in your class?	A. Homework and exercises	164	34.0%	80.8%
	B. Classroom participation (questioning and observation)	136	28.2%	67.0%
	C. Examinations and Tests	153	31.7%	75.4%
	D. Portfolio (collecting student work, assignments, self-reflections, etc.)	27	5.6%	13.3%
	E. Other	3	0.6%	1.5%
Total		483	100.0%	237.9%

Table 5 indicates that 77.3% of students perceive teachers as the primary evaluators of their learning outcomes. This clearly demonstrates that the current assessment system centres on teachers as the absolute authority. Educators hold the power to define and adjudicate evaluations, dominating student assessment through methods such as marking assignments, grading examinations, and providing classroom feedback. 35.0% of students indicated that parents evaluate their learning outcomes. This typically manifests through parental homework checks, monitoring examination results, and offering encouragement or criticism. Only 26.6% of students engage in self-assessment. This suggests that most

students lack the awareness and habit of reflecting on their own learning progress, evaluating their strengths and weaknesses. Peer assessment recorded the lowest proportion. This indicates that classroom opportunities for students to learn from one another and provide feedback are extremely limited. The absence of peer assessment means students miss an excellent learning opportunity. Evidently, the current learning evaluation system is highly externalised, centred on teachers with parents as supplementary participants. Students are viewed as passive recipients of evaluation rather than active participants in assessment and self-management.

Table 5. Statistical Overview of Evaluation Subject Selection (Multiple Choice)

\$E24 Frequency				
		Response		Percentage of Cases
		Number of Cases	Percentage	
24. After completing the mathematics learning module, () assess my learning outcomes?	A. Myself	54	17.4%	26.6%
	B. My peers	27	8.7%	13.3%
	C. Teacher	157	50.5%	77.3%
	D. Parents	71	22.8%	35.0%
	E. Other	2	0.6%	1.0%
Total		311	100.0%	153.2%

Table 6 survey results indicate that the following three difficulties were most frequently reported by students when learning about "measurement": 64.5% of students selected "estimated results consistently differ significantly from actual measurements", directly highlighting the core challenge in "measurement" teaching – establishing a sense of quantity. Over sixty percent of students struggle to develop an accurate perception of "quantity", indicating that teaching falls far short in helping students establish connections between abstract units and concrete objects. 42.4% felt that "knowledge and real life are disconnected, and they cannot apply learned knowledge to solve everyday problems." Although Question 8 indicates teachers are adept at using life-based teaching aids, over 40% of students still feel unable to

apply them. This highlights a gap between the "demonstrative" use of life-based aids and their "applied" use in solving real-world problems. Students may recognise the tools but lack understanding of when, where, and how to use them. Over one-third of students described classroom experiences as "tedious," aligning precisely with the finding in Question 10 that "75.9% of students believe teachers rarely organise game-based activities." This highlights a fundamental lack of engagement in lessons, further underscoring the urgent need to incorporate gamification, challenging tasks, and hands-on activities. Engagement is not a mere embellishment to teaching but an essential component for sustaining learning motivation.

Table 6. Statistical Summary of Students' Quantitative Learning Difficulties (Multiple-choice)

\$E25 Frequency				
		Response		Percentage of Cases
		Number of Cases	Percentage	
25. What difficulties did you encounter when learning about "measurement"?	A. The concept of units was too abstract to grasp	39	8.3%	19.2%
	B. Difficulty distinguishing between similar "quantities"	28	6.0%	13.8%
	C. Prone to errors in conversion rates between units, making accurate unit conversion difficult	45	9.6%	22.2
	D. Inability to select appropriate tools and methods for measurement	32	6.8%	15.8
	E. Estimated results consistently deviate significantly from actual measurements	131	27.9%	64.5%
	F. Perceiving knowledge and life as separate, unable to apply acquired knowledge to solve real-world problems	86	18.3%	42.4%
	G. Classroom sessions are excessively tedious and unengaging	72	15.3%	35.5%
	H. Insufficient teacher guidance	23	4.9%	11.3%
	I. Other difficulties	10	2.1%	4.9%
	J. No difficulties	4	0.9%	2.0%
Total		470	100.0%	231.5%

3. Discussion

3.1. Conclusions

3.1.1. The Deep-Seated Contradiction Between Embodied Learning Needs and Instructional Provision

From the perspective of student development, contemporary mathematics teaching focused on quantitative sense faces a structural contradiction between learning needs and instructional provision. Modern cognitive science research indicates that primary pupils' mathematical concept formation is fundamentally an embodied process, requiring sensory understanding of abstract mathematical concepts through interaction between the body and the environment. Particularly in cultivating quantitative sense, pupils naturally gravitate towards establishing understanding of measurement concepts—such as quantity, size, and weight—through diverse sensory channels including touch, observation, and manipulation. However, practical teaching arrangements often fail to meet these intrinsic cognitive needs. Within conventional mathematics lessons, pupils seldom gain opportunities to actively participate in constructing measurement concepts through hands-on engagement. This manifests concretely as follows: the use of measuring tools is often confined to teacher demonstrations, depriving pupils of hands-on experience with such instruments; the learning of measurement units relies predominantly on rote memorisation rather than establishing concrete mental images through practical measurement activities; and the cultivation of quantitative sense is frequently reduced to mechanical unit conversion drills, overlooking the importance of building accurate quantitative intuition through repeated experiential engagement.

The direct consequences of this imbalance between supply and demand are profound. Firstly, it diminishes students' motivation and interest in mathematics. When learning cannot occur through preferred methods, intrinsic drive is suppressed. Secondly, it hinders the essential understanding of mathematical concepts. Quantity sense, as an intuitive perception of magnitude, must be gradually developed through rich sensory experiences. Without these, students' comprehension of measurement concepts remains superficial. Finally, this contradiction impedes the development of

students' mathematical application skills, making it difficult for them to flexibly apply classroom measurement knowledge to real-life contexts.

3.1.2. Structural Dilemmas in the Translation of Teaching Philosophy to Practice

From the perspective of teacher professional development, primary mathematics teachers currently exhibit a significant gap between their conceptual understanding and practical implementation of quantity sense teaching. As curriculum reforms advance, most teachers have intellectually recognised the importance of embodied learning and begun actively exploring its implementation. This shift manifests in several ways: teachers increasingly create real-life teaching contexts, linking mathematical concepts to pupils' lived experiences; greater emphasis is placed on manipulative use, employing physical objects to foster concrete mental representations; and greater importance is given to classroom participation through interactive activities.

Nevertheless, this conceptual shift has yet to fully translate into systematic teaching practice. In-depth classroom observations reveal that traditional lecture-based instruction remains dominant. Even in demonstration lessons purportedly embodying new approaches, teachers often prioritise formal pedagogical innovation over a profound grasp of embodied cognition theory's essence. This manifests in several ways: Firstly, scenario creation tends towards superficiality. Many educators reduce contextualisation to a mere "gimmick" for lesson introductions rather than a cognitive framework permeating the entire learning process. While such superficial design may briefly capture students' attention, it struggles to sustain sustained inquiry-based learning. Secondly, hands-on activities lack intellectual depth. In classrooms attempting such activities, teachers frequently prioritise the outward form of tasks over the underlying development of mathematical thinking. Students may engage physically, yet their minds remain disengaged, creating a disconnect between action and thought. Finally, pedagogical innovation exhibits fragmented characteristics. Many educators perceive embodied teaching as merely refining isolated segments or activities, failing to reimagine the entire instructional system. Such piecemeal improvements fall short of generating fundamental pedagogical transformation.

At its root, this disconnect between theory and practice

stems from multiple factors: teachers' insufficiently deep understanding of embodied cognition theory, a lack of methodological guidance for translating theory into practice, inadequate support for innovative practices within the teaching evaluation system, and constraints imposed by teaching resources and technological conditions.

3.1.3. Operational Experience and the Efficacy Bottleneck in Cultivating Quantity Sense

Regarding the quality of instructional activity design, insufficient hands-on experience has become a critical factor constraining the effectiveness of cultivating a sense of magnitude. As a distinct mathematical literacy, the development of a sense of magnitude exhibits pronounced embodied characteristics. It involves not merely cognitive understanding of measurement units, but rather the establishment of bodily memory and intuitive judgement through repeated experiential engagement. This inherent nature necessitates that cultivating a sense of magnitude be grounded in ample hands-on experience.

However, practical teaching activity designs exhibit significant deficiencies in experiential provision. Firstly, in terms of time allocation, hands-on segments are often compressed within limited classroom hours, preventing students from establishing stable quantitative sense through sufficient experience. For instance, in length measurement learning, pupils may only receive one opportunity to use a ruler – such superficial exposure falls far short of forming accurate length concepts. Secondly, in terms of activity design, existing hands-on activities frequently remain at the skill-training level, neglecting attention to students' conceptual construction processes. For instance, in teaching volume measurement, teachers may prioritise training measurement techniques while overlooking the crucial opportunity to use hands-on activities to help students establish the concept of volume conservation. Moreover, activity sequences lack progressive guidance from concrete experience to abstract abstraction. Students engage in hands-on activities yet fail to elevate their mathematical thinking through these experiences. This deficiency directly results in students' understanding of measurement concepts remaining at an intuitive level, hindering the leap to rational comprehension.

Particularly noteworthy is how the orientation of teaching assessment exacerbates this issue. When evaluation excessively emphasises the outcomes of operations rather than the process, both teachers and pupils naturally prioritise achieving correct results while neglecting the cognitive development and conceptual construction occurring during the operational stages. This assessment bias strips hands-on activities of their educational value, reducing them to mere skill drills.

3.1.4. The Compatibility Dilemma Between Monolithic Models and Teaching Innovation

From the perspective of teaching evaluation, a significant mismatch exists between the current singular evaluation model and the requirements of embodied teaching. As a crucial component of the teaching system, evaluation not only serves to assess learning outcomes but also plays a vital role in guiding teaching direction. However, the traditional evaluation system proves inadequate in supporting the development of embodied teaching.

This mismatch manifests primarily in the limitations of assessment content. Existing systems over-rely on paper-and-pencil tests, focusing predominantly on students' memorisation and comprehension of measurement

knowledge alongside their mastery of computational skills. Conversely, effective tools and methodologies for evaluating quantitative sense—a core competency—remain conspicuously absent. Specifically: emphasis is placed on proficiency in unit conversion while development of estimation abilities is neglected; attention is focused on the precision of measurement results while the rationality of the measurement process is overlooked; and standard answers are prioritised at the expense of the diversity of thought processes. Secondly, the singularity of the evaluator constrains pedagogical development. In current teaching assessments, teachers are almost exclusively the evaluators, while students, as the primary learners, are excluded from the evaluation process. This single-subject evaluation model brings multiple issues: students lack opportunities for self-reflection and monitoring, hindering the development of metacognitive abilities; the absence of peer assessment deprives students of crucial avenues for mutual learning and reference; and the evaluation process becomes a one-way judgement rather than a multi-directional dialogue and exchange. Moreover, the timing of assessments exhibits clear limitations. Existing evaluations predominantly focus on summative assessments after learning concludes, with insufficient attention given to formative assessments during the learning process. This outcome-oriented approach, which prioritises results over process, prevents teachers from obtaining timely instructional feedback and dynamically adjusting teaching methods. It also deprives students of crucial opportunities for continuous improvement during their learning journey.

3.2. Recommendations

3.2.1. Constructing a Multi-dimensional Learning Environment Centred on Physical Experience

Guided by embodied cognition theory, mathematics measurement education should transcend the physical confines of traditional classrooms to establish a multidimensional learning space centred on students' bodily experiences. This space requires not only physical environment adaptation but also instructional process redesign. Firstly, establish a sequential operational loop: "experience – estimation – measurement – reflection". This closed-loop design should permeate the teaching process for each measurement concept. Secondly, a multi-sensory collaborative network for constructing quantitative sense should be established. Human perception of "quantity" is a multi-channel information integration process. Coordinated multi-sensory stimulation helps students build richer and more robust quantitative mental representations. Furthermore, the learning environment should prioritise spatial flexibility. Traditional, rigid seating arrangements should be replaced with modular learning zones, featuring distinct functional spaces such as measurement areas, hands-on activity zones, and discussion corners. These should be equipped with ample measurement tools and materials to support students' natural transition between different activities.

3.2.2. Establishing a Professional Support System for Concept-to-Practice Translation

Teachers are the key implementers of pedagogical reform. Establishing a systematic professional support mechanism is essential to assist educators in effectively translating embodied cognition principles into teaching practice.

The foremost task is constructing an embodied teaching "paradigm repository". This repository should contain a rich collection of practice-tested teaching activity templates, each

clearly labelled with applicable content, learning objectives, required materials, and implementation key points. These paradigms must not only provide operational procedures but also elucidate the underlying cognitive principles, helping teachers understand "why this approach is taken". Deepening the creation of teaching scenarios requires methodological guidance. High-quality teaching scenarios should embody three characteristics: authenticity, continuity, and challenge. Teachers require specialised training to learn how to identify such contexts within pupils' daily lives and integrate them effectively into the teaching process. Establishing teacher learning communities is equally vital. Regular lesson observations, case studies, and teaching forums should facilitate experience sharing and professional dialogue among educators. Experts in cognitive science and mathematics education may be invited to provide guidance, helping teachers deepen their theoretical understanding of embodied cognition. This enables them to creatively develop teaching activities better suited to their own pupils.

3.2.3. Deepening the Cultivation of Thinking Skills Through Operational Activities

Manipulative activities must transcend mere 'hands-on' engagement to achieve deep integration with 'mind-engaged' thinking. This requires systematic advancement across three dimensions: activity design, process guidance, and resource provision.

Activity design should embody the externalisation of thought processes. Each hands-on activity should be structured around a chain of critical questions centred on explicit mathematical concepts. These questions guide pupils in connecting concrete operations with abstract mathematical ideas and methods, thereby visualising their thinking. Teachers' guidance strategies should foster deeper thinking. During pupils' operational activities, educators should act as facilitators and catalysts, employing timely and appropriate questioning and prompts to help pupils overcome cognitive bottlenecks. Employ heuristic questions to guide students towards deeper reflection. Simultaneously, teachers should adeptly identify and capitalise on pedagogical opportunities arising during operations, promptly organising discussions and summaries to enhance the cognitive value of activities. Resource provision must support exploratory thinking. This entails ensuring ample operational time, diverse material choices, and appropriate technical support. Particular emphasis should be placed on providing varied operational resources—including both standard measuring tools and non-standard measuring materials—enabling students to deepen their understanding of measurement concepts through comparative analysis. Modern technological tools such as dynamic geometry software and virtual laboratories can also effectively broaden the depth and scope of hands-on activities.

3.2.4. Establishing a Diverse Developmental Assessment System

Reforming the assessment system is crucial to ensuring the effectiveness of teaching reforms. The new assessment framework should transcend the limitations of traditional paper-and-pencil tests, establishing a diverse and dynamic developmental evaluation mechanism.

Expanding assessment content is the primary task. Beyond traditional assessments of foundational knowledge and skills, evaluation should incorporate estimation abilities, operational standards, strategy selection, and collaborative performance. Diversifying assessment subjects represents a significant breakthrough. Alongside teacher evaluations, the roles of

student self-assessment and peer assessment should be fully leveraged. This multi-subject evaluation model not only provides a more comprehensive reflection of student learning but also cultivates self-monitoring abilities and critical thinking. Optimising assessment timing is equally crucial. Assessment should permeate the entire teaching process, organically integrating formative and summative evaluation. During routine teaching, continuous collection of student learning data through observation, interviews, and portfolio analysis enables timely adjustment of teaching strategies. At the conclusion of each unit, comprehensive evaluation methods such as project portfolio presentations and practical activity assessments can be employed to holistically gauge learning outcomes.

Furthermore, an effective mechanism for utilising assessment outcomes must be established. Assessment data should not only gauge students' learning levels but also provide evidence for teachers to refine instruction and guide students in adjusting learning strategies, thereby creating a virtuous cycle of "teaching-assessment-improvement". This systematic improvement scheme, spanning environmental design to assessment reform, forms a complete closed loop. It aims to genuinely enhance the quality of quantitative sense teaching in primary mathematics through coordinated efforts across all stages, fostering students' deep understanding and flexible application of measurement concepts.

In summary, enhancing primary mathematics teaching of quantitative sense within an embodied cognition framework constitutes a systemic endeavour encompassing learning environments, teacher professionalism, activity design, and assessment systems. It demands fundamental respect for the embodied nature of student cognition, shifting the pedagogical focus from knowledge transmission to meaning construction, thereby enabling pupils' bodies to become genuine sources of cognition and tools for thinking. By establishing a 'body-centred' learning environment, providing teachers with professional practical support, designing 'externalised thinking' operational activities, and establishing a 'process-focused' evaluation model, we can genuinely bridge the various gaps revealed in the survey. This will transform quantity sense teaching from a dry numerical exercise into a vibrant, life-affirming embodiment of bodily wisdom, thereby laying a solid foundation for cultivating pupils' core mathematical literacy.

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