MAIMON RESEARCH LLC

ARTIFICIAL INTELLIGENCE LARGE LANGUAGE MODEL INTERROGATION

REPRESENTATIONAL MEASUREMENT FAILURE IN HEALTH TECHNOLGY ASSESSMENT

SINGAPORE: THE ENDORSEMENT OF CURRICULUM INVERSION

Paul C Langley PhD Adjunct Professor, College of Pharmacy, University of Minnesota, Minneapolis, MN

LOGIT WORKING PAPER No 1580 JULY 2026

www.maimonresearch.com

Tucson AZ

ABSTRACT

This study examines whether the educational framework supporting health technology assessment (HTA) in Singapore recognizes the scientific principles required for lawful quantitative measurement. It complements an earlier interrogation of the Singapore HTA knowledge base that demonstrated a consistent pattern of measurement inversion, whereby representational measurement receives little recognition while utilities, quality-adjusted life years (QALYs), cost-effectiveness analysis, and reference-case modelling are treated as though they provide scientifically valid measures of therapy impact. The present investigation asks the complementary question: is this methodological framework reproduced through curriculum inversion?

The analysis applies a standardized large language model (LLM) interrogation to the Singapore curriculum knowledge base using ten canonical statements derived from the axioms of representational measurement. These statements address specification of the target attribute, scales of measurement, measurement status, representational measurement, unidimensionality, the distinction between manifest and latent attributes, the corresponding requirements for ratio measurement, and the requirement that therapy-impact claims be prospectively falsifiable. Categorical probabilities and normalized logits are used to characterize the degree to which these concepts are represented within the educational knowledge base.

The interrogation reveals a consistent pattern of curriculum inversion. Nine of the ten canonical statements receive negative logits, indicating weak endorsement of the principles required for lawful quantitative measurement. Only the recognition of manifest attributes as directly observable receives substantial support. Minimal recognition is found for representational measurement, measurement status, unidimensionality, the distinction between manifest and latent attributes, Rasch measurement, and the requirement that manifest and latent attributes require fundamentally different forms of ratio measurement. Educational emphasis instead centers upon utilities, QALYs, economic evaluation, patient-reported outcomes, evidence synthesis, and decision-analytic modelling, with arithmetic and modelling introduced before measurement has been established.

The analysis concludes that curriculum inversion provides the educational mechanism through which measurement inversion is reproduced within Singaporean HTA. Despite Singapore's highly developed healthcare system, centralized assessment environment, and internationally respected expertise in health economics, public health, epidemiology, pharmacy, and healthcare evaluation, the curriculum does not position representational measurement as the prerequisite for quantitative inference. The absence of an explicit distinction between manifest and latent attributes also explains the marginal role of Rasch measurement within mainstream HTA education.

The study argues that incremental refinement of existing analytical methods cannot resolve this deficiency. Reconstruction of HTA education is required, with curricula reorganized around representational measurement, lawful ratio measurement for manifest and latent attributes, and prospectively evaluable, independently replicable, and falsifiable claims regarding therapy

impact. Only by restoring measurement as the prior condition for arithmetic can Singaporean HTA satisfy the scientific requirements for quantitative evaluation.

INTRODUCTION

The present analysis complements an earlier interrogation of the Singapore health technology assessment (HTA) knowledge base that examined the extent to which the accepted principles of representational measurement are recognized within contemporary Singaporean HTA [1]. That investigation demonstrated a consistent pattern of measurement inversion across the national assessment environment, university-based health economics and health services research, pharmacy and outcomes research, and the wider professional knowledge base supporting economic evaluation and healthcare decision making. Representational measurement received little recognition, while multiattribute instruments, utilities, quality-adjusted life years (QALYs), cost-effectiveness analysis, and reference-case simulation were accepted as though they provided scientifically valid quantitative measures of therapy impact. The present study addresses the complementary question of how this methodological framework is transmitted and sustained through the educational system responsible for preparing successive generations of Singaporean HTA practitioners. It examines whether measurement inversion is accompanied by curriculum inversion.

The present analysis examines the Singapore HTA curriculum knowledge base through the application of a standardized representational measurement interrogation. Its purpose is not to evaluate individual universities, research centers, government agencies, professional organizations, or teaching programs, but to determine whether the scientific principles required for lawful quantitative measurement are embedded within the educational framework supporting Singaporean HTA practice. The interrogation employs ten canonical curriculum statements derived from the requirements of representational measurement. These encompass specification of the target attribute, the principal scales of measurement, establishment of measurement status before quantitative claims are advanced, the axioms of representational measurement, unidimensionality, the distinction between manifest and latent attributes, the corresponding requirements for ratio measurement, and the requirement that therapy-impact claims be empirically falsifiable. Together, the statements provide a consistent framework for assessing whether Singaporean HTA education is grounded in the scientific conditions required for valid quantitative evaluation.

Singapore occupies an important position in Asian HTA. It combines a highly organized healthcare system with a centralized national assessment environment and substantial expertise in health economics, public health, epidemiology, pharmacy, outcomes research, evidence synthesis, and healthcare decision making. The Agency for Care Effectiveness provides a prominent institutional focus for HTA and evidence-based guidance, while the National University of Singapore, the Saw Swee Hock School of Public Health, Duke-NUS Medical School, and associated academic and research groups contribute to the wider methodological knowledge base supporting healthcare assessment. The continuing development of economic evaluation and evidence-informed reimbursement has created a sustained demand for quantitative claims concerning comparative clinical benefit, health outcomes, resource use, and therapy value.

This institutional structure makes Singapore particularly important for an interrogation of curriculum knowledge. Singapore is not characterized by a fragmented assessment environment or an absence of technical expertise. On the contrary, its healthcare and academic institutions have developed a reputation for disciplined analysis, methodological competence, and the effective translation of evidence into policy. Health economics, epidemiology, pharmacy, medicine, statistics, public health, and health services research contribute to the wider HTA knowledge base. The scientific resources required to question the measurement foundations of quantitative therapy assessment are therefore available. The critical issue is whether those resources have been brought together to establish measurement as the prior condition for arithmetic or whether the accepted international economic-evaluation paradigm has simply defined the terms of curriculum development.

The distinction is fundamental. A technically sophisticated curriculum may become highly proficient in the application of accepted methods while leaving their scientific foundations unexamined. Students may be trained to select multiattribute instruments, estimate utilities, construct QALYs, undertake cost-effectiveness analyses, populate decision models, conduct sensitivity analyses, and characterize parameter uncertainty without first being required to establish the measurement status of the quantities entering these operations. Technical competence does not resolve this omission. If utilities, QALYs, patient-reported outcome scores, and modelled therapy-impact claims are accepted as quantitative entities without prior demonstration that they satisfy the requirements of measurement, methodological sophistication merely embeds measurement failure more deeply within professional practice.

Singapore therefore presents a particularly revealing test of curriculum inversion. The question is not whether Singaporean HTA education is technically advanced; there is little reason to doubt that it is. The question is whether technical competence is preceded by instruction in the scientific conditions required for quantitative claims. Are students first taught to specify the target attribute? Are they required to establish its measurement status? Do the properties of nominal, ordinal, interval, and ratio scales govern the permitted analysis? Are the axioms of representational measurement recognized? Is unidimensionality required before measurement? Are manifest and latent attributes distinguished, with recognition that they require different forms of ratio measurement? Are therapy-impact claims required to be empirically falsifiable?

These questions are particularly important in Singapore because the efficiency and coherence of the national HTA environment may accelerate the transmission of accepted methodological conventions. A centralized and technically coordinated system can disseminate good scientific practice rapidly, but it can also reproduce foundational errors with equal efficiency if the underlying assumptions are not challenged. Once utilities, QALYs, cost-effectiveness analysis, and reference-case simulation are established as the accepted framework for quantitative assessment, university teaching, professional training, research priorities, and assessment practice may become mutually reinforcing. The result is methodological closure: successive generations of practitioners are trained to become proficient within the accepted paradigm without being required to interrogate whether its numerical constructs satisfy the prior requirements of measurement.

If the canonical principles of measurement receive consistently weak endorsement while utilities, QALYs, economic evaluation, and decision-analytic modelling remain dominant components of

the educational framework, the result is curriculum inversion. In such a curriculum, arithmetic precedes measurement, analytical proficiency is developed before measurement competence, and methodological convention substitutes for prior scientific validation. The Singapore interrogation seeks to determine whether the educational framework supporting contemporary HTA satisfies the requirements of representational measurement or reproduces the same measurement inversion already identified within the Singapore HTA knowledge base.

CURRICULUM INVERSION

Curriculum inversion occurs when a curriculum teaches the application of quantitative methods while failing to teach the measurement principles that determine whether those methods are scientifically legitimate. In a scientifically coherent curriculum, measurement precedes arithmetic. Students first learn the nature of attributes, the requirements of representational measurement, the distinctions among nominal, ordinal, interval and ratio scales, and the conditions necessary for valid quantitative claims for manifest and the application of Rasch models for latent attributes [2] [3] [4] . Only then are they introduced to the arithmetic, statistical and modelling procedures that depend upon those measurement properties. Curriculum inversion reverses this sequence. Students learn how to calculate, model and analyze before they learn how to determine whether the quantities entering those analyses are measures. Arithmetic becomes detached from measurement and numerical manipulation is treated as though it were equivalent to quantitative science.

The consequences are profound. A curriculum affected by inversion reproduces a professional culture in which measurement is assumed rather than demonstrated. Concepts such as unidimensionality, dimensional homogeneity, admissible arithmetic, manifest and latent attributes, ratio measurement and Rasch measurement either disappear entirely or are treated as peripheral concerns. Students become proficient in the techniques of economic evaluation, utility assessment, QALY construction and simulation modelling without acquiring the conceptual tools necessary to evaluate the legitimacy of those methods. The result is that the curriculum not only fails to identify measurement errors but actively reproduces them across successive generations of researchers, analysts and decision makers. Curriculum inversion therefore serves as the educational mechanism through which measurement inversion becomes institutionalized within a discipline. In HTA this serves to support administrative decisions for therapy pricing and access.

For this reason, curriculum assessment emerges as a critical component of HTA reconstruction. The objective is not simply to determine whether students are exposed to contemporary HTA methods. Rather, it is to determine whether they are exposed to the foundational concepts that make the evaluation of those methods possible. A curriculum that emphasizes modelling, economic evaluation and decision analysis while neglecting measurement theory will inevitably reproduce the same conceptual limitations and measurement failure observed in current HTA practice.

The curriculum interrogations provide compelling support for this interpretation. While there is evidence that students and researchers are introduced to outcomes assessment, target attributes and scientific claims, there is little evidence of systematic exposure to scales of measurement, the axioms of representational measurement, unidimensionality, latent attribute measurement or ratio measurement. The concepts most frequently absent from curriculum coverage are precisely those

concepts most frequently absent from HTA practice. The relationship is unlikely to be coincidental.

The imperative of measurement inversion therefore extends beyond criticism of existing methods. It points directly to the need for educational reconstruction. If HTA is to move toward a framework based on lawful measurement, evaluable claims and empirical falsification, then curriculum reform must accompany methodological reform. The widespread and consistent pattern of measurement inversion revealed by the interrogations suggests that reconstruction cannot begin with policy guidance or analytical techniques alone. It must begin with the curriculum. Until students and researchers are introduced to the foundations of measurement science, the conditions that created measurement inversion will continue to be reproduced throughout the HTA community.

THE SINGAPORE HTA CURRICULUM KNOWLEDGE BASE

The Singapore health technology assessment curriculum knowledge base comprises the interconnected academic, government, research, and professional sources through which the accepted principles and methods of HTA are taught, transmitted, and reproduced. It is not confined to a single degree program or designated HTA curriculum. Rather, it is distributed across teaching in health economics, public health, epidemiology, pharmacy, health services research, evidence-based medicine, outcomes research, and healthcare policy. Together, these activities establish the methodological expectations that students and practitioners bring to the assessment of therapies and the formulation of quantitative claims.

At the national level, the Agency for Care Effectiveness provides an important methodological reference point. Its assessment methods, guidance, and educational activities define the analytical framework within which evidence is evaluated for healthcare decision making. Clinical effectiveness, safety, economic evaluation, cost-effectiveness, cost-utility analysis, health-related quality of life, and decision modelling occupy central positions. These methods do more than guide assessment practice. They provide an institutional statement of what constitutes acceptable quantitative evidence and therefore influence the knowledge expected of those entering or working within Singaporean HTA.

The academic knowledge base is concentrated particularly within the National University of Singapore and Duke-NUS Medical School, together with associated research centers and health services research activities. The Saw Swee Hock School of Public Health contributes teaching and research in health economics, HTA, epidemiology, evidence synthesis, economic evaluation, and healthcare policy. Pharmacy education and pharmaceutical outcomes research contribute further expertise in medication use, patient outcomes, preference assessment, and economic evaluation. Duke-NUS adds a strong emphasis on health services and systems research, cost-effectiveness, decision analysis, and the translation of evidence into healthcare decisions. These activities create a multidisciplinary curriculum environment extending beyond formal courses explicitly labelled as HTA.

The wider curriculum knowledge base also includes research publications, methodological seminars, professional training, assessment guidance, and the continuing interaction between academic researchers and national healthcare institutions. This is particularly important in

Singapore because the relatively concentrated structure of the healthcare and university environment facilitates the transmission of accepted methodological conventions. Students encounter the same broad analytical framework in university teaching, research projects, published economic evaluations, HTA methods, and professional practice. Economic evaluation, utilities, QALYs, patient-reported outcomes, evidence synthesis, and decision-analytic modelling consequently form a mutually reinforcing methodological structure.

The defining characteristic of this knowledge base is its emphasis on analytical application. Students and practitioners are prepared to identify clinical evidence, estimate costs and outcomes, assess uncertainty, construct models, and interpret economic results for decision makers. What is not visibly established as a prior curriculum requirement is a formal theory of measurement. The specification of the target attribute, establishment of measurement status, axioms of representational measurement, unidimensionality, and the distinction between manifest and latent forms of ratio measurement do not provide the organizing framework for quantitative assessment.

The Singapore curriculum knowledge base is therefore technically extensive but methodologically bounded by the accepted international HTA paradigm. Its component institutions contribute substantial expertise in economic evaluation, epidemiology, statistics, pharmacy, and decision science, but these disciplines operate within a framework in which numerical representations are generally accepted before their status as measures has been established. The curriculum interrogation assesses the consequences of this structure: whether Singaporean HTA education prepares practitioners first to establish measurement or, instead, trains them to become proficient in arithmetic and modelling within a pre-existing framework of measurement inversion.

INTERROGATING THE SINGAPORE CURRICULUM KNOWLEDGE BASE

The objective of large language model (LLM) curriculum interrogation differs from that of previous HTA knowledge-based practice assessments. Earlier interrogations focused on whether institutions recognized the requirements of representational measurement and the standards necessary for quantitative claims. Curriculum interrogation asks a different question. Are faculty, students and researchers exposed to the concepts necessary to understand and apply those standards? The focus shifts from methodological outputs to educational inputs. Rather than examining what faculty, students and researchers do, attention is directed to what they are taught and what they know.

The importance of this distinction should not be underestimated. Educational programs do not merely transmit technical skills. They define the conceptual framework through which future practitioners understand evidence, measurement and scientific inquiry. Concepts that are absent from the curriculum are unlikely to emerge spontaneously in research practice. Equally, concepts that are emphasized repeatedly become part of the intellectual assumptions that shape subsequent analysis have never been systematically incorporated into HTA teaching and research training.

For this reason, the curriculum interrogation was designed around a series of canonical statements intended to identify the presence or absence of foundational measurement concepts. These statements were deliberately elementary. The purpose was not to assess advanced methodological

knowledge but to determine whether faculty, students and researchers are likely to encounter the principles that underpin lawful quantitative claims. The resulting framework begins with the concept of an attribute as the object of measurement and proceeds through target attribute specification, scales of measurement, representational measurement, unidimensionality, manifest and latent attributes, ratio measurement and falsifiable claims. Together, these statements define the minimum intellectual foundations required for a measurement-based approach to therapy assessment in education.

These statements are:

- **An attribute is the specific outcome of interest in a therapy assessment.**
- **Every therapy assessment begins with specification of the target attribute.**
- **The principal scales of measurement (nominal, ordinal, interval and ratio) have different properties and support different forms of analysis.**
- **The measurement status of a target attribute must be established before quantitative claims can be advanced.**
- **The axioms of representational measurement underpin quantitative claims.**
- **Attributes must be demonstrated to be unidimensional before measurement is possible.**
- **A manifest attribute is directly observable and capable of supporting empirical observation.**
- **A latent attribute is not directly observable and requires a measurement model to estimate possession of the attribute.**
- **Manifest and latent attributes require different forms of ratio measurement.**
- **Therapy impact claims must be falsifiable.**

These ten statements form a logical sequence:

Attribute → Target Attribute → Scales of Measurement → Measurement Status → Representational Measurement → Unidimensionality → Manifest Attribute → Latent Attribute → Ratio Measurement → Falsifiable Claims

The categorical probabilities reported in this assessment are intended as indicators of the extent to which a concept is represented within the curriculum knowledge base. They should not be interpreted as precise statistical estimates but as measures of the likelihood that a student, researcher or professional exposed to that knowledge base would encounter, recognize and subsequently endorse the canonical statement. In practical terms, the probability reflects the visibility and prominence of a concept within the educational environment associated with a research center or policy agency.

A high probability indicates that the concept is well represented within curriculum materials, research outputs and educational activities and is therefore likely to be familiar to students and researchers. Conversely, a low probability suggests that the concept is absent, only weakly represented, or occupies a peripheral position within the curriculum knowledge base. Students exposed to such an environment would therefore be unlikely to recognize the concept as an important component of HTA education and practice.

The probabilities should be viewed comparatively rather than in isolation. Their principal value lies in identifying patterns of curriculum coverage across institutions and concepts. In particular, low probabilities associated with scales of measurement, representational measurement, unidimensionality and ratio measurement indicate that these topics are unlikely to form a substantial part of the educational experience of the average student. The resulting profile provides an indication of curriculum strengths, deficiencies and potential areas for reconstruction.

SINGAPORE AND CURRICULUM INVERSION

Table 1 presents a clear and consistent pattern of curriculum inversion within the Singapore HTA knowledge base. The categorical probability assignments are concentrated at the lowest levels of endorsement for the scientific principles required to establish quantitative measurement. Nine of the ten canonical statements are positioned at negative logits. The pattern is not one of occasional omission or uneven methodological emphasis. It indicates that the foundational requirements for measurement are largely absent as governing principles of the educational framework supporting HTA.

TABLE 1: CURRICULUM CONTENT ENDORSEMENT: SINGAPORE KNOWLEDGE BASE

CANONICAL STATEMENT	CATEGORICAL PROBABILITY	NORMALIZED LOGIT
An attribute is the specific outcome of interest in a therapy assessment	0.10	-2.20
Every therapy assessment begins with specification of the target attribute	0.10	-2.20
The principal scales of measurement (nominal, ordinal, interval and ratio) have different properties and support different forms of analysis	0.20	-1.40
The measurement status of a target attribute must be established before quantitative claims can be advanced	0.05	-2.50
The axioms of representational measurement underpin quantitative claims	0.05	-2.50
Attributes must be demonstrated to be unidimensional before measurement is possible	0.10	-2.20
A manifest attribute is directly observable and capable of supporting empirical observation	0.70	+0.85
A latent attribute is not directly observable and requires a measurement model to estimate possession of the attribute	0.20	-1.40
Manifest and latent attributes require different forms of ratio measurement	0.05	-2.50
Therapy impact claims must be falsifiable	0.15	-1.75

The most pronounced rejection concerns the requirement that measurement must be established before quantitative claims are advanced. The measurement status of the target attribute, the axioms of representational measurement, and the requirement for different forms of ratio measurement for manifest and latent attributes are each assigned a probability of 0.05 and a limiting logit of −2.50. These statements address the foundations of quantitative science. Their position at the lowest level of endorsement indicates that Singaporean HTA education does not require practitioners to demonstrate that measurement has occurred before numerical operations and quantitative claims are accepted.

The same pattern extends to attribute specification and unidimensionality. The definition of an attribute as the specific outcome of interest, the requirement that every therapy assessment begin with specification of the target attribute, and the requirement that an attribute be demonstrated to be unidimensional before measurement are each assigned a probability of 0.10 and a logit of −2.20. The implication is that the curriculum moves directly from identified outcomes, instruments, scores, or model inputs to analysis without first establishing the empirical property that is intended to be measured.

Recognition of measurement scales and latent attributes receives only limited endorsement. Although nominal, ordinal, interval, and ratio scales are likely to be encountered in general statistical teaching, their different analytical properties do not appear to govern HTA practice. Similarly, latent attributes may be recognized as not directly observable, but the requirement for a measurement model to estimate possession of the attribute is not embedded as a mandatory condition for quantitative claims. The sole positive endorsement concerns manifest attributes and reflects the familiarity of Singaporean HTA with directly observable clinical and resource outcomes.

The overall picture is therefore one of a technically sophisticated curriculum built on an inverted methodological sequence. Students and practitioners are trained in evidence synthesis, utilities, QALYs, economic evaluation, uncertainty analysis, and decision modelling before being required to establish the measurement status of the quantities entering these operations. Therapy-impact claims are not routinely framed as falsifiable propositions grounded in admissible measures. Table 1 therefore identifies the defining structure of curriculum inversion in Singapore: arithmetic precedes measurement, analytical competence precedes measurement competence, and accepted methodological convention substitutes for the prior scientific validation of quantitative claims.

STATEMENT-BY-STATEMENT REVIEW

1. An attribute is the specific outcome of interest in a therapy assessment

Probability: 0.10 | Logit: −2.20

The Singapore HTA curriculum knowledge base gives little recognition to the attribute as the foundational object of therapy assessment. Clinical outcomes, health-related quality of life, costs, utilities, and patient-reported outcomes are routinely identified, but an outcome or numerical variable is not necessarily a specified attribute. The curriculum does not appear to require students to define the particular property whose magnitude or possession is to be assessed before selecting

an instrument or analytical method. As a result, available endpoints, scores, and utility systems can effectively define the object of analysis. The low probability reflects the absence of attribute specification as an explicit and prior requirement for quantitative therapy assessment.

2. Every therapy assessment begins with specification of the target attribute

Probability: 0.10 | Logit: −2.20

Singaporean HTA typically begins with a decision problem framed around the population, intervention, comparator, and outcomes rather than the prior specification of a target attribute. Although outcomes are identified, this does not establish whether pain, fatigue, physical function, need fulfilment, treatment persistence, or another defined property is the intended object of measurement. The distinction is important because the target attribute determines the form of measurement required. Where an instrument, utility score, or model outcome is accepted before the attribute has been independently specified, the analytical process begins with a numerical representation rather than a measurement problem. The categorical assignment indicates that target-attribute specification is not embedded as the mandatory first step in Singaporean HTA education.

3. The principal scales of measurement (nominal, ordinal, interval and ratio) have different properties and support different forms of analysis

Probability: 0.20 | Logit: −1.39

The four principal scales of measurement are likely to be familiar from introductory statistics, epidemiology, and research-methods teaching in Singapore. The problem is not complete ignorance of the terminology but the failure to enforce the analytical restrictions associated with each scale. Ordinal patient-reported outcome scores and preference-based utility values may be subjected to arithmetic operations and incorporated into economic models without demonstrating interval or ratio properties. Recognition of scale classifications therefore remains largely descriptive rather than regulatory. The probability of 0.20 reflects limited curriculum recognition of the scale hierarchy but weak evidence that scale properties determine which mathematical operations and quantitative claims are considered admissible in HTA.

4. The measurement status of a target attribute must be established before quantitative claims can be advanced

Probability: 0.05 | Logit: −2.50

This statement occupies the lowest category of endorsement and identifies the central feature of curriculum inversion. Singaporean HTA education emphasizes evidence synthesis, economic evaluation, utilities, QALYs, statistical analysis, and decision modelling without imposing a prior requirement to establish whether the numerical inputs are measures. Scores, preference values, and model parameters are accepted according to established methodological convention and then subjected to arithmetic. Yet statistical sophistication and modelling cannot establish measurement retrospectively. Unless the scale properties of the target attribute are demonstrated before

quantitative claims are advanced, the legitimacy of subsequent numerical operations remains unresolved. The limiting negative logit reflects the near absence of measurement status as a gatekeeping requirement for HTA analysis.

5. The axioms of representational measurement underpin quantitative claims

Probability: 0.05 | Logit: −2.50

Representational measurement does not appear to provide a foundation for the Singapore HTA curriculum knowledge base. There is little indication that students are required to understand quantitative measurement as a lawful mapping from an empirical relational structure to a numerical relational structure or to examine requirements such as order, additivity, cancellation, solvability, invariance, and admissible transformations. Instead, established instruments and analytical conventions provide the numerical inputs for assessment. The distinction between assigning numbers and constructing measures is consequently obscured. The probability of 0.05 reflects the effective absence of representational measurement as the scientific framework governing the admissibility of quantitative claims concerning therapy impact.

6. Attributes must be demonstrated to be unidimensional before measurement is possible

Probability: 0.10 | Logit: −2.20

Unidimensionality may be encountered within psychometrics or scale-validation research, but it is not imposed as a necessary condition for measurement throughout Singaporean HTA. The continued acceptance of multiattribute health-status instruments illustrates the problem. Mobility, pain, emotional status, self-care, and usual activities may be combined into a single numerical index without demonstrating that they represent one common attribute. Aggregation into a single score does not create unidimensionality. If a quantitative measure is intended to represent one attribute, the empirical structure must first demonstrate that a single construct is being measured. The low probability indicates that unidimensionality is treated as a methodological consideration in selected applications rather than as a universal prerequisite for measurement.

7. A manifest attribute is directly observable and capable of supporting empirical observation

Probability: 0.70 | Logit: +0.85

This is the sole statement receiving positive endorsement. Singaporean healthcare assessment makes extensive use of directly observable clinical and resource outcomes, including mortality, hospital admissions, hospital days, procedures, treatment events, medication use, and adverse events. These provide familiar empirical observations and, where appropriately defined, may support conventional ratio measurement. The positive probability reflects this strong practical orientation toward observable healthcare data. However, recognition of observable outcomes is not necessarily embedded within an explicit theory of manifest attributes or ratio measurement. The curriculum uses these observations extensively but does not consistently contrast their

measurement properties with the fundamentally different requirements involved in constructing measures of latent attributes.

8. A latent attribute is not directly observable and requires a measurement model to estimate possession of the attribute

Probability: 0.20 | Logit: −1.39

Singaporean researchers are likely to recognize that attributes such as pain, fatigue, depression, and physical functioning cannot be observed directly. The curriculum failure arises in the response to this problem. Questionnaire responses, summed scores, factor scores, utilities, and other numerical representations are routinely accepted without requiring a measurement model capable of estimating possession of a defined latent attribute. Item responses are observations; they are not themselves measures of the latent construct. The probability of 0.20 reflects partial recognition of latent constructs but limited acceptance of the requirement for conjoint measurement and invariant estimation of possession. Rasch measurement may appear in individual research applications, but it does not govern the admissibility of latent-attribute claims within HTA.

9. Manifest and latent attributes require different forms of ratio measurement

Probability: 0.05 | Logit: −2.50

The distinction between manifest and latent forms of ratio measurement is effectively absent from the Singapore HTA curriculum knowledge base. Manifest attributes such as hospital days may support a linear ratio scale with a meaningful zero, while latent attributes require a measurement model capable of constructing a continuum of possession. Within the Rasch framework, persons and items are located conjointly on a logit scale, with ratios expressed through the corresponding odds. These are fundamentally different measurement problems. Conventional HTA instead treats counts, scores, utilities, and model estimates as numerical inputs within a common analytical framework. The limiting negative logit reflects the failure to recognize that the empirical status of the attribute determines the form of ratio measurement required.

10. Therapy impact claims must be falsifiable

Probability: 0.15 | Logit: −1.73

Singaporean HTA emphasizes evidence quality, uncertainty analysis, model validation, and informed decision making, but these are not equivalent to requiring therapy-impact claims to be falsifiable. A falsifiable claim must specify the target attribute, admissible measure, population, comparator, timeframe, success criterion, and rule for empirical failure in advance. Reference-case simulations and cost-effectiveness models instead generate conditional conclusions from assumptions, selected evidence, utility values, and extrapolations. When results are challenged, assumptions or model structures may be revised rather than the therapy-impact claim being decisively rejected. The low probability reflects the absence of prospective falsifiability as a governing curriculum requirement and the substitution of model evaluation for direct empirical testing of quantitative claims.

MANIFEST AND LATENT ATTRIBUTES: THE MISSING FOUNDATION OF SINGAPOREAN HTA

A central finding of the Singapore curriculum interrogation is the absence of any explicit framework distinguishing manifest from latent attributes and the corresponding measurement requirements that follow from this distinction. This omission is particularly significant because the distinction between manifest and latent attributes is not a methodological refinement but one of the foundational concepts of representational measurement. Without it, there is no coherent basis for determining how therapy outcomes should be measured, what constitutes a lawful quantitative claim, or whether the arithmetic applied within HTA is scientifically admissible.

Manifest attributes are directly observable. Their existence and magnitude can be established through empirical observation without the need for an intervening measurement model. Examples include survival time, hospital admissions, emergency department visits, medication adherence, treatment discontinuation, adverse events, laboratory values, and healthcare resource utilization. These attributes are observable phenomena that can be counted, timed, or otherwise recorded directly. When properly specified, they support linear ratio measures with a meaningful zero and lawful arithmetic operations. The scientific task is straightforward: define the attribute, establish the unit of observation, specify the observation period, and subject the resulting claim to empirical evaluation and independent replication.

Latent attributes present a fundamentally different measurement problem. Pain, fatigue, depression, anxiety, physical functioning, treatment satisfaction, health confidence, and need fulfilment cannot be observed directly. Their existence must be inferred from observable indicators, typically responses to structured questionnaire items. Consequently, latent attributes require a measurement model capable of estimating possession of the attribute while satisfying the axioms of representational measurement. Within HTA this requirement is met through Rasch measurement, which provides a logit ratio measure possessing the properties required for lawful quantitative inference.

The importance of this distinction cannot be overstated. Manifest attributes require linear ratio measures, whereas latent attributes require Rasch logit ratio measures. These are the only two measurement frameworks capable of supporting lawful quantitative claims regarding therapy impact. The distinction therefore determines the entire measurement strategy adopted within HTA.

The interrogation suggests that the Singapore curriculum knowledge base does not recognize this distinction as an organizing principle for HTA education. Instead, outcomes are organized within broad methodological categories such as patient-reported outcomes, health-related quality of life, utility assessment, clinical effectiveness, evidence synthesis, health economics, economic evaluation, value assessment, and decision-analytic modelling. These categories are operationally useful but scientifically inadequate because they fail to distinguish between directly observable attributes and attributes requiring a measurement model. The measurement requirements governing each type of outcome consequently remain obscured.

Once this distinction disappears, virtually any numerical output can be treated as though it possesses equivalent measurement status. Utility scores, preference weights, composite indices,

patient-reported outcome scores, observational counts, resource-use measures, and model outputs are incorporated within the same analytical framework despite possessing fundamentally different measurement properties. The consequence is a loss of measurement discipline in which numerical construction is mistaken for quantitative measurement.

For Singapore, this omission has particular significance. Singapore possesses a highly developed and centrally coordinated HTA environment supported by substantial expertise in health economics, epidemiology, public health, pharmacy, health services research, evidence synthesis, biostatistics, and healthcare evaluation. The Agency for Care Effectiveness, together with the National University of Singapore, Duke-NUS Medical School, and associated academic and research groups, provides an integrated institutional framework for the development and application of HTA methodology. Singapore cannot readily be characterized as a system that adopted HTA without sufficient scientific resources. It has had both the institutional stability and the academic capacity to develop rigorous methodological foundations for quantitative therapy assessment.

This makes the absence of the manifest–latent distinction more consequential rather than less. The scientific disciplines required to recognize the distinction are present. Psychometrics recognizes latent constructs. Epidemiology and clinical research routinely investigate observable outcomes. Statistics distinguishes between different forms of data and the mathematical operations they support. Health economics is explicitly concerned with quantitative comparison, while pharmacy and health services research focus on the evaluation of therapy outcomes. Yet these disciplinary contributions have not been integrated within a common representational measurement framework that begins by asking whether the target attribute is manifest or latent.

Instead, the internationally accepted HTA reference-case paradigm appears to provide the organizing architecture for Singaporean HTA education. Utilities, QALYs, cost-effectiveness analysis, patient-reported outcome instruments, evidence synthesis, and decision-analytic modelling are taught as accepted methodological components of therapy assessment. Educational competence is therefore defined largely by the ability to understand, apply, and interpret these methods. The prior scientific question—whether different classes of therapy outcome require fundamentally different forms of measurement—remains outside the curriculum framework.

The Singapore case therefore illustrates how curriculum inversion can persist within an exceptionally well-organized and technically sophisticated healthcare system. The problem is not a lack of quantitative expertise or analytical capability. Rather, measurement science has not been established as the overarching framework governing the diverse disciplines that contribute to HTA. Each discipline supplies methods, instruments, statistical procedures, models, and numerical outputs, yet no prior measurement framework determines whether these outputs constitute lawful measures or whether the arithmetic subsequently applied to them is scientifically admissible.

If the distinction between manifest and latent attributes continues to be absent from Singaporean HTA education, the same omission will continue to be reproduced throughout health economics, evidence synthesis, pharmacy, public health, outcomes research, healthcare evaluation, and professional practice. Until this distinction becomes an organizing principle of Singaporean HTA

education, curriculum inversion will continue to reinforce the measurement inversion embedded within the contemporary reference-case paradigm.

Singapore's challenge is therefore not simply to add greater coverage of measurement theory to an otherwise unchanged curriculum. The educational framework itself must be reorganized around the nature of the target attribute and the corresponding form of lawful ratio measurement required to evaluate therapy impact. The first question in every therapy assessment must become: what is the attribute? The second must be: is it manifest or latent? Only after these questions have been answered can the appropriate measurement framework be selected and quantitative claims legitimately advanced.

THE ABSENCE OF RASCH IN SINGAPOREAN HTA

The absence of the manifest–latent distinction also explains the marginal position of Rasch measurement within the Singapore HTA curriculum knowledge base. If latent attributes are not explicitly recognized as requiring a measurement model, there is no perceived need to introduce the one measurement framework capable of constructing lawful quantitative measures of latent attribute possession. Instead, ordinal questionnaire responses are transformed into utility scores, composite indices, and quality-adjusted life years (QALYs), and subsequently treated as though measurement has already been achieved. The measurement problem is therefore bypassed rather than solved.

From the perspective of curriculum design, this represents a classic example of curriculum inversion. Students are introduced to utilities, QALYs, patient-reported outcomes, health economics, cost-effectiveness analysis, and decision-analytic modelling before they are taught to distinguish between manifest and latent attributes. Consequently, they are not encouraged to ask the fundamental scientific questions that should precede every HTA assessment: What is the target attribute? Is it manifest or latent? Which lawful form of ratio measurement is required?

For Singapore, this omission is particularly significant because HTA is embedded within a highly organized and technically sophisticated academic and assessment environment. Singaporean universities and research institutions possess substantial expertise in health economics, epidemiology, public health, pharmacy, health services research, psychometrics, outcomes research, and quantitative methods. The Agency for Care Effectiveness, together with the National University of Singapore, Duke-NUS Medical School, and associated research groups, has created a coherent institutional framework for evidence assessment and economic evaluation. The intellectual resources required to recognize the problem of latent attribute measurement are therefore present. Yet that problem has not acquired a foundational position within mainstream HTA education.

Singapore has developed within the international HTA environment in which economic evaluation, cost-utility analysis, utility measurement, QALYs, and reference-case modelling possess substantial institutional legitimacy. Professional competence has consequently become associated with proficiency in utility assessment, QALY construction, cost-effectiveness analysis, uncertainty analysis, and decision modelling. The prior scientific question of whether patient-reported observations have been transformed into lawful measures of latent attribute possession

remains outside the mainstream curriculum. Methodological sophistication has refined the accepted analytical framework without requiring reconsideration of its measurement foundations.

This places Rasch in a unique position. Rasch is not simply another psychometric technique competing with item response theory, PROMIS, utility instruments, or preference-based scoring systems. It addresses an entirely different scientific problem. Its purpose is to determine whether ordinal observations can be transformed into a quantitative measure of possession of a latent attribute. In doing so, it provides the only established framework capable of demonstrating whether the conditions required for measurement have been satisfied.

The distinction is fundamental. Patient-reported outcomes begin with ordinal responses to questionnaire items describing pain, fatigue, depression, anxiety, physical functioning, treatment satisfaction, need fulfilment, and other latent attributes. These responses provide information about order but not quantity. Arithmetic performed directly on ordinal observations cannot create measurement. Summed scores, averages, weighted algorithms, utility values, and preference functions remain numerical constructions unless it has first been demonstrated that the underlying latent attribute has been measured. Numerical manipulation is not measurement.

Rasch measurement was developed precisely to solve this problem. Through the conjoint calibration of persons and items, the Rasch model estimates the location of individuals on a latent continuum while simultaneously testing whether the observations satisfy the conditions required for lawful measurement. Unidimensionality, specific objectivity, invariance, item fit, response-category functioning, local independence, and differential item functioning are not optional methodological refinements. They are empirical conditions that must be satisfied before a claim regarding possession of a latent attribute can be advanced. Rasch therefore provides both the measurement model and the empirical tests necessary to determine whether measurement has actually been achieved.

The interrogation indicates that this perspective is not embedded within the Singapore HTA curriculum knowledge base. Rasch methods may occasionally appear within specialist psychometrics, rehabilitation research, psychology, outcomes measurement, or instrument development, but they do not occupy the required foundational position within mainstream HTA education. Students and practitioners are introduced to patient-reported outcomes, utilities, multiattribute health-status instruments, preference weights, QALYs, economic evaluation, and decision models without first confronting the measurement problem these constructs are intended to solve. The educational sequence moves directly from ordinal responses to scoring systems, utility algorithms, and economic models. The essential intermediate step of demonstrating that a latent attribute has been measured is effectively bypassed.

This omission has profound implications. Without Rasch measurement, latent attributes remain unmeasured. Utility scores, composite indices, and preference algorithms may generate numerical outputs, but they do not establish that the underlying attribute has been measured. The existence of a number should never be confused with the existence of a measure. Nevertheless, the Singapore HTA curriculum proceeds as though this distinction does not exist. Students consequently learn how utilities are generated, how QALYs are constructed, and how reference-case models are populated, yet they are not taught how latent attributes themselves can be measured. The

curriculum therefore introduces numerical representations of patient benefit before introducing the scientific framework required to justify those representations. This is curriculum inversion in its clearest form.

For Singapore, the integrated nature of the HTA environment gives this omission additional significance. University teaching, health economics, public health, pharmacy, evidence synthesis, health services research, outcomes research, and national assessment practice are closely interconnected. Methodological expectations established within the Agency for Care Effectiveness are reinforced through university teaching and professional practice, while graduates entering the healthcare system reproduce the same analytical framework. Once utilities, QALYs, and decision-analytic modelling become accepted professional competencies, curricula naturally evolve to support those expectations. The absence of Rasch measurement is therefore not simply a gap within specialist psychometric training. It represents the absence from mainstream Singaporean HTA of the measurement framework required to evaluate latent therapy outcomes.

The Singapore case is particularly revealing because the relevant scientific expertise is already available. The omission cannot readily be attributed to a lack of quantitative sophistication, academic capability, or familiarity with advanced analytical methods. Rather, it reflects a failure to position the measurement of latent attributes as a prior scientific requirement for therapy assessment. Until Rasch measurement occupies this foundational position within Singaporean HTA education, curriculum inversion will continue to reproduce the broader pattern of measurement inversion identified throughout the Singapore HTA knowledge base.

CONCLUSION: CURRICULUM INVERSION AND THE FUTURE OF HTA IN SINGAPORE

The companion interrogation of the Singapore HTA knowledge base demonstrated that contemporary health technology assessment in Singapore is characterized by measurement inversion. The accepted principles of representational measurement receive little recognition, while utilities, quality-adjusted life years (QALYs), cost-effectiveness analysis, and reference-case modelling continue to be treated as though they provide scientifically valid quantitative measures of therapy impact. The present study has addressed the complementary question of how this framework is transmitted, sustained, and reproduced across successive generations of practitioners. The answer is curriculum inversion.

The interrogation demonstrates that the Singapore HTA curriculum knowledge base introduces students and practitioners to the methods of contemporary HTA before introducing them to the scientific principles required to evaluate those methods. Educational emphasis is placed upon comparative effectiveness, health economics, economic evaluation, utilities, QALYs, decision modelling, evidence synthesis, patient-reported outcomes, healthcare policy, and healthcare assessment rather than upon specification of the target attribute, representational measurement, admissible arithmetic, unidimensionality, manifest and latent attributes, Rasch measurement, dimensional homogeneity, and the requirement that therapy-impact claims be prospectively evaluable, independently replicable, and capable of falsification. Graduates therefore acquire technical competence in applying the contemporary HTA framework without first acquiring the scientific framework necessary to determine whether it supports lawful quantitative claims.

For Singapore, this conclusion has particular significance. Singapore possesses a highly developed and internationally respected healthcare system supported by substantial expertise in medicine, pharmacy, public health, epidemiology, biostatistics, health economics, health services research, evidence synthesis, and healthcare evaluation. The Agency for Care Effectiveness provides a nationally coordinated focus for health technology assessment and methodological guidance, while the National University of Singapore, Duke-NUS Medical School, and associated academic and research groups provide a strong educational and scientific infrastructure. Singapore is not a health system that adopted HTA without the opportunity to develop robust methodological foundations. It is a mature and technically sophisticated participant in the international HTA community with the institutional capacity to establish measurement as the foundation of quantitative assessment.

The persistence of curriculum inversion in this environment is therefore particularly difficult to defend. The scientific disciplines required to recognize the measurement problem are already present. Psychometrics addresses latent constructs. Statistics is concerned with the properties of data and permissible inference. Epidemiology distinguishes observations, outcomes, and study designs. Health economics depends upon quantitative comparison. Pharmacy, medicine, and health services research are fundamentally concerned with evaluating therapy outcomes. Yet these disciplines have not been integrated within a common framework of representational measurement. The result is a multidisciplinary HTA environment in which each discipline contributes methods and numerical outputs, but no overarching measurement discipline determines whether those outputs constitute lawful measures.

The interrogation indicates that curriculum inversion has become the mechanism through which measurement inversion is reproduced. Utilities, QALYs, cost-effectiveness ratios, patient-reported outcome scores, and reference-case simulation models enter teaching and professional practice without first satisfying the requirements for lawful measurement. The technical sophistication of Singaporean HTA has not corrected this failure. On the contrary, continuing methodological refinement has allowed the accepted analytical framework to become increasingly sophisticated while its measurement foundations remain unexamined. Analytical development has institutionalized the prevailing paradigm rather than subjected it to first-principles scientific scrutiny.

This conclusion leaves no room for incremental reform. A framework whose constituent quantities fail the axioms of representational measurement cannot be rescued through improved modelling, better utility instruments, more sophisticated statistical or econometric methods, expanded real-world evidence, richer administrative health data, artificial intelligence, or increasingly elaborate simulation techniques. None of these developments can create measurement where measurement does not exist. Arithmetic cannot rescue quantities that are not measures. The persistence of the problem despite Singapore's considerable scientific expertise demonstrates that the failure lies beneath the methodology itself—in the absence of lawful measurement.

The implications for Singaporean universities are therefore direct. Continuing to educate students in utility assessment, QALY construction, cost-effectiveness analysis, and reference-case modelling without first teaching the scientific principles governing lawful measurement is incompatible with the central purpose of higher education. Universities exist to advance objective

knowledge rather than perpetuate analytical traditions whose measurement foundations cannot support quantitative claims. Students should certainly understand the historical development and policy influence of utilities, QALYs, patient-reported outcome instruments, cost-effectiveness analysis, and reference-case modelling, but they should understand them as examples of a methodological paradigm that failed to satisfy the accepted standards governing quantitative science. They should not be taught that these constructs provide valid measures of therapy impact because they do not.

The implications extend well beyond the universities. Singapore's HTA system depends upon practitioners trained to prepare, review, interpret, and apply economic evaluations and model-based assessments. The Agency for Care Effectiveness, university research groups, health economists, clinicians, pharmacy researchers, public health specialists, consultants, and the life sciences sector all operate within a common methodological framework. Universities teach the methods expected by the national assessment system; researchers refine and apply those methods; manufacturers prepare submissions within the accepted framework; assessment bodies evaluate those submissions according to the same conventions; and professional training reinforces the competencies required by this integrated system. At no point is there a systematic requirement to return to the prior scientific question: are the quantities being manipulated lawful measures?

The Singapore case is particularly revealing because the usual defence of methodological immaturity is unavailable. Singapore possesses the institutions, scientific disciplines, academic expertise, analytical capability, and organizational coherence required to recognize the measurement problem. The continued absence of representational measurement can therefore no longer be regarded as an early stage in the evolution of HTA. Rather, it represents an intellectual closure in which accepted methods define the boundaries of methodological discussion. The paradigm continues to evolve internally through increasingly sophisticated analytical techniques, but its measurement assumptions remain largely insulated from scientific examination.

The only scientifically defensible path forward is reconstruction. Every HTA assessment should begin with explicit specification of the target attribute. Manifest attributes should be evaluated through lawful linear ratio measures. Latent attributes should be evaluated through Rasch logit ratio measures that satisfy the axioms of representational measurement. Every quantitative claim should be accompanied by a prospective protocol specifying the attribute, measurement method, comparator, evaluation period, replication strategy, and conditions for empirical falsification. Measurement must precede arithmetic in every assessment without exception.

Taken together, the companion interrogations of measurement inversion and curriculum inversion demonstrate that the methodological framework underpinning Singaporean HTA has reached its intellectual limit. It has undoubtedly contributed to the development of sophisticated economic evaluation, evidence synthesis, healthcare assessment, and evidence-informed policy, yet it has failed to establish the scientific legitimacy of the quantities upon which its quantitative claims depend. That framework has no scientific future because it rests upon measurement impossibilities. Its place is no longer at the centre of HTA education but in the history of the discipline as an instructive example of how methodological sophistication can develop independently of measurement science.

Singapore now faces a clear choice. It can continue to reproduce measurement inversion through a curriculum designed to supply practitioners proficient in the established international reference-case paradigm, or it can redefine professional competence around the requirements of quantitative science. The future of Singaporean HTA depends not upon further refinement of an analytically sophisticated but measurement-deficient framework. It depends upon replacing that framework with one founded on representational measurement, lawful quantitative inference, and prospectively evaluable, independently replicable, and falsifiable claims regarding therapy impact.

To facilitate this transition, Maimon Research LLC has developed a comprehensive nine-unit HTA Reconstruction Program [5]. The program provides a systematic introduction to representational measurement, the theory of attributes, the principal scales of measurement, admissible arithmetic, dimensional homogeneity, manifest and latent attributes, Rasch logit ratio measurement, protocol development, and the construction of evaluable, replicable, and falsifiable claims regarding therapy impact. Its purpose is not to modify the existing reference-case paradigm but to replace it with a scientific framework in which measurement once again precedes arithmetic.

The program has been designed for universities, HTA agencies, reimbursement organizations, research centers, professional societies, pharmaceutical companies, and health economists seeking a transition from assumption-driven modelling to scientifically defensible measurement. It provides a structured pathway for professional development while establishing the competencies required for the next generation of HTA practitioners. In this way, it offers not simply a critique of the existing paradigm but a practical route toward the reconstruction of HTA as a measurement-based scientific discipline.

ACKNOWLEDGEMENT

I acknowledge that I have used OpenAI technologies, including the large language model, to assist in the development of this work. All final decisions, interpretations, and responsibilities for the content rest solely with me.

REFERENCES

[1] Singapore: The absence of representational measurement in health technology assessment. Logit Working Paper No 385. https://maimonresearch.com/logit-working-paper-no-385-may-2026/

[2] Stevens S. On the Theory of Scales of Measurement. *Science*. 1946;103(2684):677-80

[3] Krantz D, Luce R, Suppes P, Tversky A. Foundations pf Measurement Vol 1: Additive and Polynomial Representations. New York: Academic Press, 1971

[4] Bond T, Zi Yan, Heene M. Applying the Rasch Model: Fundamental Measurement in the Human Sciences (4th Ed). New York Routledge, 2021

[5] Maimon Research. HTA Reconstruction. https://maimonresearch.com/hta-reconstruction-program-and-fees/