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**REPRESENTATIONAL MEASUREMENT FAILURE IN  
HEALTH TECHNOLOGY ASSESSMENT**

**AUSTRALIA: THE HTA CURRICULUM AND THE  
ABSENCE OF REPRESENTATIONAL MEASUREMENT**

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## **ABSTRACT**

*Recent large language model (LLM) interrogations of health technology assessment (HTA) knowledge bases across multiple countries have revealed a consistent pattern of measurement inversion. Across reimbursement agencies, research centers, journals, professional organizations and educational programs there is little recognition of scales of measurement, representational measurement, unidimensionality, ratio scales and the distinction between manifest and latent attributes. At the same time, quantitative claims regarding therapy impact continue to rely upon analytical frameworks that assume these concepts are understood and applied. The persistence and international consistency of these findings raises an important question: does measurement inversion originate, at least in part, from deficiencies in HTA education and training?*

*This paper addresses that question through an interrogation of the curriculum knowledge bases associated with seven Australian HTA research centers together with the Pharmaceutical Benefits Advisory Committee (PBAC). The curriculum knowledge base is defined as the collection of publicly accessible materials that contribute to HTA education and training, including curriculum descriptions, teaching materials, methodological guidance, research outputs and professional development resources. Ten canonical curriculum statements were developed to represent the minimum concepts required for a measurement-based approach to therapy assessment. These statements address attributes, scales of measurement, representational measurement, unidimensionality, manifest and latent attributes, ratio measurement and falsifiable claims.*

*The results reveal a consistent pattern across all centers. There is moderate recognition of outcomes, target attributes and scientific claims. However, there is little evidence that students and researchers are systematically exposed to the foundations of measurement science. Endorsement of representational measurement, unidimensionality, latent attribute measurement and ratio measurement is uniformly low. The concepts most frequently absent from curriculum coverage are the same concepts most frequently absent from HTA practice.*

*These findings suggest that curriculum deficiencies provide a plausible explanation for the persistence of measurement inversion within HTA. Researchers appear to be trained in the application of analytical methods without equivalent exposure to the measurement principles necessary to evaluate the validity of quantitative claims. The consequence is an educational environment in which numerical competence is mistaken for measurement competence. The paper concludes that the curriculum knowledge bases of PBAC and the seven Australian HTA research centers exhibit substantial deficiencies in coverage of the foundational concepts required for lawful quantitative claims. Curriculum reform therefore emerges as a necessary precursor to any broader reconstruction of HTA.*

## **INTRODUCTION**

Curriculum coverage in any subject area must ensure, particularly for professional programs such as health technology assessment (HTA), that it is sufficiently broad to equip graduates with the skills and standards of normal science. Students should not simply be trained in the application of

established methods. They must also understand the conceptual foundations upon which those methods rest and possess the ability to evaluate whether the claims generated by those methods are scientifically credible.

For quantitative disciplines, this requirement begins with measurement theory. Students should be introduced to the principal scales of measurement—nominal, ordinal, interval and ratio—and understand the properties and limitations associated with each scale. They should recognize that arithmetic operations are not universally applicable and that the admissibility of addition, subtraction, multiplication and division depends upon the measurement properties of the quantities involved. Above all, they should understand the fundamental principle that measurement precedes arithmetic. Before numerical operations can be undertaken, it must first be demonstrated that the quantities concerned satisfy the requirements of measurement.

A core curriculum must therefore address the concept of attributes. Every empirical claim regarding therapy impact concerns an attribute of interest. The first question in any assessment is not which analytical method should be applied but what attribute is being measured and whether that attribute possesses the properties required to support quantitative claims. This introduces students to the distinction between manifest attributes, which are directly observable, and latent attributes, which require a measurement model to estimate possession of the attribute. Equally important is the requirement that attributes be demonstrated to be unidimensional before measurement is possible.

Students should also be introduced to the axioms of representational measurement that underpin quantitative reasoning throughout the sciences. Without an understanding of these principles there is no basis for evaluating whether numerical claims are legitimate. A curriculum that neglects measurement theory risks producing graduates who are proficient in the use of analytical techniques but unable to assess whether the outputs generated by those techniques have scientific meaning.

Finally, the curriculum must emphasize that scientific claims are provisional and subject to challenge. Quantitative claims regarding therapy impact should be evaluable, replicable and capable of falsification. The objective of HTA is not the construction of increasingly complex numerical models but the generation of credible empirical claims that can be tested against observation. A curriculum that fails to provide these foundations may train analysts, but it cannot train scientists.

The purpose of this paper is to evaluate the curriculum coverage of HTA within programs and training environments associated with seven Australian HTA research centers together with the Pharmaceutical Benefits Advisory Committee (PBAC). The assessment is not directed towards specific courses or individual instructors but towards the broader curriculum knowledge base that informs teaching, research and professional development. To achieve this objective, a series of canonical curriculum coverage statements was developed to represent the minimum concepts required for a measurement-based approach to therapy assessment. These statements address attributes, scales of measurement, representational measurement, unidimensionality, manifest and latent attributes, ratio measurement and falsifiable claims. The curriculum knowledge base associated with each research centre was then interrogated to determine the extent to which these

foundational concepts are present or absent. The resulting profile provides an indication of whether students and researchers are likely to be exposed to the principles necessary to support lawful quantitative claims regarding therapy impact and, consequently, whether existing curricula provide an adequate foundation for the reconstruction of HTA.

## **THE IMPERATIVE OF MEASUREMENT INVERSION**

The starting point for any reconstruction of health technology assessment (HTA) must be an understanding of the scale and consistency of the measurement inversion that characterizes the field. Over the past several months, a series of large language model (LLM) interrogations has been undertaken to evaluate HTA knowledge bases across multiple jurisdictions. These interrogations have encompassed national reimbursement agencies, academic research centers, professional organizations, journals, pharmacy schools and HTA teaching programs in Australia, Canada, New Zealand, the United Kingdom, Europe, Singapore and the United States. Although the institutions differ in structure, mission and geographical location, the results have been remarkably consistent. The same pattern of measurement inversion appears irrespective of country, discipline or organizational setting.

The concept of measurement inversion is straightforward. In the physical and social sciences, measurement precedes arithmetic. Before quantities can be added, multiplied, transformed or modelled, the measurement properties of those quantities must first be established. HTA reverses this sequence. Numerical operations are routinely undertaken without demonstrating that the quantities involved satisfy the requirements of measurement. Arithmetic is treated as a substitute for measurement rather than a consequence of measurement. The result is a framework in which numerical manipulation takes precedence over the validation of the quantities being manipulated.

The LLM interrogations reveal this inversion repeatedly. Across institutions there is little awareness of scales of measurement, the distinction between ordinal, interval and ratio scales, the role of unidimensionality, the axioms of representational measurement, dimensional homogeneity, or the distinction between manifest and latent attributes. At the same time, there is widespread endorsement of analytical frameworks that depend upon precisely those concepts. Utilities are treated as though they possess interval or ratio properties. Quality-adjusted life years are accepted as quantitative measures despite the absence of demonstrable ratio-scale foundations. Reference-case simulation models are employed to generate lifetime cost-effectiveness claims without establishing the measurement properties of the underlying inputs. The pattern is universal. The details vary from one institution to another, but the underlying logic remains unchanged.

The significance of these findings lies not merely in the demonstration of measurement failure but in the realization that measurement inversion is now institutionalized. It is embedded in teaching programs, methodological guidance, research publications and policy frameworks. Researchers entering the field encounter an intellectual environment in which the requirements of measurement are rarely discussed and almost never presented as prerequisites for quantitative claims. Consequently, the acceptance of measurement inversion becomes self-reinforcing. Successive generations of researchers inherit analytical frameworks without being introduced to the measurement principles required to evaluate them.

This observation raises an obvious question. If measurement inversion is so widespread and persistent, where does it originate? The answer cannot be found solely in research practice or policy guidance. Attention must also be directed toward education. If the concepts necessary to recognize measurement failure are absent from the curriculum, then measurement inversion becomes the expected outcome rather than an isolated error. Researchers cannot be expected to evaluate measurement claims if they have never been introduced to scales of measurement, representational measurement, ratio scales, unidimensionality, or the distinction between manifest and latent attributes.

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 observed in current HTA practice.

The curriculum interrogations undertaken across Australian HTA research centers and PBAC 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 LLM 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.

## **DEFINING THE KNOWLEDGE BASE**

The first step in any LLM interrogation is to define the knowledge base to be interrogated. The validity of the interrogation depends upon ensuring that the knowledge base reflects the information environment that shapes teaching, research and professional practice. In the present assessment, the curriculum knowledge base for each research centre is defined as the totality of publicly accessible materials that contribute to HTA education and training. These include curriculum descriptions, course outlines, program objectives, teaching materials, methodological guidance documents, seminar and workshop content, faculty publications, doctoral training resources, research centre reports, conference presentations, policy briefs and other materials through which knowledge is communicated to students, researchers and professional staff.

The objective is not to evaluate individual courses or instructors but to assess the broader intellectual environment within which HTA concepts are introduced, reinforced and transmitted. The resulting curriculum knowledge base is assumed to represent the concepts and principles that students and researchers are most likely to encounter during their exposure to the research centre and its associated educational activities. It is this knowledge base that is interrogated to determine the extent to which the foundational concepts required for a measurement-based approach to therapy assessment are present, absent or only weakly represented.

## **INTERROGATING THE CURRICULUM**

The identification of measurement inversion across HTA research centers, reimbursement agencies and academic programs raises an obvious question: where does this inversion originate? If the same conceptual failures are observed repeatedly across institutions and jurisdictions, then the explanation cannot rest solely with individual researchers, policy analysts or decision makers. A more plausible explanation is that these failures reflect deficiencies in the educational environment that prepares future HTA practitioners. If concepts central to measurement science are absent from curriculum content, then their absence from research practice should not be surprising. This realization provides the rationale for interrogating the curriculum.

The objective of curriculum interrogation differs from that of previous HTA knowledge-base 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 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 researchers do, attention is directed to what they are taught.

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 researchers 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. If measurement inversion is widespread, then one possibility is that the educational foundations required to recognize and avoid measurement inversion 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 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.

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**

Together they define the minimum curriculum content required for a measurement-based approach to HTA and provide the framework for evaluating curriculum coverage in Australian HTA research centers and PBAC.

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.

## **CURRICULUM INTERROGATION RESULTS**

At first sight these findings might appear encouraging (Table 1) They suggest that Australian HTA education and research centers are concerned with outcomes, empirical evaluation and the assessment of claims. Yet this impression changes dramatically when attention shifts from outcomes to measurement.

The most striking feature of the results is the uniformly low endorsement of concepts that define the foundations of measurement science. Awareness of the principal scales of measurement remains weak across all centers. Probabilities range only from 0.20 to 0.25. While nominal, ordinal, interval and ratio scales are among the most basic concepts in measurement theory, there is little evidence that they occupy a significant place within the curriculum knowledge base.

The situation becomes even more pronounced when attention turns to representational measurement. Across PBAC and all seven research centers, the proposition that the axioms of representational measurement underpin quantitative claims receives a probability of only 0.05. This is the lowest possible level of endorsement and is one of the most important findings in the assessment.

Representational measurement provides the foundation upon which quantitative claims are constructed throughout the natural and social sciences. The axioms of order, cancellation, solvability, additivity and admissible transformation determine whether a quantity can legitimately support arithmetic operations. If students and researchers are not exposed to these concepts, then there is little reason to expect that they will subsequently evaluate the measurement properties of the claims and instruments they employ.

A similar pattern is observed for unidimensionality. Across all centers, endorsement of the proposition that attributes must be demonstrated to be unidimensional before measurement is possible remains at 0.10. This finding is significant because unidimensionality is a prerequisite for both manifest and latent measurement. Without a single underlying attribute, there is no basis for claiming that numerical observations represent varying magnitudes of the same quantity.

The interrogation also examined awareness of manifest and latent attributes. Moderate endorsement is observed for the proposition that manifest attributes are directly observable, with probabilities ranging from 0.30 to 0.40. This is not surprising. Manifest attributes such as survival, hospital admissions, treatment persistence and physician visits are commonly encountered in health services research and outcomes assessment.

**TABLE 1: CURRICULUM CONTENT ENDORSEMENT: PBAC AND 7 AUSTRALIAN HTA RESEARCH CENTERS**

CANONICAL STATEMENT	CATEGORICAL PROBABILITY ENDORSEMENT							
	PBAC	MSPGH	CHE	HEG	CAHE	LEEDER	CHERE	DEAKIN
An attribute is the specific outcome of interest in a therapy assessment	0.75	0.75	0.75	0.70	0.70	0.75	0.75	0.65
Every therapy assessment begins with specification of the target attribute	0.65	0.65	0.65	0.60	0.60	0.65	0.65	0.55
The principal scales of measurement (nominal, ordinal, interval and ratio) have different properties and support different forms of analysis	0.20	0.25	0.25	0.20	0.20	0.20	0.25	0.20
The measurement status of a target attribute must be established before quantitative claims can be advanced	0.15	0.20	0.20	0.15	0.15	0.15	0.20	0.15
The axioms of representational measurement underpin quantitative claims	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Attributes must be demonstrated to be unidimensional before measurement is possible	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
A manifest attribute is directly observable and capable of supporting empirical observation	0.40	0.40	0.40	0.35	0.40	0.40	0.40	0.30
A latent attribute is not directly observable and requires a measurement model to estimate possession of the attribute	0.10	0.15	0.15	0.10	0.10	0.10	0.15	0.10
Manifest and latent attributes require different forms of ratio measurement	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Therapy impact claims must be falsifiable	0.80	0.75	0.75	0.65	0.70	0.70	0.70	0.60

Note PBAC: Pharmaceutical Benefits Advisory Committee; MSPGH : Melbourne School of Population and Global Health; CHE: Centre for Health Economics, Monash University; HEG: Health Economics Group, University of Adelaide; CAHE: Centre for Applied Health Economics, Griffith University; LEEDER: Center for Health Policy, University of Sydney; CHERE: Centre for Health Economics Research and Evaluation (UTS); Deakin: HTA group Deakin University

The situation is markedly different for latent attributes. Probabilities range only from 0.10 to 0.15 for the proposition that latent attributes are not directly observable and require a measurement model to estimate possession of the attribute. This finding suggests limited awareness of one of the most important distinctions in measurement science. Attributes such as pain, fatigue, depression, anxiety, physical functioning and need fulfilment cannot be observed directly. Their measurement requires a formal measurement model and an explicit theory of attribute possession. The low endorsement probabilities indicate that this distinction occupies little visible space within the curriculum knowledge base.

Perhaps the most revealing result concerns ratio measurement. Across PBAC and all seven centers, the proposition that manifest and latent attributes require different forms of ratio measurement receives a probability of only 0.05. This is a remarkable finding. Ratio measurement is not a specialized methodological preference. It is the foundation for quantitative comparison, multiplication, division and proportional reasoning. The absence of ratio measurement from the curriculum knowledge base suggests that students and researchers may receive extensive training in statistical and modelling techniques without first being exposed to the measurement principles that determine whether quantitative operations are legitimate.

Taken together, these findings identify a consistent pattern. Students and researchers appear to be introduced to outcomes, endpoints, claims assessment and policy evaluation. However, there is little evidence that they are systematically exposed to the conceptual foundations required to evaluate the measurement properties of those outcomes and claims. The result is a curriculum structure in which methods and applications receive attention while the principles that justify quantitative analysis remain largely absent.

The significance of these findings extends beyond curriculum design. They provide a plausible explanation for the results of the earlier measurement inversion interrogations. Those assessments demonstrated that Australian HTA research centers and PBAC routinely endorse propositions that conflict with representational measurement while failing to recognize the requirements for lawful quantitative claims. The present assessment suggests that these findings are not isolated methodological errors. Rather, they may reflect an underlying educational deficit.

In this sense, the curriculum assessment and the measurement inversion assessment are complementary. The measurement inversion interrogations identify the consequences of neglecting measurement science. The curriculum interrogations identify a possible source of that neglect. If concepts such as scales of measurement, representational measurement, unidimensionality, latent attributes and ratio measurement are largely absent from educational programs, then it is unsurprising that they are also absent from research practice and policy evaluation.

The implications for reconstruction are substantial. A transition to a measurement-based framework for HTA cannot begin solely with changes to analytical methods or decision frameworks. Reconstruction must also address the educational foundations upon which HTA is built. Students and researchers need exposure to the principles of measurement before they can evaluate the validity of quantitative claims. Without this foundation, attempts at methodological reform are likely to reproduce the same conceptual limitations that characterize current practice.

The findings therefore point to a challenge that is educational as well as methodological. If HTA is to move toward a framework based on lawful measurement, evaluable claims and empirical falsification, then curriculum content must expand to include the concepts that make such a framework possible. The present assessment suggests that these concepts remain largely absent from the Australian HTA educational environment.

The conclusion is straightforward. The curriculum knowledge bases of PBAC and the seven Australian HTA research centers demonstrate a substantial deficiency in coverage of the foundational concepts required for measurement-based therapy assessment. The resulting knowledge deficit maps closely to the measurement inversion identified in previous interrogations. Curriculum reconstruction therefore emerges as a necessary first step in any broader reconstruction of HTA.

## **A RESTRICTED CURRICULUM: THE ABSENCE OF REPRESENTATIONAL MEASUREMENT**

The results presented in Table 1 make clear there is only moderate recognition of outcomes and target attributes. There is also evidence that students and researchers are exposed to the concept of empirical claims and, to some extent, scientific falsification. These findings indicate that contemporary HTA curricula are not devoid of scientific content. Yet, students are taught how to perform calculations but not how to determine whether the quantities entering those calculations possess the properties necessary for arithmetic. They learn the mechanics of cost-effectiveness analysis before being introduced to the conditions required for quantitative claims. The consequence is that numerical competence is mistaken for measurement competence. Graduates may become highly proficient users of analytical techniques while remaining unfamiliar with the principles that determine whether those techniques generate scientifically meaningful results.

The most striking feature of the curriculum interrogations is the consistently low endorsement of concepts central to measurement science. There is little evidence that students are systematically introduced to scales of measurement and their properties. Awareness of representational measurement is almost entirely absent. Unidimensionality receives minimal recognition despite its role as a prerequisite for measurement. The distinction between manifest and latent attributes is largely ignored. Most significantly, there is little evidence that students are made aware of the critical role of ratio measurement in supporting quantitative claims.

This pattern is important because it mirrors the findings of the measurement inversion interrogations. The concepts that receive the lowest levels of endorsement in curriculum assessments are precisely those concepts that are absent from HTA practice. Researchers appear comfortable discussing outcomes, endpoints, evidence and policy implications. Yet there is little evidence that they have been exposed to the measurement principles necessary to determine whether those outcomes and claims possess the properties required for quantitative analysis. The curriculum findings therefore provide a plausible explanation for the persistence of measurement inversion.

The implications extend beyond Australia. The Australian centers were selected as a pilot assessment because they represent a mature and internationally recognized HTA community. If

deficiencies in curriculum coverage can be identified in such institutions, then there is reason to suspect that similar deficiencies may be present elsewhere. Indeed, the consistency of previous knowledge-base interrogations across multiple countries suggests that curriculum deficiencies may themselves be international in scope. The Australian research center results therefore have significance beyond the institutions examined. They point toward a broader educational problem within HTA.

The obvious yet difficult question is whether the contemporary HTA curriculum evolved in parallel with the requirements of the reference case, with the consequence that concepts central to measurement science gradually disappeared from view. It is clear from a number of evaluations presented in these logit papers that the reference case fails as a coherent assessment framework once we challenge its methods: the focus on the time trade-off technique and the valuation of health state descriptions, the application of TTO scores in econometric models, the creation of health description weights to populate utility algorithms, the status afforded utilities, the creation of QALYS and the construction of simulation models to produce non-falsifiable therapy outcomes and cost-effectiveness claims. These collapse once they are matched against the required standards for measurement, notably the ratio scale,

In the case of representational measurement, it is not whether its principles are correct, but how health technology assessment managed to proceed for over four decades while systematically ignoring them. The axioms of representational measurement were never hidden discoveries. By the early 1970s the framework had been formally articulated through *Foundations of Measurement*<sup>i</sup>. Stevens had already established the distinctions among nominal, ordinal, interval and ratio scales decades earlier<sup>ii</sup>. Rasch measurement and practical software implementations emerged during the late 1970s and 1980s, providing a coherent approach to transforming manifestations of latent attributes into lawful measures<sup>iii iv</sup>. The intellectual foundations existed. The methodological tools existed. The question therefore is not one of absence but one of avoidance.

Health technology assessment emerged during a period when economic evaluation and decision modelling became increasingly influential in healthcare policy. Policymakers wanted mechanisms for comparing therapies and allocating resources. Manufacturers sought frameworks capable of supporting claims concerning value. Agencies wanted standardized methods capable of generating apparently objective recommendations. Faced with these demands, HTA adopted methodological approaches that appeared practical and numerically attractive. Utility scores, composite outcomes, simulation models and cost-effectiveness ratios promised solutions.

The attraction was understandable. Decision makers wanted answers even when evidence was incomplete. Future outcomes could not always be observed directly. Long-term comparative evidence was often unavailable. Health systems nevertheless required decisions. Yet practical difficulty does not justify abandoning the standards of scientific measurement. The inability to satisfy evidentiary requirements does not permit the invention of quantities that fail to meet the axioms required for quantitative claims.

Just because the car will not start does not mean we substitute a bicycle and pretend we have solved the transportation problem. The substitute may move. It may appear useful. It may create the appearance of progress. But it cannot perform the function required of the original system. This

became the intellectual logic of HTA. Unable to establish lawful measures of value, the discipline substituted utility scores, QALYs and simulation outputs and proceeded as though the scientific destination remained unchanged. Arithmetic continued. Numbers proliferated. Sophisticated models emerged. But the vehicle chosen could never reach the destination claimed for it.

This represented a profound break with the standards governing every other quantitative discipline. In physics, engineering and the natural sciences, measurement precedes arithmetic. Attributes must first demonstrate lawful scale properties before mathematical operations can proceed. In HTA, this sequence was effectively reversed. Numbers were generated first, manipulated second and questioned rarely. Arithmetic became detached from measurement itself. A maintenance manual for the reference case holds center stage,

Educational systems reinforced this inversion. Once utility frameworks, QALYs and simulation methods entered textbooks and training programs, they acquired the status of accepted knowledge. Students learned how to calculate incremental cost-effectiveness ratios, construct reference-case models and interpret utility estimates, but were rarely asked whether the quantities entering these calculations possessed lawful measurement properties. Questions concerning unidimensionality, ratio scales, dimensional homogeneity and admissible transformations largely disappeared from view. Arithmetic itself became mistaken for evidence of legitimacy.

Professional structures completed the process. Journals, agencies, reporting standards and reference cases institutionalized common practices and assumptions. While standardization offered administrative consistency, it also produced intellectual closure. Entire professional communities can stabilize around conventions that escape foundational scrutiny. Assumptions cease to appear as assumptions. They become part of the environment itself. The result is a closed cognitive framework where methods reproduce themselves through repetition rather than through empirical challenge.

## **THE STATUS OF QUANTITATIVE CLAIMS**

The consequences are far more serious than methodological untidiness. HTA did not merely overlook a technical requirement. It abandoned the conditions necessary for quantitative claims themselves. Utilities remained ordinal preference structures while being treated as interval or ratio measures. QALYs combined incompatible dimensions while assuming dimensional coherence. Reference-case simulations generated elaborate numerical outputs detached from any possibility of empirical falsification. Cost-effectiveness claims acquired institutional authority despite violating the standards required to support arithmetic operations.

No other quantitative discipline has institutionalized such a rejection. No branch of physics, chemistry, engineering or measurement science begins by ignoring the scale properties of its variables and then proceeds as though arithmetic can rescue the situation. HTA stands alone. It constructed an entire evidentiary architecture upon assumptions that should have been interrogated at the outset. Four decades of methodological development therefore represent not cumulative scientific progress but cumulative measurement failure.

Recent large language model interrogations suggest that the consequences are now visible globally. Across agencies, journals, educational programs and research centers, representational measurement remains almost entirely absent. What emerges instead is systematic *measurement inversion*: a state in which the prerequisites for quantitative reasoning disappear while quantitative outputs proliferate. This is not a minor curriculum oversight, a historical accident or a technical gap. It is a complete failure of scientific stewardship.

The implications are unavoidable. Academic institutions, professional organizations and HTA agencies possessed a duty of care to distinguish numerical convenience from scientific legitimacy. That duty was not met. The result is a discipline that increasingly invites ridicule: a field that constructed increasingly elaborate quantitative architectures while neglecting the first question every science must ask: what exactly is being measured? Until measurement is restored as the prerequisite for arithmetic, HTA remains not a science of value assessment but a prolonged exercise in numerical storytelling.

## **CONCLUSION: FROM CRITICISM TO RECONSTRUCTION**

The most important contribution of curriculum interrogation is that it shifts the discussion from criticism to reconstruction. Measurement inversion identifies a problem. Curriculum interrogation identifies a source of that problem. The challenge is no longer limited to demonstrating methodological failure. It becomes a question of determining what concepts must be introduced if future generations of researchers are to avoid repeating the same mistakes. In this respect, curriculum interrogation provides a roadmap for reconstruction.

The findings also explain why proposals for HTA reconstruction often appear unfamiliar or even controversial. The reconstruction framework begins with attributes, scales of measurement, representational measurement, ratio measures, unidimensionality and Rasch measurement. Yet these are precisely the concepts that appear least visible within existing curricula. Consequently, the issue is not resistance to reconstruction but unfamiliarity with the concepts upon which reconstruction rests. Before researchers can evaluate the merits of a measurement-based framework, they must first be introduced to the principles that define it.

Interrogating the curriculum therefore represents an essential next step in the evolution of HTA. The purpose is not to assign blame but to understand how measurement inversion has become institutionalized. The evidence suggests that deficiencies in curriculum coverage have contributed directly to the reproduction of measurement failures across research centers and policy agencies. If this interpretation is correct, then reconstruction must begin with education. A measurement-based HTA requires a measurement-based curriculum. Without that foundation, the cycle of measurement inversion is likely to continue indefinitely.

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