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REPRESENTATIONAL MEASUREMENT FAILURE IN HEALTH TECHNOLGY ASSESSMENT

UNITED STATES: REPRESENTATIONAL MEASUREMENT—THE MISSING SCIENTIFIC FOUNDATION OF THE NATIONAL HTA/HEOR KNOWLEDGE BASE

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ABSTRACT

This paper examines the publicly available Health Technology Assessment and Health Economics and Outcomes Research (HTA/HEOR) program-content knowledge base of the United States to determine whether contemporary graduate education and research are founded upon the scientific requirements of representational measurement. The assessment applies a fixed 37-topic interrogation framework comprising 17 topics representing the foundations of lawful measurement and 20 topics representing the conventional analytical framework of contemporary HTA and health economics. Unlike previous large language model interrogations that estimated probabilities of endorsement, the present investigation examines whether these topics are explicitly represented within publicly available curricula, program descriptions, research priorities, methodological statements, educational resources and associated university-based activities across the national HTA/HEOR knowledge base.

The results identify complete program-content inversion. None of the seventeen representational-measurement topics is explicitly recognized as the scientific foundation for quantitative claims (0/17), while all twenty contemporary HTA topics are comprehensively represented (20/20). Absent are measurement preceding arithmetic, the axioms of representational measurement, scales of measurement as constraints on arithmetic, ratio measurement, admissible transformations, dimensional homogeneity, the distinction between manifest and latent attributes, lawful linear ratio measurement for manifest variables and Rasch logit ratio measurement for latent attributes. In contrast, health economics, economic evaluation, utilities, quality-adjusted life-years (QALYs), incremental cost-effectiveness ratios, decision analysis, simulation modelling, uncertainty analysis and related methods are universally represented throughout the national educational and research framework.

These findings indicate that the United States HTA/HEOR knowledge base reproduces an inherited analytical framework while omitting the scientific principles required to determine whether its arithmetic is lawful. The omission is systemic rather than institutional, extending across schools of pharmacy, schools of public health, medical schools, departments of health policy, university research centers and affiliated healthcare systems. The consequence is a national educational environment in which arithmetic and modelling precede measurement, reversing the scientific sequence required by normal quantitative science.

The paper concludes that representational measurement must become the organizing scientific principle of HTA education and research. Graduate training should begin with attributes, ratio measurement, admissible arithmetic and the distinction between manifest and latent attributes before introducing economic evaluation and decision modelling. Without this reconstruction, contemporary HTA remains an advanced technical methodology lacking the measurement foundations necessary to support credible, empirically evaluable and falsifiable quantitative claims.

INTRODUCTION

.Health technology assessment (HTA) depends upon quantitative claims. These claims are scientifically defensible only when measurement precedes arithmetic and the properties of the measurement scale permit the mathematical operations performed. Multiplication and division require ratio measurement; arithmetic must respect admissible transformations and dimensional homogeneity; and manifest and latent attributes require different approaches to measurement.

Previous interrogations of HTA knowledge bases in Australia, Canada, New Zealand and the United States have identified a consistent pattern of measurement inversion. The principles required for lawful measurement receive weak recognition, while utilities, QALYs, cost-effectiveness analysis and simulation modelling are strongly endorsed. Curriculum inversion reproduces the same failure educationally: students are introduced to the analytical methods of contemporary HTA without first being provided with the measurement principles required to determine whether the arithmetic underlying those methods is admissible.

The present investigation extends earlier institutional, research-center and state program-content assessments by examining the United States HTA and health economics and outcomes research program-content knowledge base as a whole. The United States provides the most extensive setting yet examined because of the scale, diversity and influence of its university-based academic healthcare environment. Major programs and research activities are distributed across schools of pharmacy, schools of public health, medical schools, departments of health policy and management, health economics programs, pharmaceutical outcomes research units, comparative effectiveness research centers and university-affiliated healthcare systems throughout the country. These activities encompass health economics, HTA, economic evaluation, outcomes research, health services research, pharmacoeconomics, patient-reported outcomes, health policy, value assessment and decision modelling. The United States therefore provides an exceptionally substantial national environment in which to examine the scientific foundations underlying contemporary quantitative health research.

The unit of analysis is not an individual university, research center, state or investigator. It is the publicly available program content through which the national HTA/HEOR knowledge base is expressed and reproduced. This includes teaching and training, program and course descriptions, curricula and syllabi where available, research priorities, methodological statements, projects, publications, seminars, workshops and other publicly available descriptions of what relevant United States programs research, apply and teach. The purpose is therefore to characterize the national program-content knowledge base rather than to infer what individual faculty members may know or address outside that publicly presented framework.

Two contrasting bodies of content are assessed using the fixed 37-topic framework. The first comprises 17 topics representing the requirements of representational measurement, including measurement preceding arithmetic, scales of measurement, admissible transformations, ratio measurement, dimensional homogeneity, the distinction between manifest and latent attributes, linear ratio measurement and Rasch measurement. The second comprises 20 topics representing contemporary health economics and HTA, including health economics, economic evaluation, utilities, QALYs, cost-effectiveness and cost-utility analysis, patient-reported outcomes, decision analysis, simulation and microsimulation, uncertainty analysis, value-of-information analysis, budget impact and related methods.

The question is deliberately narrow: does the United States HTA/HEOR program-content knowledge base establish representational measurement as the scientific foundation for quantitative claims before introducing or applying the arithmetic of contemporary HTA? If the requirements of representational measurement are absent while conventional HTA methods are extensively represented, the result is program-content inversion: a national educational and research environment in which arithmetic and modelling proceed without first establishing that the quantities involved possess the measurement properties required to support the operations performed.

The United States adds a particularly important dimension to this question because it has played a central role in the historical development of representational measurement. The work of R. Duncan Luce, Patrick Suppes and other United States scholars contributed substantially to the axiomatic foundations of modern measurement. The issue is therefore not whether representational measurement has existed within American academia. It is whether that scientific tradition has been incorporated into the national program-content framework of HTA, health economics and outcomes research as the governing standard for quantitative claims.

This distinction is fundamental. Representational measurement is not another methodology that can simply be added to contemporary HTA. It establishes the scientific rules governing the admissibility of arithmetic itself. Once those rules are applied, every numerical construct must satisfy them. The national review therefore assesses whether lawful measurement provides the scientific foundation for United States HTA/HEOR program content or whether the legacy framework of contemporary HTA occupies that position without it. Given the scale, diversity and international influence of the United States academic health-economics and outcomes-research environment, the national knowledge base provides the most demanding test yet of whether contemporary HTA program content is grounded in the measurement requirements of normal quantitative science

.FOUNDATIONS OF QUANTITATIVE ANALYSIS

Before examining United States program content, it is important to identify the scientific principles against which that content is assessed. These are not matters of methodological preference. They are the requirements of representational measurement that determine whether quantitative claims and the arithmetic operations supporting them are admissible.

Two principles are fundamental. First, measurement must precede arithmetic. Numerical operations cannot create measurement where measurement does not exist. Second, the arithmetic performed must be admissible for the measurement scale concerned. Operations involving multiplication, division and ratios require ratio measurement. For claims of therapy impact in HTA, this requires linear ratio measurement for manifest attributes or Rasch measurement for latent attributes.

These requirements establish the boundary between the manipulation of numbers and lawful quantitative measurement. Contemporary United States HTA, health economics and outcomes research, by contrast, are organized around economic evaluation, utilities, QALYs, cost-effectiveness and cost-utility analysis, decision analysis and modelling. Over some forty years, these methods have become deeply embedded throughout the national university and research environment, including schools of pharmacy, schools of public health, medical schools, departments of health policy and management, health economics programs, pharmaceutical outcomes research units, comparative effectiveness research centers and university-affiliated healthcare systems across the country. Institutional acceptance, methodological sophistication and longevity, however, do not determine measurement status. The prior scientific question remains whether the quantities entering these analyses possess the measurement properties required for the arithmetic performed.

The United States program-content review therefore asks a straightforward question: does the publicly available national HTA/HEOR knowledge base recognize representational measurement as the foundation for quantitative claims, or does it proceed directly to the methods and arithmetic of contemporary HTA without first establishing their measurement admissibility? This is the criterion governing the analysis that follows.

.MEASUREMENT BEFORE ARITHMETIC

Measurement must precede arithmetic because arithmetic has no independent scientific authority. Numbers do not become measures simply because they can be manipulated mathematically. Before any quantitative operation can be performed, it must first be established that the numbers represent a defined attribute on a scale possessing the properties required for the proposed arithmetic. This principle has guided quantitative science for more than seventy-five years through the axioms of representational measurement. The measurement scale determines the arithmetic, not the reverse. Nominal scales permit classification, ordinal scales permit ranking, interval scales permit meaningful differences, and only ratio scales support multiplication, division and ratio formation. Arithmetic therefore cannot create measurement where measurement does not already exist. It merely operates upon quantities whose measurement properties have previously been established. For a discipline such as health technology assessment (HTA), whose purpose is to generate quantitative claims concerning therapy impact, measurement is therefore the indispensable scientific starting point.

The implications for the United States HTA/HEOR knowledge base are profound. Contemporary HTA routinely multiplies utilities by time to generate QALYs, divides costs by QALYs to produce incremental cost-effectiveness ratios, and combines utilities, probabilities, durations and resource quantities within increasingly sophisticated simulation models. Each of these operations presupposes that the quantities entering the analysis possess the measurement properties required by the arithmetic performed. Unless this condition is satisfied, no amount of statistical sophistication, computational power, machine learning or simulation can establish scientific legitimacy retrospectively. Arithmetic cannot compensate for the absence of lawful measurement. It simply propagates the consequences of that omission through increasingly elaborate analytical structures. The first scientific question is therefore not how the arithmetic should be performed, but whether the quantities involved are lawful measures capable of supporting that arithmetic.

This principle also establishes the correct educational sequence for graduate instruction. Students should first learn how attributes are defined, how they are measured, how scales constrain arithmetic, and why manifest and latent attributes require different measurement frameworks. Only after these principles have been mastered should they be introduced to economic evaluation, utilities, QALYs, cost-effectiveness analysis or decision modelling. Reversing this sequence produces measurement inversion, where arithmetic is taught before students possess the scientific criteria needed to determine whether it is admissible. The national assessment reported here demonstrates precisely this inversion. Across the United States HTA/HEOR program-content knowledge base, the methods of contemporary HTA are comprehensively represented, while the measurement principles required to establish their scientific legitimacy are absent. Restoring measurement before arithmetic is therefore not a curricular refinement. It is the essential first step in reconstructing HTA as a discipline consistent with the requirements of normal quantitative science.

THE CRITICAL ROLE OF RATIO SCALES

The United States HTA/HEOR program-content assessment rests upon a fundamental requirement of representational measurement: arithmetic operations are determined by the properties of the measurement scale. Numerical values cannot legitimately be multiplied, divided or otherwise manipulated merely because numbers have been assigned. Measurement must first be established and the proposed arithmetic must be admissible for the scale concerned.

The distinction between nominal, ordinal, interval and ratio scales is therefore critical. Nominal scales classify; ordinal scales establish order; interval scales provide equal intervals but lack a non-arbitrary zero. Only ratio scales possess both equal units and a non-arbitrary zero and therefore support meaningful ratios and the multiplicative arithmetic required for quantitative claims.

This requirement has immediate consequences for United States HTA, health economics and outcomes research. QALYs multiply health-state values by time; incremental cost-effectiveness ratios divide differences in costs by differences in outcomes; and decision models combine probabilities, utilities, durations and other numerical inputs. These methods are comprehensively represented throughout the national HTA/HEOR educational and research environment. Where the quantities involved lack the measurement properties required for these operations, however, the arithmetic is inadmissible. Subsequent statistical analysis, modelling, simulation, artificial intelligence or machine learning cannot correct that prior failure.

For claims of therapy impact, two forms of ratio measurement are relevant. Manifest attributes require lawful linear ratio measurement. Latent attributes require Rasch measurement to construct an invariant quantitative continuum. This distinction provides the scientific foundation for determining whether subsequent arithmetic is admissible.

The United States assessment therefore applies a straightforward criterion. Does the publicly available national HTA/HEOR program-content knowledge base recognize ratio measurement, admissible arithmetic, dimensional homogeneity and the different measurement requirements of manifest and latent attributes before introducing the quantitative methods of contemporary HTA?

Or does it proceed directly to economic evaluation, utilities, QALYs, cost-effectiveness analysis and modelling without first establishing the measurement properties required for their arithmetic?

Ratio measurement is therefore not simply another topic within an HTA curriculum or research program. It establishes the boundary between admissible quantitative analysis and the manipulation of numbers that lack the measurement properties required to support that analysis. For the United States, this criterion applies across the nation's extensive academic and research infrastructure encompassing schools of pharmacy, schools of public health, colleges of medicine, departments of health policy and management, health economics programs, pharmaceutical outcomes research units, HTA research centers, outcomes research programs, health services research institutes and university-affiliated healthcare systems. The issue is therefore not whether the United States possesses sophisticated quantitative expertise. It unquestionably does. The issue is whether that expertise is founded upon the measurement requirements necessary to support the quantitative claims being made. The national 0/17 versus 20/20 program-content profile indicates that it is not. Instead, the United States HTA/HEOR knowledge base systematically teaches and applies increasingly sophisticated quantitative methods without first establishing the lawful measurement framework upon which those methods necessarily depend.

THE KNOWLEDGE BASE

The assessment uses the large language model interrogation framework applied in previous studies of measurement and curriculum inversion. The present analysis differs in one important respect: rather than estimating categorical probabilities of endorsement, it examines whether specified scientific and methodological topics are explicitly represented in the publicly available program content of the United States HTA and Health Economics and Outcomes Research (HTA/HEOR) knowledge base.

The United States knowledge base comprises the publicly accessible teaching, research and training environment associated with universities and university-affiliated programs in health economics, health technology assessment, outcomes research, comparative effectiveness research, health services research, pharmacoeconomics, decision science and health policy. Material considered includes program descriptions, curricula, research priorities, methodological statements, projects, publications, seminars, training activities and related publicly available evidence. The national knowledge base encompasses the educational and research activities of schools of pharmacy, schools of public health, colleges of medicine, departments of health policy and management, health economics programs, pharmaceutical outcomes research units and university-affiliated HTA and HEOR research centers throughout the United States. Representative institutions include Harvard University, Johns Hopkins University, the University of Washington, the University of Michigan, the University of Minnesota, the University of North Carolina, Duke University, the University of Pennsylvania, Stanford University, the University of California system, the University of Southern California, the University of Florida, the University of Texas system and numerous other public and private universities. The objective is not to evaluate individual investigators, courses or institutions, but to characterize the methodological framework represented across the United States HTA/HEOR knowledge base as a whole.

As noted above, two contrasting groups of content are examined. The first represents representational measurement. It includes measurement preceding arithmetic, scales of measurement, the axioms of representational measurement, ratio measurement, admissible transformations and arithmetic, dimensional homogeneity, the distinction between manifest and latent attributes, linear ratio measurement for manifest attributes and Rasch measurement for latent attributes.

The second represents contemporary HTA. It includes health economics, economic evaluation, utilities and preference-based outcomes, QALYs, incremental cost-effectiveness ratios, decision analysis, decision trees, Markov models, simulation and microsimulation, probabilistic sensitivity analysis, value-of-information analysis and related modelling methods. The United States provides exceptionally extensive representation of these methods through its schools of pharmacy, schools of public health, colleges of medicine, health economics programs, university-based HTA and HEOR research centers, comparative effectiveness research initiatives, pharmaceutical outcomes research programs, health services research institutes and health policy programs distributed throughout the national university system.

The interrogation asks a single question: does the United States HTA/HEOR program-content knowledge base establish representational measurement as the scientific foundation for quantitative claims before presenting the analytical methods of contemporary HTA? The criterion is the presence or absence of explicit program content rather than a probability of endorsement.

This distinction is important. Earlier interrogations demonstrated the relative strength with which knowledge bases endorsed the propositions associated with measurement inversion and curriculum inversion. Program-content interrogation provides a more direct test. If representational measurement is absent while the methods of contemporary HTA are comprehensively represented, the result is program-content inversion. Arithmetic, modelling and simulation are taught, researched and applied without representational measurement being established as the prior scientific framework determining whether those operations are admissible.

The United States assessment therefore focuses on a narrow but fundamental question: whether the scientific requirements governing measurement are present in the national program-content knowledge base through which contemporary HTA, health economics and outcomes research are taught, researched and transmitted. The purpose is to determine whether lawful measurement provides the scientific foundation for quantitative analysis in the United States or whether the methods of the legacy HTA framework are represented without the prior measurement standards required to establish their arithmetic admissibility. Given the scale, diversity and international influence of the United States academic HTA/HEOR enterprise, the national knowledge base provides the most comprehensive test to date of whether contemporary HTA program content is grounded in the measurement requirements of normal quantitative science.

ASSESSMENT FRAMEWORK

For this assessment, the United States HTA/HEOR program-content knowledge base was defined as the publicly available material describing relevant teaching and training in health economics, health technology assessment, health economics and outcomes research, pharmacoeconomics and related fields. Sources included program and curriculum descriptions, courses and modules, syllabi where available, learning objectives, seminars, workshops, teaching resources and associated educational material. The purpose was to establish what students and trainees are expected to encounter across the United States HTA/HEOR educational environment, not what individual faculty members may know or address in their independent research.

The relationship between the two components is the critical issue. Contemporary HTA methods cannot be taught independently of the measurement requirements governing their arithmetic. If students are taught that measurement precedes arithmetic, that multiplication and division require ratio measurement, and that manifest and latent attributes require different measurement strategies, they possess the scientific criteria required to judge whether subsequent HTA methods are admissible. Where these foundations are absent, utilities, QALYs, cost-effectiveness ratios and simulation models can be introduced without confronting the measurement properties required for their arithmetic.

Program-content inversion is therefore identified where contemporary HTA methods are comprehensively represented (20/20 topics) while the prior requirements of representational measurement are absent (0/17 topics). This is considerably more than an imbalance in program content. It reverses the scientific sequence upon which every quantitative discipline depends: arithmetic and modelling are introduced before the measurement conditions governing their admissibility have been established.

Program-content inversion places the United States HTA/HEOR knowledge base in direct conflict with the standards of normal quantitative science. Scientific status does not follow from generating numbers, employing sophisticated statistical methods or constructing increasingly complex computational models. Quantitative science requires lawful measurement, admissible arithmetic, empirical evaluation, independent replication and the possibility of falsification. If the foundational requirements of representational measurement are absent while utilities, QALYs, ICERs and simulation models are comprehensively represented without first establishing that their arithmetic is admissible, HTA is operating outside those requirements. The national 0/17 versus 20/20 result therefore identifies considerably more than an educational deficiency. It demonstrates a fundamental separation between the United States HTA/HEOR program-content framework and the measurement standards required by normal quantitative science.

This finding is particularly significant because it cannot plausibly be attributed to a lack of quantitative expertise, methodological sophistication or academic resources. The United States possesses one of the largest, most diverse and technically accomplished academic environments for health economics, outcomes research, decision science and health technology assessment in the world. Its schools of pharmacy, schools of public health, medical schools, departments of health policy, university research centers and healthcare systems have made major contributions to statistical methodology, clinical research, epidemiology, decision analysis, artificial intelligence and health services research. The program-content inversion identified here therefore occurs not within an immature academic environment but throughout one of the world's most sophisticated quantitative research enterprises. The problem is not insufficient analytical capability. It is the absence of the prior measurement framework required to determine whether that analytical capability is being applied to quantities capable of supporting the arithmetic performed.

The two frameworks are consequently incompatible as foundations for quantitative analysis. Representational measurement requires arithmetic to be constrained by measurement. Once that principle is accepted, every subsequent quantitative method must satisfy its requirements. Numerical constructions cannot be exempted simply because they have become established components of contemporary HTA, are taught throughout United States universities, or have been reinforced by four decades of methodological convention. Conversely, where representational measurement is absent from the organizing framework, there is no corresponding scientific constraint preventing such constructions from being taught, researched and applied. The national **0/17 versus 20/20** finding captures this incompatibility in its clearest possible form. It demonstrates that the United States HTA/HEOR educational and research enterprise has developed extraordinary technical sophistication while failing to establish the scientific measurement foundations upon which that sophistication ultimately depends.

ASSESSMENT RESULTS: PROGRAM CONTENT REVIEW

Jurisdiction
United States

Knowledge Base
United States Health Technology Assessment (HTA) and Health Economics and Outcomes Research (HEOR) Program-Content Knowledge Base

Purpose

This review evaluates the publicly available program content associated with health technology assessment (HTA), health economics, health economics and outcomes research (HEOR), economic evaluation, outcomes research, health services research, pharmaceutical economics and related quantitative health research throughout the United States against the fixed 37-topic framework. The criterion is whether representational measurement is explicitly established as the scientific foundation for quantitative claims before the methods of contemporary HTA and health economics are taught, researched or applied.

The national knowledge base comprises the publicly represented educational and research activities of United States schools of pharmacy, schools of public health, colleges of medicine, departments of health policy, health services research, pharmacoeconomics and health economics together with university-affiliated HTA and HEOR research centers. It encompasses major academic programs distributed across institutions including Harvard University, Johns Hopkins University, the University of Washington, the University of Michigan, the University of Minnesota, the University of North Carolina, the University of Pennsylvania, Duke University, Stanford University, the University of California system, the University of Southern California, the University of Florida, the University of Texas system, the University of Colorado, Oregon Health & Science University, the University of Iowa and numerous other public and private universities. Publicly available program descriptions consistently identify health economics, pharmacoeconomics, economic evaluation, comparative effectiveness research, patient-reported outcomes, outcomes research, health services research, implementation science, healthcare policy, cost-effectiveness analysis, value assessment and decision modelling as core components of graduate teaching and research. Collectively these programs constitute the United States HTA/HEOR program-content knowledge base evaluated here.

Topic results are presented in Table 1 for representational measurement.

TABLE 1: REPRESENTATIONAL MEASUREMENT

Topic	Explicitly recognized	United States program evidence
Representational measurement	No evidence identified	—
Scales of measurement as constraints on arithmetic	No evidence identified	—
Measurement precedes arithmetic	No evidence identified	—
Axioms of representational measurement	No evidence identified	—
Ratio measurement as prerequisite for multiplication and division	No evidence identified	—
True zero and equal units	No evidence identified	—
Admissible transformations	No evidence identified	—
Admissible arithmetic by scale type	No evidence identified	—
Dimensional homogeneity	No evidence identified	—
Manifest and latent attributes as distinct measurement classes	No evidence identified	—
Linear ratio measurement for manifest attributes	No evidence identified	—
Possession of latent attributes	No evidence identified	—
Rasch measurement as requirement for latent attributes	No evidence identified	—
Person-item conjoint measurement	No evidence identified	—
Specific objectivity and invariance	No evidence identified	—
Rasch logit ratio measurement for latent attributes	No evidence identified	—

Two admissible ratio measures for therapy impact	No evidence identified	—

Result: 0/17 representational-measurement topics explicitly recognized as the scientific foundation of the publicly available United States HTA/HEOR program-content knowledge base reviewed.

This finding is particularly noteworthy because the United States has played a central role in the historical development of representational measurement. Foundational contributions by scholars including R. Duncan Luce, Patrick Suppes and others established much of the modern axiomatic framework governing meaningful measurement and admissible arithmetic. Yet the present review found no evidence that this scientific tradition has been incorporated into the publicly represented educational or research framework of the national HTA/HEOR knowledge base. Across graduate programs, research centers and associated educational activities, representational measurement is absent as the organizing scientific foundation for quantitative claims.

Topic results for contemporary HTA and health economics are presented in Table 2.

TABLE 2: CONTEMPORARY HEALTH ECONOMICS AND HTA FRAMEWORK

Topic	Explicitly represented	United States program evidence
Health economics	Yes	Graduate programs throughout the United States
Health technology assessment	Yes	University research centers and HTA-related research activities nationwide
Economic evaluation	Yes	Schools of pharmacy, public health and medicine
Cost-effectiveness analysis	Yes	Widely represented across university teaching and research
Cost-utility analysis	Yes	Health economics and HTA programs
Pharmacoeconomics	Yes	Colleges of Pharmacy and pharmaceutical outcomes research programs
Utilities and preference-based outcomes	Yes	Patient-reported outcomes and health utility research
Quality-adjusted life-years (QALYs)	Yes	Economic evaluation and value-assessment research
Incremental cost-effectiveness ratios (ICERs)	Yes	Health economics teaching and publications
Measurement and valuation of health outcomes / patient-reported outcomes	Yes	Outcomes research programs nationwide

Decision analysis	Yes	Graduate instruction and HTA methodology
Decision-tree modelling	Yes	Economic evaluation curricula
Markov modelling	Yes	Health economic modelling programs
Simulation and microsimulation modelling	Yes	Decision modelling and comparative effectiveness research
Probabilistic sensitivity and uncertainty analysis	Yes	Economic evaluation and modelling research
Value-of-information analysis	Yes	Health economic modelling and methodological research
Budget impact analysis	Yes	Health economics and reimbursement research
Health care priority setting and resource allocation	Yes	Health policy and population health programs
Value-for-money / value assessment	Yes	HTA, HEOR and reimbursement research
Policy, reimbursement and decision use of economic evaluation	Yes	Health policy, payer research and HTA activities

Result: 20/20 contemporary HTA and health economics topics explicitly represented in the publicly available United States HTA/HEOR program-content knowledge base reviewed.

RESULTS ASSESSMENT

The national program-content assessment identifies a complete inversion in the scientific ordering of United States health technology assessment and health economics and outcomes research. Across the fixed 37-topic framework, none of the 17 topics defining representational measurement is explicitly recognized as the scientific foundation for quantitative claims, while all 20 topics associated with contemporary HTA and health economics are represented. The resulting 0/17 versus 20/20 profile is not a minor imbalance in curriculum design. It demonstrates that the United States HTA/HEOR knowledge base is comprehensive in technical method while lacking the prior scientific framework required to determine whether those methods support lawful quantitative claims.

The significance of the national result is greater than that of any individual university, research center or state. An isolated 0/17 finding might be dismissed as an omission in a particular program description. A national 0/17 finding cannot be dismissed so easily. The United States contains an exceptionally large and diverse academic infrastructure encompassing schools of pharmacy, public health and medicine; departments of health policy and management; health economics and pharmaceutical outcomes programs; research centers in comparative effectiveness, health services research and decision science; and professional networks connecting universities, healthcare systems, government, consulting organizations and industry. If representational measurement were recognized anywhere within contemporary HTA as the governing framework for quantitative claims, it should be visible within this extensive national environment. The finding that it is not explicitly represented across any of the 17 defining topics therefore indicates a structural absence, not a local curricular oversight.

The absence begins at the most fundamental level. No evidence was identified that representational measurement itself is established as the foundation for quantitative analysis. There is no explicit recognition that measurement must precede arithmetic, that numerical assignment does not automatically create a measure or that the properties of a measurement scale determine which mathematical operations are admissible. Without these principles, students and researchers are introduced to arithmetic before they are given the scientific criteria required to decide whether that arithmetic is lawful.

This reversal is decisive. Contemporary HTA routinely multiplies, divides, aggregates and forms ratios. Utilities are multiplied by time to construct QALYs. Differences in costs are divided by differences in outcomes to construct incremental cost-effectiveness ratios. QALYs are aggregated across individuals and modelled populations. Probabilities, utilities, durations, resource quantities and other numerical inputs are combined within decision trees, Markov models and microsimulations. Yet the national program-content knowledge base does not explicitly establish the measurement conditions that must be satisfied before these operations can be interpreted quantitatively.

The failure to recognize scales of measurement as constraints on arithmetic is particularly serious. Nominal, ordinal, interval and ratio scales are not interchangeable ways of assigning numbers. Each possesses different empirical and mathematical properties. Ordinal scales support order but not equal differences. Interval scales support differences but lack a non-arbitrary zero. Ratio scales alone support meaningful ratios, multiplication and division. Where this hierarchy is absent from the curriculum, students may learn increasingly sophisticated statistical and modelling techniques without learning whether the numbers entering those techniques possess the scale properties required for the operations performed.

The absence of ratio measurement as a prerequisite for multiplication and division therefore strikes directly at the core of contemporary HTA. The central analytical construct of cost-utility analysis depends upon multiplying a health-state value by time. Time is a lawful ratio measure. That does not establish the measurement status of the health-state value. Unless the utility component possesses equal units, a non-arbitrary zero and the required invariance properties, multiplication by time cannot create a lawful quantitative measure. The fact that one factor is a ratio measure cannot confer ratio properties on the other.

The same issue applies to incremental cost-effectiveness ratios. Division produces a meaningful ratio only where the quantities involved possess the required measurement properties. If the denominator is a QALY constructed from an ordinal or otherwise non-ratio preference value, the resulting cost-per-QALY claim cannot acquire scientific legitimacy through division. Arithmetic cannot repair the absence of measurement. The national 0/17 result shows that the program-content framework does not explicitly provide students with the principle required to identify this failure.

No evidence was identified for true zero and equal units, admissible transformations or admissible arithmetic by scale type. These concepts are not abstract mathematical refinements. They determine whether a numerical representation remains meaningful under transformation and whether statements involving differences, ratios and proportional change preserve empirical interpretation. A lawful ratio measure must retain its empirical meaning under similarity transformations and possess a non-arbitrary zero. Without these properties, claims that one therapy provides twice the benefit of another, that a patient has experienced a proportional improvement or that a treatment produces a specified cost per unit of benefit cannot be interpreted as lawful quantitative propositions.

Dimensional homogeneity is also absent from the publicly represented national framework. This omission is fundamental because meaningful arithmetic requires dimensional coherence. Quantities may be added only where they share the same dimension. Multiplication and division create compound dimensions that must be interpretable. The QALY is conventionally treated as a product of time and utility, yet the dimensional status of utility is not established. Where utility lacks a defined measurement dimension, the resulting product cannot be assumed to be dimensionally homogeneous. Subsequent aggregation does not correct this defect. It merely compounds it.

The national program-content knowledge base also fails to distinguish manifest and latent attributes as fundamentally different measurement classes. This distinction should precede instrument selection, data collection and analytical design. Manifest attributes are directly observable. Examples include survival time, hospital days, emergency department visits, treatment administrations, medication possession and walking distance. Where a defined unit and non-arbitrary zero exist, these attributes may support lawful linear ratio measurement.

Latent attributes cannot be observed directly. Pain, fatigue, depression, physical function, anxiety, need fulfilment and related constructs must be inferred from ordered responses. Assigning numbers to questionnaire categories or summing item scores does not create measurement. A measurement model is required to construct a unidimensional continuum and test whether the proposed instrument satisfies the conditions necessary for invariant measurement.

The absence of the manifest-latent distinction means that fundamentally different kinds of attributes are placed within a common numerical vocabulary. Counts, durations, utility values, questionnaire totals, preference weights and modelled outcomes are all treated as quantitative inputs without first establishing the measurement requirements appropriate to the attribute concerned. This is not merely a technical omission. It is a foundational category error. Before therapy impact can be quantified, the attribute must be defined and the lawful measurement system appropriate to that attribute must be established.

No evidence was identified for linear ratio measurement for manifest attributes. This is especially striking because manifest attributes offer the clearest path to credible and empirically evaluable therapy-impact claims. Hospital admissions, hospital days, treatment administrations, emergency visits, persistence and time to discontinuation can be specified prospectively in protocols, observed directly, replicated independently and subjected to clear falsification rules. Yet the national knowledge base does not identify lawful linear ratio measurement as the required foundation for such claims.

The omissions are even more extensive for latent attributes. Possession of latent attributes, Rasch measurement as the requirement for latent measurement, person-item conjoint measurement, specific objectivity, invariance and Rasch logit ratio measurement are all absent. Together these topics define the scientific conditions required to transform ordered categorical responses into measures capable of supporting quantitative claims.

Rasch measurement is not simply another psychometric option among many. It requires the data to conform to a measurement model that establishes unidimensionality, invariant item calibration, person-item conjoint measurement and specific objectivity. It distinguishes measurement from score construction. Its purpose is not merely to fit data more effectively or improve reliability. It is to determine whether a latent attribute can be represented on a quantitative continuum and whether persons can be located on that continuum in terms of possession of the defined attribute.

The absence of possession is particularly revealing. For latent attributes, the relevant question is not simply whether a questionnaire total increased or decreased. It is whether a person possesses more or less of the defined attribute and whether that difference is measured on an invariant continuum. Without this framework, numerical change is easily mistaken for measured therapy impact even where the instrument remains multidimensional, ordinal, sample-dependent or affected by differential item functioning.

The national 0/17 result therefore means that neither of the two lawful measurement foundations for therapy impact is explicitly established. Linear ratio measurement for manifest attributes is absent. Rasch logit ratio measurement for latent attributes is absent. The national knowledge base does not identify the measurement systems required to support therapy-impact claims before introducing the analytical methods that depend upon those claims.

The contrast with the 20/20 result could not be sharper. Every topic associated with contemporary HTA and health economics is represented. Health economics, HTA, economic evaluation, cost-effectiveness analysis, cost-utility analysis and pharmacoeconomics are embedded throughout graduate teaching and research. Utilities, preference-based outcomes, QALYs and ICERs form part of the accepted analytical vocabulary. Patient-reported outcomes and the valuation of health states are widely represented, but without the prior distinction between measurement and valuation.

Decision analysis, decision trees, Markov modelling, simulation, microsimulation, probabilistic sensitivity analysis, uncertainty analysis and value-of-information analysis are also comprehensively represented. These methods demonstrate substantial technical sophistication. Yet their scientific status depends upon the measurement properties of the quantities entering them. A model can propagate assumptions, combine inputs, simulate outcomes and quantify uncertainty. It cannot transform non-measures into measures. It cannot create dimensional homogeneity where none exists. It cannot supply a non-arbitrary zero or establish invariance. It cannot rescue arithmetic that was inadmissible before the model was constructed.

The presence of budget-impact analysis, healthcare priority setting, resource allocation, value-for-money assessment and the policy use of economic evaluation confirms the administrative orientation of the national knowledge base. Programs prepare graduates to support pricing, reimbursement, formulary and resource-allocation decisions. Students learn the methods required to function effectively within the existing HTA and HEOR environment. They may become highly competent in applying the conventions of economic evaluation and decision modelling. What they are not first provided with is the scientific framework required to determine whether the quantitative claims generated by those conventions are lawful.

The 0/17 versus 20/20 result therefore defines national program-content inversion. The scientific sequence is reversed. Contemporary HTA methods are taught, researched and applied comprehensively, while the measurement principles required to determine whether those methods are admissible are absent. Arithmetic, modelling and numerical construction become the starting point. Measurement is assumed, inferred retrospectively or treated as unnecessary.

This cannot be explained as a shortage of quantitative sophistication. The United States contains some of the most technically accomplished health economics, outcomes research, decision science, biostatistics and modelling programs in the world. The finding occurs within an academic environment possessing exceptional computational expertise, extensive research funding, advanced graduate programs and substantial methodological influence. The problem is therefore not an inability to undertake complex analysis. It is the absence of the prior scientific framework required to determine whether that complexity is applied to lawful measures.

Nor can the finding be dismissed as a semantic disagreement over the word measurement. The issue is not whether programs use terms such as outcomes measurement, health utility measurement or quality-of-life measurement. The issue is whether they explicitly establish the axioms, scale properties, admissible transformations and invariance requirements that distinguish lawful measurement from numerical scoring or valuation. The 0/17 finding indicates that they do not.

This distinction is critical because contemporary HTA often treats numerical construction as equivalent to measurement. Preference values are called utilities. Questionnaire totals are called scores or measures. QALYs are treated as outcomes. ICERs are treated as ratios. Model outputs are reported with decimals and confidence intervals. None of these presentational conventions establishes measurement. Scientific legitimacy cannot be inferred from numerical precision, statistical complexity or widespread professional usage.

The two bodies of knowledge identified in the tables are therefore not complementary. Representational measurement cannot simply be added as another module alongside cost-effectiveness analysis, decision modelling and value assessment. It is the framework that determines whether those methods are quantitatively admissible. Once measurement preceding arithmetic, ratio measurement, admissible transformations and dimensional homogeneity are taught, utilities, QALYs, ICERs and reference-case simulations cease to be unquestioned starting points. They become objects of scientific evaluation.

This is why the contradiction is irreconcilable. A curriculum cannot teach that multiplication requires ratio measurement while continuing to present utility-by-time multiplication as lawful without demonstrating that utility is a ratio measure. It cannot teach dimensional homogeneity while accepting QALY aggregation without specifying coherent dimensions and common units. It cannot teach invariant latent measurement while treating summed questionnaire scores or preference algorithms as measures without Rasch conformity. It cannot teach falsifiability while presenting projected model outputs as evidence without prospectively specified empirical tests.

The national framework survives because these contradictions are not brought into the same educational space. Representational measurement is absent, while the conventional HTA framework is fully represented. The absence is therefore not merely a missing component. It is the condition that permits the inherited analytical system to remain unchallenged within graduate education and research.

The implications for universities are substantial. A university does not discharge its scientific responsibility merely by training students to apply an accepted methodology competently. It must also provide them with the principles required to determine whether that methodology satisfies the standards of quantitative science. Where those principles are absent, education becomes technical training within a closed framework. Students learn how to perform the accepted operations but not how to determine whether those operations are scientifically admissible.

The national scope creates an additional responsibility. These programs do not merely educate local students. They influence healthcare systems, industry, government, professional organizations, journals and international HTA practice. Graduates carry the framework into payer organizations, consulting firms, pharmaceutical companies, academic research and policy. A foundational omission in national graduate education is therefore reproduced throughout the wider healthcare decision environment.

The appropriate response is not to blame individual instructors or programs. Most faculty were themselves educated within the same inherited framework and teach the methods recognized by textbooks, journals, professional organizations and established practice. The finding concerns the content of the national knowledge base, not the intentions or competence of individual academics. Its importance lies precisely in showing that the omission is systemic.

That systemic character, however, makes inaction increasingly difficult to defend. Once the national 0/17 versus 20/20 result has been documented, universities and professional organizations have a duty to inform students and researchers that the measurement foundations of contemporary HTA have been fundamentally challenged. Continuing to teach the inherited framework without disclosing the measurement problem would preserve epistemic closure rather than encourage scientific scrutiny.

The path forward requires reconstruction, not supplementation. The curriculum should begin with attributes, scales of measurement, admissible transformations, dimensional homogeneity and the requirement that multiplication, division and ratio formation depend upon lawful ratio measures. Students should then learn to distinguish manifest from latent attributes. Manifest therapy-impact claims should be developed through linear ratio measurement. Latent therapy-impact claims should be developed through Rasch logit ratio measurement, including unidimensionality, person-item conjoint measurement, invariance, specific objectivity and possession.

Only after lawful measurement has been established should statistical analysis, economic evaluation and modelling be introduced. Claims should be specified prospectively through protocols identifying the target population, comparator, attribute, measurement instrument, observation period, success criterion and falsification rule. The sequence should be explicit: define the attribute; establish the measure; determine the admissible arithmetic; formulate the claim; observe the outcome; and subject the claim to replication and potential falsification.

The national program-content review therefore reaches an unequivocal conclusion. The United States HTA/HEOR knowledge base is comprehensive in the technical methods of contemporary health economics and health technology assessment but empty at the level of the scientific measurement foundations required to justify those methods. The 0/17 versus 20/20 profile is the clearest possible expression of national program-content inversion.

The United States has built an extensive and highly sophisticated system for teaching utilities, QALYs, ICERs, economic evaluation and decision modelling. It has not built the corresponding educational framework required to determine whether the quantities entering those methods are lawful measures. Until representational measurement becomes the organizing scientific principle of the national HTA/HEOR knowledge base, the field cannot credibly claim to provide education in normal quantitative science. It provides advanced technical training within an inherited analytical framework whose central arithmetic has not first satisfied the requirements of lawful measurement.

.CONCLUSION: THE CHALLENGE OF TRANSFORMATION

Now that the measurement problem has been exposed, the challenge facing United States universities, research centers and the wider HTA and health economics and outcomes research (HTA/HEOR) community is substantial. The issue is no longer whether contemporary HTA might benefit from greater attention to measurement theory. The national program-content findings, together with the earlier demonstrations of measurement inversion and curriculum inversion, identify a foundational problem: the central analytical framework of contemporary HTA depends upon arithmetic operations that are inadmissible under the requirements of representational measurement and the standards of normal quantitative science. The measurement cat is now out of the contemporary HTA litter box. It cannot simply be put back.

There is therefore no scientific basis for defending the status quo. The relevant question is no longer whether utilities, QALYs and economic models have been useful, widely adopted or employed for decades. Longevity, technical sophistication and institutional acceptance do not establish quantitative validity. Once the requirements governing admissible arithmetic are applied, the problem becomes transparent. Multiplication requires ratio measurement. Arithmetic operations are constrained by scale properties. Dimensional homogeneity must be respected. Numerical assignment cannot substitute for measurement. Where these requirements are violated, the resulting arithmetic is inadmissible. No subsequent modelling, probabilistic sensitivity analysis, artificial intelligence, machine learning or computational sophistication can reverse that conclusion.

The challenge is consequently one of transformation: how should United States HTA and HEOR be reconstructed to meet the requirements of lawful measurement? United States universities, research centers and professional organizations bear a particular responsibility because they educate future practitioners, undertake methodological research and influence healthcare policy, reimbursement, pharmaceutical evaluation and technology assessment throughout the United States and internationally. The national **0/17 versus 20/20** program-content finding provides an opportunity to reconsider not simply what students are taught, but the scientific order in which they are taught it. The issue is not the technical sophistication of the United States academic enterprise, but whether that sophistication rests upon a scientifically defensible foundation.

The starting point is straightforward. Representational measurement must become the foundation of HTA rather than an optional addition to the existing curriculum. Students must first learn to define the target attribute, distinguish manifest from latent attributes, establish the appropriate form of ratio measurement, determine which arithmetic operations are admissible, and formulate claims capable of empirical evaluation, independent replication and falsification. Only after these requirements have been satisfied should statistical analysis, economic evaluation, decision modelling or other quantitative procedures be undertaken.

This transformation does not abandon HTA. It brings HTA within the requirements of normal quantitative science. United States universities, research centers, professional organizations and HTA agencies face a clear choice: continue reproducing a legacy framework whose arithmetic fails the representational-measurement test, or lead the reconstruction of HTA around lawful measurement. Given the size, diversity and international influence of the United States HTA/HEOR enterprise, such a transformation would extend well beyond individual universities or states. The same measurement standards must govern quantitative claims whether they originate in academic research, industry-sponsored analysis, healthcare systems, technology assessment, reimbursement agencies or healthcare decision making.

Faculty necessarily have the leading educational role. This does not require an assumption that instructors have knowingly disregarded representational measurement. Most have themselves been educated within contemporary HTA and teach the methodological framework transmitted through universities, textbooks, journals, professional organizations and established research practice. The national **0/17** finding indicates the extent to which representational measurement is absent from the publicly represented HTA/HEOR program-content knowledge base. Transformation must therefore begin by providing faculty with the knowledge and practical tools required to reconsider the scientific foundations of what they teach and to reconstruct HTA education around measurement, admissible arithmetic, claims assessment and the standards of normal quantitative science.

The challenge extends beyond curriculum development. The evidence documenting measurement inversion, curriculum inversion and program-content inversion has now accumulated across national HTA agencies, professional organizations, university curricula, research centers, state knowledge bases and the United States HTA/HEOR knowledge base itself. This creates a professional duty of care. Universities, journals, research organizations and professional societies can no longer reasonably present the inherited analytical framework as though its scientific foundations were uncontested. Students, researchers and practitioners should be informed that the quantitative basis of contemporary HTA has been fundamentally challenged and that a scientifically coherent alternative now exists. The objective is not simply to criticize the legacy framework, but to provide a practical pathway for its replacement. Representational measurement, together with the structured transition framework that follows from it, offers that pathway. The challenge for the United States is therefore no longer whether change is necessary, but whether the national HTA/HEOR community is prepared to undertake the scientific reconstruction that lawful measurement now requires.

It is precisely this gap that the Maimon Research nine-unit transformation program is intended to address [1]. Designed specifically for HTA, the program provides a structured transition from the legacy framework to one grounded in representational measurement. To our knowledge, it is the only transition program currently available developed expressly for HTA around these requirements. Beginning with the principle that measurement precedes arithmetic, it addresses attributes, scales of measurement, admissible arithmetic, dimensional homogeneity, manifest and latent attributes, linear ratio measurement, Rasch measurement, attribute possession and the construction of empirically evaluable therapy-impact claims. Its purpose is not to add a measurement module to contemporary HTA. It is to demonstrate how HTA itself changes when representational measurement becomes its organizing scientific principle.

The opportunity for Florida HTA is constructive rather than destructive. The objective is not simply to demonstrate why the legacy framework depends upon inadmissible arithmetic, but to provide a scientifically coherent replacement. Florida universities, research centers and their faculty are well positioned to participate in that transformation through their contributions to health economics, pharmaceutical economics, outcomes research, technology assessment and healthcare decision making. Once measurement is restored to its required position before arithmetic, the path forward is clear: define the attribute, establish the appropriate ratio measure, permit only admissible arithmetic, and formulate claims that can be evaluated, replicated and falsified. After four decades of contemporary HTA, the challenge for Florida is not to defend what has been inherited, but to build what normal quantitative science requires.

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