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ARTIFICIAL INTELLIGENCE LARGE LANGUAGE MODEL INTERROGATION

REPRESENTATIONAL MEASUREMENT FAILURE IN HEALTH TECHNOLGY ASSESSMENT

OHIO: THE ABSENCE OF REPRESENTATIONAL MEASUREMENT IN HTA RESEARCH CENTER PROGRAMS

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ABSTRACT

Health technology assessment (HTA) depends upon quantitative claims whose scientific legitimacy requires measurement to precede arithmetic. Representational measurement establishes that numerical operations are admissible only when the properties of the measurement scale support them. This study examines whether these requirements are represented within the publicly available program-content knowledge base of four major Ohio university affiliated health technology assessment, health-economics, pharmacoeconomic and outcomes-research environments.

A large language model interrogation framework was applied to publicly available program descriptions, curricula, research priorities, methodological statements, projects, publications, seminars and training activities. The unit of analysis was the composite Ohio program-content knowledge base rather than individual investigators or institutions. A fixed 37-topic framework, established in advance, compared 17 topics representing the requirements of representational measurement with 20 topics defining contemporary health economics and HTA.

The contrast was pronounced. None of the 17 representational-measurement topics was explicitly identified as providing the prior scientific foundation for quantitative claims (0/17). In contrast, 19 of the 20 contemporary health-economics and HTA topics were explicitly represented (19/20), including economic evaluation, cost-effectiveness and cost-utility analysis, pharmacoeconomics, utilities, QALYs, ICERs, patient-reported outcomes, decision analysis, Markov modelling, simulation, probabilistic sensitivity analysis, budget-impact analysis and value assessment. Value-of-information analysis was the sole contemporary topic for which sufficiently explicit evidence was not identified.

The resulting 0/17 versus 19/20 profile identifies program-content inversion: an extensively developed downstream analytical framework without an explicitly represented upstream measurement foundation determining whether its arithmetic is admissible. This is not evidence of limited quantitative sophistication. It demonstrates that sophisticated quantitative methods can be taught, researched and applied without first establishing the measurement properties required to justify their mathematical operations.

Ohio universities therefore face a foundational educational and scientific challenge. Representational measurement cannot be treated as an optional addition to an otherwise unchanged HTA curriculum. Reconstruction requires restoration of the correct scientific sequence: attribute definition, measurement, scale determination and admissible arithmetic before quantitative analysis. For therapy-impact claims, this requires appropriate linear ratio measurement for manifest attributes and Rasch measurement for latent attributes. Once the measurement failure has been exposed, continuing to transmit the inherited framework without providing students with the principles required to interrogate it is no longer scientifically defensible.

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 [1 2 3]. Multiplication and division require appropriate ratio properties; 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 these earlier research-center and program-content assessments by examining a composite Ohio academic HTA, health-economics and outcomes-research program-content knowledge base. Four university-affiliated environments are included: the Ohio State University Center for Health Outcomes and Policy Evaluation Studies (HOPES); the Ohio State University College of Pharmacy outcomes and pharmacoeconomic research environment; the University of Cincinnati Health Outcomes and Pharmacoeconomics research and graduate environment; and the University of Toledo Health Outcomes and Value Analytics/Health Outcomes and Socioeconomic Sciences environment.

Collectively, these environments encompass health economics, HTA, pharmacoeconomics, economic evaluation, cost-effectiveness and cost-utility analysis, outcomes research, patient-reported outcomes, healthcare value, decision analysis and modelling, simulation, uncertainty analysis, budget impact and health-policy applications. Ohio therefore provides a substantial academic setting in which to examine whether representational measurement has been incorporated as the scientific foundation for quantitative health evaluation.

The unit of analysis is not an individual university, research center or investigator. It is the publicly available program content through which the composite Ohio academic HTA and health-economics knowledge base is expressed and reproduced. This includes teaching and training materials, program and course descriptions, research priorities, methodological statements, projects, publications and other publicly available descriptions of what the included research environments investigate, apply and teach. The purpose is to characterize the Ohio academic program-content knowledge base rather than to infer what individual faculty members may know, teach informally or address outside that publicly represented framework.

Two contrasting bodies of content are assessed using the fixed 37-topic framework. The first comprises 17 predetermined 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 predetermined topics representing contemporary health economics and HTA, including health economics, HTA, 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. These topics were established in advance and applied consistently; they were not selected or modified in response to the Ohio knowledge base.

The question is deliberately narrow: does the Ohio academic HTA and health-economics program-content knowledge base establish representational measurement as the 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: an educational and research environment in which arithmetic, statistical analysis and modelling proceed without first establishing that the quantities involved possess the measurement properties required to support the operations performed.

Ohio provides a demanding test of this proposition. The environments included in the interrogation represent substantial expertise in pharmacy, health economics, pharmacoeconomics, outcomes research, economic evaluation, health policy and quantitative healthcare research. The issue is therefore emphatically not whether Ohio universities possess quantitative expertise. They clearly do. Nor is the question whether sophisticated economic, statistical and modelling methods are available. The question is whether representational measurement has been incorporated into this sophisticated academic environment as the governing scientific standard for quantitative claims.

This distinction is fundamental. Representational measurement is not simply another methodology that can be appended to an existing HTA curriculum alongside economic evaluation, econometrics, decision modelling, biostatistics or sensitivity analysis. It establishes the scientific rules governing the admissibility of the arithmetic itself. Once those rules are applied, every numerical construct must satisfy the relevant measurement requirements before subsequent mathematical operations can be justified.

This becomes particularly important where contemporary HTA requires multiplication and division. The existence of a numerical value does not establish ratio measurement, and the desire or requirement to perform a mathematical operation cannot confer upon a number the properties necessary to make that operation admissible. Utilities do not acquire ratio properties because analysts wish to multiply them by time. A QALY does not become a lawful quantity because it is required for a cost-utility model, and an ICER does not become a scientifically meaningful ratio simply because cost per QALY is conventionally reported. The measurement status of the quantities must be established before, rather than inferred from, the arithmetic performed upon them.

The Ohio review therefore asks whether lawful measurement provides the scientific foundation for its academic HTA and health-economics program content or whether the inherited analytical framework of contemporary HTA occupies that space without it. The distinction is between two fundamentally different scientific sequences: attribute → measurement requirements → scale → admissible arithmetic → quantitative claim and required analytical output → selected numbers → assumed mathematical properties → arithmetic → modelled claim. \The former places measurement before arithmetic. The latter constitutes measurement inversion.

The subsequent interrogation makes the contrast particularly stark. The composite Ohio knowledge base identifies 19 of the 20 predetermined topics defining contemporary health economics and legacy HTA, with value-of-information analysis the sole topic for which sufficiently explicit evidence was not identified. Yet none of the 17 predetermined representational-measurement topics was explicitly established as the prior scientific foundation for that analytical framework.

The resulting 0/17 versus 19/20 profile cannot reasonably be explained by an absence of quantitative expertise or methodological development. Ohio demonstrates extensive representation of the downstream analytical apparatus while providing no evidence that the upstream measurement requirements necessary to determine whether that apparatus is quantitatively admissible occupy a corresponding foundational position.

For Ohio universities, this makes the result consequential. These institutions educate future health economists, outcomes researchers, pharmacists, industry scientists, consultants, academics and healthcare decision makers. The question is therefore not confined to the scientific status of current research. It concerns what knowledge is transmitted to the next generation.

If students are taught utilities, QALYs, cost-effectiveness analysis, ICERs, decision models, simulation and uncertainty analysis without first being taught how to establish whether the quantities entering those operations constitute lawful measures, the problem is not simply an incomplete curriculum. The scientific sequence itself has been inverted. A 0/17 versus 19/20 finding in Ohio therefore does not demonstrate a shortage of quantitative sophistication. It demonstrates that sophistication has developed in the wrong scientific order.

FOUNDATIONS OF QUANTITATIVE ANALYSIS

Before examining Ohio 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 the appropriate ratio properties. 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 HTA and health economics in Ohio, by contrast, are organized around health economics, pharmacoeconomics, economic evaluation, utilities, QALYs, cost-effectiveness and cost-utility analysis, patient-reported and health outcomes, decision analysis and modelling, simulation, uncertainty analysis, budget impact, healthcare value and policy applications. These methods are represented across major university-affiliated environments at the Ohio State University, the University of Cincinnati and the University of Toledo, providing a substantial concentration of expertise in health economics, pharmacoeconomics, outcomes research, HTA, health policy and quantitative healthcare evaluation.

Institutional acceptance, methodological sophistication and longevity, however, do not determine measurement status. Nor does the reputation of an Ohio university, college of pharmacy or research center confer measurement properties upon the numbers employed in its analyses. The prior scientific question remains whether the quantities entering those analyses possess the measurement properties required for the arithmetic performed. The fact that utilities, QALYs, ICERs, cost-effectiveness analyses and economic models are well established within Ohio academic and research environments cannot substitute for demonstrating that their constituent quantities support the mathematical operations required of them.

Indeed, the breadth of contemporary quantitative expertise represented in the Ohio knowledge base makes the test particularly demanding. The subsequent program-content interrogation identifies 19 of the 20 predetermined contemporary health-economics and HTA topics, with value-of-information analysis the sole topic for which sufficiently explicit evidence was not identified. This is therefore not an academic environment in which an absence of representational measurement can readily be attributed to a general lack of methodological development or quantitative expertise. The downstream analytical framework is extensively represented.

The Ohio program-content review therefore asks a straightforward question: does the publicly available Ohio academic HTA, health-economics and outcomes-research 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

Before students are introduced to health technology assessment, health economics, cost-effectiveness analysis or decision modelling, they should understand the scientific conditions that determine whether quantitative claims are possible. The governing principle is straightforward: measurement must precede arithmetic. Numbers cannot be manipulated legitimately merely because they have been assigned to observations. The properties of the measurement scale determine which arithmetic operations are admissible.

Representational measurement provides this foundation. The target attribute must first be identified and defined, its measurement properties established, and the appropriate scale constructed. Only then can arithmetic proceed. Multiplication and division require the appropriate ratio properties, admissible transformations must be respected, and dimensional homogeneity must be maintained. Reversing this sequence allows arithmetic to precede measurement and produces numerical constructions that cannot be interpreted as lawful quantitative measures.

This distinction is particularly important for Ohio HTA, health economics and outcomes research because its academic knowledge base demonstrates considerable expertise in precisely those methods that depend upon quantitative operations. Economic evaluation, cost-effectiveness analysis, cost-utility analysis, utilities, QALYs, decision analysis and modelling, simulation, uncertainty analysis, patient-reported outcomes, pharmacoeconomics, budget-impact analysis and policy-oriented evaluation are represented across the Ohio knowledge base. Indeed, the program-content interrogation identifies 19 of the 20 predetermined contemporary health-economics and HTA topics**.** The question is therefore not whether Ohio researchers know how to perform sophisticated quantitative analyses. They clearly do. The question is whether the measurement requirements that determine whether those operations are scientifically admissible have first been established.

For HTA claims of therapy impact, the distinction between manifest and latent attributes is fundamental. Manifest attributes are directly observable. Examples include survival time, hospital days, emergency department visits, treatment administrations and walking distance. Where a defined unit and non-arbitrary zero are established and the required measurement properties are satisfied, these attributes support linear ratio measurement and the arithmetic permitted by a ratio scale.

Latent attributes, such as pain, fatigue, physical function or need fulfilment, cannot be observed directly. Assigning numbers to questionnaire responses or adding item scores does not establish measurement. Nor does transforming those scores statistically create the required measurement properties. A measurement model is required to construct a unidimensional continuum and demonstrate invariant measurement. For this purpose, Rasch measurement provides person-item conjoint measurement, specific objectivity and a logit continuum upon which possession of the latent attribute can be assessed.

The distinction is critical because contemporary health economics and outcomes research frequently treat numerical outputs as though the act of numerical assignment itself establishes quantitative measurement. It does not. A number is not necessarily a measure**.** A preference score does not acquire ratio properties because it is bounded between zero and one. A questionnaire total does not become an interval measure because its items have been added together. A numerical construct does not acquire the properties required for multiplication or division merely because an economic model requires those operations.

The educational requirement can therefore be stated simply. Claims concerning manifest attributes require appropriate linear ratio measurement; claims concerning latent attributes require Rasch measurement. Students should understand these requirements before being introduced to utilities, QALYs, cost-effectiveness ratios or simulation models. Numerical constructions do not acquire measurement properties through arithmetic, statistical analysis, professional convention, institutional acceptance or incorporation into increasingly sophisticated models.

This ordering is especially important in Ohio because the academic environments examined are actively involved in educating future pharmacists, health economists, outcomes researchers, industry scientists, consultants and healthcare decision makers. Once arithmetic is allowed to precede measurement, the analytical framework becomes self-reinforcing. Students learn how to calculate utilities, QALYs and ICERs; researchers refine model structures and parameter estimates; sensitivity and uncertainty analyses become increasingly sophisticated; and the resulting methods acquire legitimacy through repeated academic and professional application. The reputation of the universities and research environments in which these methods are taught can further reinforce that legitimacy. Yet neither methodological sophistication nor institutional reputation answers the logically prior question of whether the quantities being manipulated possess the measurement properties required for those operations.

The Ohio findings make this problem unusually clear. Across the composite publicly available program-content knowledge base, none of the 17 predetermined representational-measurement topics was explicitly identified**,** while 19 of the 20 predetermined contemporary health-economics and HTA topics were represented. The contrast is therefore not between a poorly developed measurement curriculum and an equally incomplete HTA curriculum. It is between an extensively represented downstream analytical framework and an absent upstream measurement foundation.

If representational measurement, scale theory, ratio measurement, admissible transformations, dimensional homogeneity and the distinction between manifest and latent measurement are absent while economic evaluation, utilities, QALYs, cost-effectiveness analysis, patient-reported outcomes and modelling are extensively represented, the result is program-content inversion**.** Ohio's 0/17 versus 19/20 profile provides a particularly stark example: the arithmetic and analytical methods of contemporary HTA are extensively represented, while the measurement principles required to determine whether that arithmetic is admissible are not.

RATIO MEASUREMENT AND ADMISSIBLE ARITHMETIC

The Ohio 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, the scale properties demonstrated, and the proposed arithmetic shown to 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. Ratio scales possess both equal units and a non-arbitrary zero and therefore permit meaningful ratio comparisons and the multiplicative arithmetic required for many quantitative claims. Their admissible transformations are similarity transformations of the form $x' = ax$, $a > 0$, under which ratios are preserved. Ratio status is therefore not established merely by the presence of a zero or by assigning numerical values to observations. The required measurement structure must first be demonstrated.

This requirement has immediate consequences for HTA, health economics and outcomes research in Ohio. 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, costs and other numerical inputs through sequences of arithmetic operations. These methods are extensively represented across the Ohio academic environments examined.

The scientific question, however, precedes their application: do the quantities entering these operations possess the measurement properties required for the arithmetic performed upon them? Where they do not, the arithmetic is inadmissible. The fact that an operation can be executed mathematically or computationally does not establish that it has empirical meaning. Nor can subsequent statistical analysis, probabilistic sensitivity analysis, modelling or simulation correct a measurement failure that occurred before the arithmetic began. Increasing the sophistication of a model cannot manufacture measurement properties that its inputs do not possess.

The QALY provides the clearest example. Its familiar construction, QALY = U × T**,** requires multiplication. Time can satisfy the requirements for linear ratio measurement. The critical question is therefore whether the utility value possesses the measurement properties required to operate as a dimensionless proportional adjustment to time. The need for the multiplication cannot itself confer those properties upon utility. They must be demonstrated independently before the operation is undertaken.

The same principle applies downstream. If the QALY has not been established as a legitimate quantitative measure, subtraction to create an incremental QALY does not repair the problem. Nor can division of incremental costs by an inadmissible ΔQALY create a scientifically meaningful cost-per-QALY ICER. Arithmetic cannot rescue a failure of measurement by adding further arithmetic.

For claims of therapy impact, two measurement pathways are relevant. Manifest attributes require appropriate linear ratio measurement. These include directly observable attributes such as survival time, hospital days, treatment administrations and walking distance where the required unit, zero and measurement properties can be established. Latent attributes—including pain, fatigue, physical function and need fulfilment—require a different measurement pathway. Rasch measurement provides person-item conjoint measurement, specific objectivity, invariance and a logit continuum for establishing possession of a defined unidimensional latent attribute.

The distinction between these two measurement pathways is fundamental. A manifest attribute cannot simply be treated as though any numerical representation of it were a ratio measure, and a latent attribute does not become a measure because questionnaire responses have been assigned numbers, summed or transformed statistically. Measurement status must be demonstrated rather than assumed.

The Ohio assessment therefore applies a straightforward criterion. Does the publicly available composite Ohio academic HTA, health-economics and outcomes-research program-content knowledge base recognize scales of measurement, ratio measurement, admissible transformations, 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 and cost-utility analysis, patient-reported outcomes and decision modelling without first establishing the measurement properties required for their arithmetic?

This question is particularly important because the Ohio knowledge base represents substantial quantitative expertise. The academic environments examined at the Ohio State University, the University of Cincinnati and the University of Toledo collectively encompass health economics, pharmacoeconomics, HTA, economic evaluation, outcomes research, patient-reported outcomes, decision analysis and modelling, simulation, healthcare value, budget-impact analysis and health-policy applications. The issue is not whether these environments possess advanced quantitative expertise. They clearly do. The issue is whether that expertise begins with the scientific requirements governing what can legitimately be quantified and what arithmetic can subsequently be performed.

Ratio measurement is therefore not simply another topic that might usefully be added to an Ohio HTA, health-economics or outcomes-research curriculum. It establishes a boundary between lawful quantitative analysis and the manipulation of numbers that lack the measurement properties required to support the operations performed upon them.

This is why the absence of ratio measurement from the Ohio program-content knowledge base is substantially more consequential than the absence of one additional methodological topic. The empirical result is particularly stark**:** 0/17 representational-measurement topics compared with 19/20 topics defining contemporary health economics and legacy HTA. The sole contemporary topic for which sufficiently explicit evidence was not identified was value-of-information analysis. Students can therefore encounter an almost complete analytical framework encompassing health economics, HTA, economic evaluation, utilities, QALYs, cost-effectiveness and cost-utility analysis, ICERs, patient-reported outcomes, decision modelling, simulation, uncertainty analysis and budget-impact analysis without the program-content knowledge base first establishing why multiplication and division require appropriate ratio properties.

The Ohio result consequently presents the scientific inversion in unusually clear form. Almost everything required to perform the arithmetic is represented; the measurement framework required to determine whether that arithmetic is lawful is absent**.** Students and researchers are exposed to the downstream analytical apparatus without first being provided with the upstream scientific principles required to interrogate it. Given the substantial concentration of health-economic, outcomes-research and quantitative expertise represented in the Ohio environments examined, this result cannot readily be explained by lack of methodological sophistication. It instead points to the organization of the knowledge base itself.

Indeed, the 19/20 result makes the 0/17 finding more, rather than less, consequential. The Ohio knowledge base is demonstrably capable of representing almost the entire contemporary HTA framework. Its failure to represent any of the 17 predetermined topics establishing the measurement foundation cannot therefore readily be dismissed as the consequence of sparse program content. The asymmetry is systematic: extensive representation of downstream methods is accompanied by complete absence of the upstream measurement requirements that determine whether those methods are quantitatively admissible.

For Ohio, therefore, the program-content interrogation asks a foundational rather than merely methodological question. Across major university-affiliated health-economics, pharmacoeconomic and outcomes-research environments, are researchers and students being taught first how to measure, or first how to manipulate the numbers required by the inherited HTA framework? The distinction is between measurement determining admissible arithmetic **and** required arithmetic determining presumed measurement properties. It is the distinction between measurement preceding arithmetic and arithmetic preceding measurement, and it is the distinction upon which the Ohio program-content assessment rests.

THE KNOWLEDGE BASE: PROGRAM CONTENT AND COVERAGE

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 probabilities of endorsement, it examines whether specified scientific and methodological topics are explicitly represented in the publicly available program content of the Ohio academic HTA, health-economics and outcomes-research knowledge base**.**

The Ohio knowledge base comprises publicly accessible teaching, research and training content associated with four major university-affiliated research and educational environments: the Ohio State University Center for Health Outcomes and Policy Evaluation Studies (HOPES); the Ohio State University College of Pharmacy outcomes and pharmacoeconomic research environment; the University of Cincinnati Health Outcomes and Pharmacoeconomics research and graduate environment; and the University of Toledo Health Outcomes and Value Analytics/Health Outcomes and Socioeconomic Sciences environment. Material considered includes program and course descriptions, research priorities, methodological statements, projects, publications, seminars and training activities. The objective is not to evaluate individual investigators, courses or institutions, but to characterize the composite Ohio academic HTA, health-economics and outcomes-research program-content knowledge base.

Two contrasting groups of content are examined using a fixed 37-topic framework. The first comprises 17 topics representing representational measurement, including measurement preceding arithmetic, scales of measurement, axioms of representational measurement, ratio measurement, admissible transformations and arithmetic, dimensional homogeneity, manifest and latent attributes, linear ratio measurement and Rasch measurement.

The second comprises 20 topics representing contemporary health economics and HTA, including economic evaluation, cost-effectiveness and cost-utility analysis, pharmacoeconomics, utilities, QALYs, ICERs, patient-reported outcomes, decision analysis, Markov and simulation modelling, uncertainty analysis, value-of-information analysis, budget impact and value assessment.

The interrogation asks a single question: does the Ohio academic HTA, health-economics and outcomes-research program-content knowledge base establish representational measurement as the foundation for quantitative claims before presenting or applying the analytical methods of contemporary HTA?

A topic is classified as explicitly represented where identifiable public evidence demonstrates its presence within the research, teaching or methodological knowledge base. Failure to identify such evidence is reported as “No evidence identified.” This does not imply that individual Ohio researchers are unfamiliar with the topic. It means that the topic was not identified as part of the publicly represented program-content framework examined.

Importantly, references to *measurement*, *outcome measurement*, *preference measurement*, *health-state measurement* or *psychometrics* do not by themselves establish recognition of representational measurement. Similarly, numerical ratios, bounded values or values incorporating a zero do not establish recognition of ratio measurement. The criterion is whether the measurement principles themselves, and their implications for admissible arithmetic, are explicitly represented. This distinction is particularly important in an HTA environment in which numerical health-state valuation and patient-reported outcomes may routinely be described as measurement without demonstrating the representational properties required to justify that description.

If representational measurement is absent while contemporary HTA methods are extensively 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 Ohio assessment therefore asks whether lawful measurement provides the scientific foundation for quantitative HTA or whether the legacy HTA framework is represented without the measurement standards required to establish the admissibility of its arithmetic. Given the breadth and methodological sophistication of the environments examined, Ohio provides a demanding test of that question. These are not environments lacking quantitative expertise; collectively they represent substantial expertise in health economics, HTA, pharmacoeconomics, economic evaluation, cost-effectiveness and cost-utility analysis, outcomes research, patient-reported outcomes, decision modelling, simulation, budget-impact analysis, healthcare value and health-policy applications.

The significance of the test is therefore straightforward. If an Ohio academic knowledge base capable of representing 19 of the 20 predetermined analytical topics of contemporary health economics and HTA does not explicitly represent any of the 17 predetermined topics establishing the scientific requirements of representational measurement, the issue **cannot** readily be attributed to a lack of quantitative sophistication. It identifies the absence of the scientific measurement framework that should logically precede and govern that sophistication.

The resulting 0/17 versus 19/20 comparison therefore provides the empirical test of program-content inversion in Ohio: an almost complete representation of the downstream analytical framework accompanied by no identified representation of the upstream measurement requirements needed to determine whether its quantitative operations are admissible.

ASSESSMENT RESULTS PROGRAM CONTENT REVIEW

Jurisdiction

Ohio, United States

Knowledge Base

Ohio Academic Health Technology Assessment, Health Economics and Outcomes Research Knowledge Base (Program Content)

University-affiliated environments

1. The Ohio State University — Center for Health Outcomes and Policy Evaluation Studies (HOPES)
2. The Ohio State University — College of Pharmacy / outcomes and pharmacoeconomic research environment
3. University of Cincinnati — Health Outcomes and Pharmacoeconomics Research

The criterion is whether representational measurement is explicitly established as the scientific foundation for quantitative claims before the analytical methods of contemporary HTA and health economics are introduced, taught, researched or applied.

Ohio provides a substantial setting for this interrogation. The Ohio State University combines health economics, outcomes research, cost-effectiveness analysis and health-policy evaluation through HOPES and its College of Pharmacy research environment. The University of Cincinnati provides graduate education and research in health outcomes and pharmacoeconomics, including economic evaluation and decision-analytic modelling. The University of Toledo provides a Health Outcomes and Value Analytics environment encompassing pharmacoeconomics, HTA, outcomes research and healthcare analytics.

The unit of analysis is the composite publicly available program-content knowledge base, not the private knowledge of individual faculty members.

TABLE 1: REPRESENTATIONAL MEASUREMENT

Topic	Explicitly recognized	Ohio 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

No topic from the fixed 17-topic representational-measurement framework was explicitly identified as providing the prior scientific foundation for quantitative HTA claims within the publicly represented Ohio knowledge base reviewed.

This result requires an important qualification. Ohio programs certainly use the language of *measurement*. Outcomes research, health-outcomes assessment, patient-reported outcomes, utility estimation, preference assessment and related quantitative activities all involve terminology that may be described as measurement.

Those usages were not counted as evidence of representational measurement. The criterion is narrower: explicit recognition that an attribute must first be defined and measured, that the scale achieved determines admissible transformations and arithmetic, that multiplication and division require appropriate ratio properties, that dimensional homogeneity constrains permissible operations, and that manifest and latent attributes require distinct measurement pathways.

Targeted interrogation also distinguishes isolated references to measurement terminology from incorporation of representational measurement into the HTA and health-economics knowledge base. The question is not whether measurement theory, scale terminology or Rasch methods can be found somewhere within an Ohio university. The question is whether representational measurement provides the organizing scientific foundation for the quantitative HTA, health-economics and outcomes-research program content under review.

On that criterion, the result is 0/17.

TABLE 2: CONTEMPORARY HEALTH ECONOMICS AND HTA FRAMEWORK

Topic	Explicitly represented	Ohio program evidence
Health economics	**Yes**	Ohio State HOPES and College of Pharmacy; Cincinnati and Toledo outcomes/pharmacoeconomic environments
Health technology assessment	**Yes**	Cincinnati and Toledo explicitly represent HTA within their health-outcomes, pharmacoeconomic and value environments
Economic evaluation	**Yes**	Explicitly represented across the composite Ohio knowledge base
Cost-effectiveness analysis	**Yes**	HOPES and associated Ohio State research; Cincinnati and Toledo pharmacoeconomic environments
Cost-utility analysis	**Yes**	Utility/QALY-based economic evaluation represented within Ohio research and graduate program content
Pharmacoeconomics / pharmaceutical economic evaluation	**Yes**	Explicitly represented at Ohio State Pharmacy, Cincinnati and Toledo
Utilities and preference-based outcomes	**Yes**	Health-state utilities and preference-based outcomes represented within economic-evaluation and outcomes research
Quality-adjusted life-years (QALYs)	**Yes**	QALYs explicitly represented in Ohio economic-evaluation research
Incremental cost-effectiveness ratios (ICERs)	**Yes**	Cost-per-QALY and incremental cost-effectiveness analysis explicitly represented

Measurement and valuation of health outcomes / patient-reported outcomes	**Yes**	Outcomes and patient-reported outcomes represented across Ohio research environments
Decision analysis	**Yes**	Cincinnati and Toledo explicitly represent decision-analytic methods
Decision-tree modelling	**Yes**	Explicitly represented within Cincinnati decision-analytic and pharmacoeconomic training
Markov modelling	**Yes**	Explicitly represented in Cincinnati training and Ohio economic-evaluation research
Simulation and microsimulation modelling	**Yes**	Simulation/microsimulation represented in associated Ohio economic-evaluation research
Probabilistic sensitivity and uncertainty analysis	**Yes**	Probabilistic and other sensitivity analyses explicitly represented in Ohio cost-effectiveness research
Value-of-information analysis	No evidence identified	—
Budget-impact analysis	**Yes**	Budget-impact analysis explicitly represented in Ohio economic-evaluation research
Healthcare priority setting and resource allocation	**Yes**	Health-policy evaluation, allocation and decision applications represented in the composite knowledge base
Value-for-money / value assessment	**Yes**	Value assessment and economic value explicitly represented within Ohio health-outcomes and pharmacoeconomic environments
Policy, reimbursement and decision use of economic evaluation	**Yes**	HOPES, Cincinnati, Toledo and associated research link economic and outcomes evidence to healthcare decision making

RESULT: 19/20

The contemporary side of the Ohio knowledge base is extensively represented. Ohio State's HOPES environment explicitly encompasses health economics, health outcomes and policy evaluation, including cost and cost-effectiveness analysis. Its purpose is not simply methodological development but the application of economic and outcomes evidence to healthcare and policy questions. The wider Ohio State research environment provides additional evidence through economic evaluations employing QALYs, incremental cost-effectiveness ratios, decision modelling, simulation and sensitivity analysis.

The Ohio State College of Pharmacy adds a substantial pharmaceutical and outcomes-research component. Its research environment encompasses medication outcomes, pharmacoeconomic analysis, healthcare value and related quantitative methods. Associated research provides further evidence of the use of utilities, QALYs, cost-effectiveness analysis and modelling within the composite Ohio knowledge base.

The University of Cincinnati provides particularly clear evidence of contemporary program content. Its Health Outcomes and Pharmacoeconomics environment explicitly addresses health technology assessment, pharmacoeconomics, economic evaluation and health outcomes. Graduate program content includes cost-effectiveness and cost-utility analysis together with decision-analytic modelling, including decision trees and Markov models. The Cincinnati environment therefore demonstrates that the downstream methods of contemporary HEOR are represented not only in research but in formal graduate education.

The University of Toledo adds a further health-outcomes and value-assessment component. Its Health Outcomes and Value Analytics environment encompasses pharmacoeconomics, HTA, healthcare outcomes, value and quantitative healthcare analytics. Decision-analytic modelling and patient-reported outcomes form part of the associated program environment, reinforcing the representation of contemporary HEOR and HTA methods within the Ohio composite knowledge base.

The interrogation also identified explicit Ohio research applications of budget-impact analysis, probabilistic sensitivity analysis, simulation and cost-per-QALY economic evaluation. These findings substantially extend the evidence beyond the descriptions of the four research environments themselves and demonstrate an established downstream quantitative research architecture.

The sole predetermined contemporary topic for which sufficiently explicit evidence was not identified was value-of-information analysis. This topic was therefore scored as absent rather than inferred from the extensive representation of decision modelling, probabilistic sensitivity analysis or uncertainty analysis.

ASSESSMENT OF OHIO RESULTS

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 probabilities of endorsement, it examines whether specified scientific and methodological topics are explicitly represented in the publicly available program content of the Ohio academic HTA, health-economics and outcomes-research knowledge base.

Two contrasting groups of content are examined using a fixed 37-topic framework. The first comprises 17 topics representing representational measurement, including measurement preceding arithmetic, scales of measurement, axioms of representational measurement, ratio measurement, admissible transformations and arithmetic, dimensional homogeneity, manifest and latent attributes, linear ratio measurement and Rasch measurement.

The second comprises 20 topics representing contemporary health economics and HTA, including economic evaluation, cost-effectiveness and cost-utility analysis, pharmacoeconomics, utilities, QALYs, ICERs, patient-reported outcomes, decision analysis, Markov and simulation modelling, uncertainty analysis, value-of-information analysis, budget impact and value assessment.

The interrogation asks a single question: does the Ohio academic HTA, health-economics and outcomes-research program-content knowledge base establish representational measurement as the foundation for quantitative claims before presenting or applying the analytical methods of contemporary HTA?

A topic is classified as explicitly represented where identifiable public evidence demonstrates its presence within the research, teaching or methodological knowledge base. Failure to identify such evidence is reported **as** "No evidence identified." This does not imply that individual Ohio researchers are unfamiliar with the topic. It means that the topic was not identified as part of the publicly represented program-content framework examined.

Importantly, references to *measurement*, *outcome measurement*, *preference measurement*, *health-state measurement* or *psychometrics* do not by themselves establish recognition of representational measurement. Similarly, numerical ratios, bounded values or values incorporating a zero do not establish recognition of ratio measurement. The criterion is whether the measurement principles themselves, and their implications for admissible arithmetic, are explicitly represented. This distinction is particularly important in an HTA environment in which numerical health-state valuation and patient-reported outcomes may routinely be described as measurement without demonstrating the representational properties required to justify that description.

If representational measurement is absent while contemporary HTA methods are extensively 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 Ohio assessment therefore asks whether lawful measurement provides the scientific foundation for quantitative HTA or whether the legacy HTA framework is represented without the measurement standards required to establish the admissibility of its arithmetic. Given the breadth and methodological sophistication of the environments examined, Ohio provides a demanding test of that question. These are not environments lacking quantitative expertise; collectively they represent substantial expertise in health economics, HTA, pharmacoeconomics, economic evaluation, cost-effectiveness and cost-utility analysis, outcomes research, patient-reported outcomes, decision modelling, simulation, budget-impact analysis, healthcare value and health-policy applications.

The significance of the test is therefore straightforward. If an Ohio academic knowledge base capable of representing 19 of the 20 predetermined analytical topics of contemporary health economics and HTA does not explicitly represent any of the 17 predetermined topics establishing the scientific requirements of representational measurement, the issue cannot readily be attributed to a lack of quantitative sophistication. It identifies the absence of the scientific measurement framework that should logically precede and govern that sophistication.

The resulting 0/17 versus 19/20 comparison therefore provides the empirical test of program-content inversion in Ohio: an almost complete representation of the downstream analytical framework accompanied by no identified representation of the upstream measurement requirements needed to determine whether its quantitative operations are admissible.

The Ohio knowledge base therefore exhibits pronounced program-content inversion. The analytical methods of contemporary HTA and health economics are extensively represented, while the representational-measurement requirements that should provide their prior scientific foundation are not.

The Ohio result is difficult to dismiss as a minor curriculum imbalance. The contrast is too pronounced. Across the composite knowledge base of four major university-affiliated HEOR, pharmacoeconomic and outcomes-research environments, none of the 17 predetermined representational-measurement topics was identified, while 19 of the 20 predetermined topics representing contemporary HTA and health economics were explicitly represented. The sole exception on the contemporary side was value-of-information analysis. The resulting profile 0/17nand 20/20 is not evidence of an immature analytical environment. It is evidence of a highly developed analytical environment constructed downstream of a measurement foundation that is not represented.

That distinction is critical. Ohio cannot be characterized as lacking quantitative sophistication. Its universities demonstrate extensive competence in health economics, pharmacoeconomics, utilities, QALYs, cost-effectiveness and cost-utility analysis, ICERs, outcomes research, decision analysis, decision trees, Markov models, simulation, probabilistic sensitivity analysis, budget-impact analysis and healthcare value. The contemporary analytical apparatus is substantially in place. The problem is that the knowledge base appears to begin where lawful quantitative analysis should begin much earlier.

The missing material is foundational, not decorative. Representational measurement determines whether numerical assignments correspond to an identified empirical attribute, what scale has been achieved, what transformations preserve meaning and what arithmetic can legitimately be performed. Ratio measurement determines whether multiplication and division have empirical interpretation. Dimensional homogeneity constrains the quantities that can lawfully be combined. The distinction between manifest and latent attributes determines which measurement pathway is appropriate. These requirements should govern downstream analysis. Yet none was identified as an organizing prerequisite within the Ohio knowledge base.

This makes the Ohio finding more serious than a simple omission of measurement theory. The result indicates program-content inversion: the methods that depend upon measurement are represented, while the measurement requirements that should authorize those methods are absent. Students and researchers can therefore become increasingly proficient in manipulating numerical outputs without first being required to establish whether those numerical outputs possess the properties necessary for the arithmetic performed upon them.

The QALY provides the most obvious example. Ohio's knowledge base contains utilities, QALYs, cost-utility analysis and cost-per-QALY claims. But the 0/17 result provides no evidence that the prior measurement question is being asked: what exactly does the utility measure, what scale properties has it demonstrated, and what authorizes its multiplication by time? If those questions are not answered, the ability to calculate QALYs is not evidence that QALYs are legitimate measures. It merely demonstrates that the arithmetic can be executed.

The same problem extends downstream. If the QALY has not first been established as a lawful quantitative measure, subtraction to produce incremental QALYs does not repair the failure. Division of incremental costs by an inadmissible outcome denominator does not create a scientifically meaningful ICER. Probabilistic sensitivity analysis, simulation and increasingly elaborate decision models likewise cannot manufacture measurement properties that were absent before the model began. Sophistication downstream does not compensate for failure upstream.

The Ohio result therefore raises an uncomfortable question for universities: what exactly is being taught when students are trained to become technically proficient in contemporary HEOR without first being required to establish the scientific legitimacy of the quantities they manipulate? It is not sufficient to respond that these methods are standard practice, appear in professional guidelines or are widely used in the literature. Institutional acceptance cannot establish measurement properties. Nor can widespread repetition convert an inadmissible arithmetic operation into an admissible one.

The educational implications are particularly important. Faculty may reasonably argue that they were themselves trained within the same legacy framework and were never introduced to representational measurement as the gatekeeper to quantitative analysis. That helps explain how the present knowledge architecture developed. It does not justify reproducing it indefinitely. Once the absence of the measurement foundation has been exposed, another generation of students cannot simply be taught utilities, QALYs, cost-effectiveness analysis and modelling as though the scientific problem had never been identified.

Ohio therefore faces a choice that is increasingly difficult to avoid. One option is to defend the existing framework by demonstrating that its central quantitative constructs satisfy the requirements of lawful measurement. That requires more than pointing to convention, precedent or computational practice. The measurement properties themselves must be shown. If that demonstration cannot be provided, then the affected methods should not be protected simply because they are familiar.

The alternative is reconstruction. This does not mean adding one or two lectures on measurement to an otherwise unchanged curriculum. The 0/17 versus 19/20 result indicates that the ordering itself must change. Attribute definition and measurement must come first. Scale properties must determine admissible arithmetic. Manifest and latent attributes must be treated through appropriate measurement pathways. Only quantities that pass the measurement gate should proceed to downstream quantitative analysis.

The Ohio result is therefore not evidence that contemporary HEOR requires modest methodological improvement. It is evidence that its intellectual architecture is inverted. The universities examined have built a substantial downstream apparatus while leaving the measurement foundation unrepresented. The task is not to decorate that apparatus with additional measurement terminology. It is to reverse the sequence on which the present framework rests.

Measurement must precede arithmetic. Until that requirement becomes the organizing principle of Ohio HTA and HEOR, the 0/17 versus 19/20 profile remains evidence of a scientifically unresolved knowledge base.

CONCLUSION: OHIO TRANSITION TO LAWFUL MEASUREMENT

Now that the measurement problem has been exposed, the challenge facing Ohio universities, research centers and the wider HTA and health-economics community is substantial. The issue is no longer whether contemporary HTA might benefit from greater attention to measurement theory. The Ohio program-content findings, together with the accompanying evidence of measurement and program-content inversion, identify a foundational problem: the central analytical framework of contemporary HTA depends upon arithmetic operations whose admissibility has not first been established under the requirements of representational measurement and the scales of measurement. 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 simply by appealing to established American or international practice. The relevant question is no longer whether utilities, QALYs, cost-effectiveness models and related methods have proved useful, achieved widespread professional acceptance or been employed for decades in research, reimbursement and healthcare decision-making. Longevity, institutional acceptance and methodological sophistication do not establish quantitative validity. Once the requirements governing admissible arithmetic are applied, the problem becomes transparent. Multiplication and division require the appropriate ratio properties. Arithmetic operations are constrained by scale properties. Dimensional homogeneity must be maintained. Numerical assignment cannot substitute for measurement. Where these requirements are violated, the resulting arithmetic is inadmissible. No degree of statistical sophistication, simulation modelling, uncertainty analysis or methodological refinement can repair a measurement failure that occurs before the arithmetic begins.

The challenge for Ohio is therefore one of transformation: how should established academic environments for health economics, pharmacoeconomics, outcomes research and healthcare evaluation be reconstructed to satisfy the requirements of lawful measurement?

The four environments included in the present interrogation—the Ohio State University Center for Health Outcomes and Policy Evaluation Studies (HOPES); the Ohio State University College of Pharmacy outcomes and pharmacoeconomic research environment; the University of Cincinnati Health Outcomes and Pharmacoeconomics research and graduate environment; and the University of Toledo Health Outcomes and Value Analytics/Health Outcomes and Socioeconomic Sciences environment—represent a substantial concentration of quantitative healthcare expertise. Through graduate education, research, professional training and collaboration with healthcare, industry and policy communities, these environments contribute to the analytical framework applied within and beyond Ohio.

The 0/17 versus 19/20 program-content finding therefore provides an opportunity to reconsider not simply what is included in Ohio academic HTA and health economics, but the scientific sequence in which that knowledge is organized. The contrast is striking. Nineteen of the twenty predetermined topics defining contemporary health economics and legacy HTA are explicitly represented, while none of the seventeen predetermined topics defining representational measurement is explicitly established as the scientific foundation upon which those methods depend. Ohio does not lack quantitative sophistication. The problem is almost precisely the reverse: it possesses a highly developed analytical superstructure without the publicly represented measurement foundation required to establish whether its central operations are quantitatively admissible.

This makes the Ohio result difficult to dismiss. The contemporary knowledge base is sufficiently developed to represent virtually the entire downstream analytical framework. The sole topic for which sufficiently explicit evidence was not identified was value-of-information analysis. The 0/17 finding cannot therefore readily be attributed to an academically immature environment, generally sparse program content or an absence of quantitative methods. The environments examined possess substantial expertise in health economics, pharmacoeconomics, outcomes research, economic evaluation, patient-reported outcomes, modelling and health-policy applications. The absence of representational measurement instead points to the scientific organization of the knowledge base itself.

The starting point for reconstruction is straightforward. Representational measurement must become the organizing scientific principle for quantitative therapy evaluation rather than an optional supplement to the existing HTA curriculum. Students and researchers must first learn to identify and define the target attribute, establish unidimensionality, distinguish manifest from latent attributes, determine the appropriate measurement pathway, establish the scale achieved and identify the arithmetic operations admissible for that scale. They must understand why multiplication and division impose ratio requirements, why dimensional homogeneity matters and why assigning numbers to health states, questionnaire responses or preferences cannot manufacture measurement properties that have not been demonstrated empirically.

For manifest attributes, the appropriate pathway is linear ratio measurement. For latent attributes, the alternative is Rasch measurement, with its requirements for conjoint measurement, invariance and specific objectivity. These two measurement pathways provide the foundation for constructing attribute-specific therapy-impact claims that can be empirically evaluated, replicated and potentially falsified. Only after these measurement requirements have been satisfied should arithmetic, statistical analysis, economic evaluation or other quantitative procedures be undertaken. This requirement has been place for the physical and more sophisticated social sciences for some 70 years.

The required transformation does not abandon HTA. It rescues therapy evaluation from a legacy analytical framework and places it within the accepted standards of normal quantitative science.

Ohio universities and research centers therefore face a clear choice. They can continue reproducing an inherited framework of measurement failure in which utilities, QALYs, ICERs and modelled claims are accepted without first demonstrating that their constituent quantities support the arithmetic required of them. Or they can begin the reconstruction of quantitative therapy evaluation around defined attributes, lawful measurement, admissible arithmetic and empirically evaluable claims.

The Ohio environments examined do not operate in methodological isolation. Their faculty educate future pharmacists, health economists, outcomes researchers and other healthcare professionals; publish research; collaborate with pharmaceutical manufacturers, healthcare organizations and policy communities; and contribute to the wider development and application of quantitative healthcare methods. The scientific standards governing measurement cannot change according to institutional prestige or professional influence. The same requirements must apply whether a quantitative claim originates at Ohio State, Cincinnati, Toledo, another university, a pharmaceutical manufacturer, an HTA organization or a government agency. Institutional authority cannot confer measurement properties upon numbers that do not possess them.

Faculty necessarily have the leading educational role in this transition. This does not imply that Ohio investigators have knowingly disregarded representational measurement. Contemporary faculty were themselves largely educated within the established health-economics and HTA paradigm. They learned the methods transmitted through universities, textbooks, journals, professional organizations, methodological guidelines and accepted research practice. If representational measurement and the arithmetic of scales of measurement were absent from that education, there was little reason for investigators subsequently to recognize that the arithmetic they had inherited rested upon measurement assumptions that had never been demonstrated.

The Ohio 0/17 finding demonstrates how complete that omission remains within the publicly represented program-content knowledge base. It helps explain how the legacy could have been transmitted from one generation of researchers to another. It cannot justify transmitting it again.

Once the measurement problem has been explicitly identified, faculty and universities acquire a different responsibility. Students entering Ohio health-economics, HTA, pharmacoeconomics and outcomes-research programs should not simply be trained to reproduce methods because those methods are professionally established. They should be given the scientific knowledge necessary to determine whether those methods are quantitatively admissible. Faculty who believe that utilities support multiplication by time, that QALYs constitute legitimate quantitative measures, or that cost-per-QALY ICERs possess the properties attributed to them should be entirely free to defend those propositions. But students must equally be provided with the principles of representational measurement and scale theory necessary to determine whether those propositions can be sustained.

This is where the 19/20 finding becomes particularly uncomfortable. The Ohio academic knowledge base is demonstrably capable of providing students with virtually the complete methodological apparatus of legacy HTA. Students can encounter economic evaluation, utilities, QALYs, cost-effectiveness and cost-utility analysis, ICERs, patient-reported outcomes, decision trees, Markov models, simulation, probabilistic sensitivity analysis and budget-impact analysis. It therefore cannot reasonably be argued that introducing the scientific principles required to interrogate that apparatus is beyond the educational capacity of these institutions. If students can master the downstream sophistication, they can certainly master the upstream measurement principles that determine whether the downstream arithmetic is lawful.

The question is one of priority.

This creates a particular responsibility for universities. A university is not simply a mechanism for reproducing prevailing professional practice. Its responsibility is to expose established claims and methods to critical scientific scrutiny. Academic freedom protects faculty who wish to defend conventional utilities, QALYs, ICERs and reference-case modelling. It equally requires an intellectual environment in which students are provided with the scientific principles necessary to challenge them. The appropriate university response to a foundational criticism is not to determine in advance which side must prevail. It is to ensure that students possess the knowledge necessary to evaluate the competing claims.

The implications for students are therefore immediate. Graduate students invest substantial time and resources in their education and may subsequently spend decades applying the methods they have been taught. They are entitled to expect more than technical proficiency in an inherited analytical framework. They should understand the scientific conditions under which quantitative claims are possible and be capable of determining whether those conditions have been met.

The responsibility becomes still more difficult now the challenge is publicly available. Another generation of students cannot simply be introduced to the same analytical framework as though no measurement problem had been identified. Universities and faculty do not have to endorse the critique. They do not have to accept the conclusion that the QALY or the cost-per-QALY reference case fails representational-measurement requirements. But they should expose students to the principles necessary to decide that question for themselves.

Otherwise, the question that may eventually be directed back at today's faculty is straightforward: Why were we taught how to construct utilities, QALYs, ICERs and increasingly sophisticated models, but never taught the measurement principles required to determine whether those operations were scientifically admissible when those principles and the challenge they posed were already available?

That is not a question that can satisfactorily be answered by pointing to established practice, professional consensus or the reputation of the institution that provided the education.

Transformation must therefore begin with faculty. Ohio universities and research centers need to introduce the scientific knowledge and practical tools required for faculty themselves to reconsider the measurement foundations of what they research and teach. This cannot be accomplished merely by inserting an isolated lecture on measurement into an otherwise unchanged curriculum. Once students understand that measurement precedes arithmetic, the implications extend throughout economic evaluation, utility measurement, QALY construction, cost-effectiveness analysis, outcomes measurement and decision modelling. Measurement cannot be taught seriously and then quarantined from the methods it calls into question.

The route out is nevertheless surprisingly straightforward. It requires neither another economic model nor another refinement of the reference case. It requires restoration of the scientific sequence that legacy HTA abandoned: science demands measurement, not merely numbers. Identify the attribute; establish its measurement requirements; determine whether it is manifest or latent; construct the appropriate measure; establish the arithmetic permitted by that measure; and then formulate therapy-impact claims that are empirically evaluable, replicable and capable of falsification.

The 0/17 versus 19/20 finding should consequently be treated not as a criticism of Ohio quantitative expertise but as a warning about its scientific foundations. Ohio has developed a substantial infrastructure for contemporary health economics, pharmacoeconomics, outcomes research and HTA. What is now required is an equally serious commitment to establishing whether the numbers manipulated within that infrastructure are measures and whether the arithmetic performed upon them is lawful.

Ohio also has an opportunity. Its universities do not need to wait for ISPOR, an HTA agency or another central authority to reconstruct the scientific foundations of what they teach. The requirements of representational measurement already exist, and the transition can begin within individual academic and research environments. The fact that the inherited framework is internationally established does not require Ohio universities to continue reproducing it once its measurement foundations have been challenged.

The choice is therefore straightforward. Ohio can continue reproducing an inherited legacy HTA paradigm in which arithmetic precedes demonstrated measurement, or its universities can help lead the transition to a post-legacy framework in which measurement precedes arithmetic, ratio properties precede multiplication and division, and empirically evaluable claims replace assumption-driven numerical storytelling.

The measurement problem has been identified. The scientific standards are available. The alternative measurement framework is available. The remaining question is whether another generation of Ohio students will be taught the legacy as though none of this had happened.

It is precisely this challenge that the Maimon Research nine-unit transformation program is intended to address [4]. This program provides a structured template for faculty, researchers and practitioners seeking to understand and implement the transition from the measurement failure of legacy HTA to a framework grounded in representational measurement. The program comprises 45,000 words of structured instructional material with the nine units moving progressively from measurement preceding arithmetic through attributes, scales of measurement, admissible arithmetic and dimensional homogeneity to the distinction between manifest and latent attributes, linear ratio measurement, Rasch measurement, attribute possession and the construction of empirically evaluable therapy-impact claims. The program can therefore be used for individual faculty preparation, as a framework for reconsidering existing graduate teaching, or as the foundation for developing a new postgraduate course in HTA organized around the requirements of lawful measurement and normal science.

The material presented can be integrated into existing programs without requiring wholesale curriculum reconstruction. The essential change is one of scientific sequence. At the beginning of a course, students should be provided with the measurement principles required to interrogate every quantitative method that follows: what is the attribute to be measured; is it unidimensional; is it manifest or latent; what measurement scale has been established; what transformations and arithmetic are admissible; and does the proposed analysis preserve dimensional homogeneity? These questions can then be applied systematically as students encounter utilities, QALYs, reference case economic evaluation, patient-reported outcomes, decision models and the other established components of legacy HTA.

Representational measurement thereby becomes not another topic added to an already crowded curriculum but the organizing scientific framework through which the existing curriculum is critically assessed. Importantly, this places students in a position to judge the merits of the alternatives for themselves: whether there is a defensible scientific basis for continuing to support the legacy HTA framework, or whether quantitative therapy evaluation should instead be reconstructed around lawful measurement, admissible arithmetic, evaluable claims, replication and falsification; the standards expected of normal science. The educational responsibility is therefore not to prescribe the conclusion students must reach, but to ensure that they possess the scientific knowledge required to make that judgment.

An important feature of the program is that participants are not left simply to work through the material independently. Those enrolled have access to continuing 24/7 on line Q&A support from Maimon Research as they study the units and, importantly, as they begin to apply the framework in teaching, research or therapy evaluation**.** Questions arising from particular attributes, proposed measures, Rasch applications, therapy-impact claims, protocols or curriculum development can be raised as they occur. The purpose is to support the transition from understanding the principles to applying them in practice. This continuing interaction is particularly important for faculty whose previous education did not include representational measurement and who may be reconsidering assumptions embedded in many years of teaching and research. The objective is not simply completion of nine units, but development of the capability to use the measurement framework independently and to introduce it confidently to students and colleagues.

The program can also provide a starting point for broader institutional engagement. Where universities, research centers, academic departments or professional groups wish to explore the implications of the new HTA in greater depth, additional activities can be developed around their particular requirements, including seminars, faculty discussions, workshops, small-group sessions, curriculum-development support and presentations addressing specific measurement or therapy-evaluation problems. These activities allow institutions to move beyond individual enrollment toward a wider reconsideration of how HTA is taught and applied.

A fee is charged for access to the nine-unit program to support the maintenance, administration, updating and continuing availability of the system, including participant support. The larger objective, however, is transformation: to provide faculty and institutions with an accessible, supported pathway for replacing the legacy of measurement failure with graduate education grounded in lawful measurement, admissible arithmetic and empirically evaluable claims.

The nine-unit program is therefore offered as a template for faculty preparation and the development of a post-legacy graduate HTA program. Universities may use the framework to reconsider existing teaching or as the foundation for constructing a new graduate course organized explicitly around representational measurement

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