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REPRESENTATIONAL MEASUREMENT FAILURE IN HEALTH TECHNOLGY ASSESSMENT

AUSTRALIA: UNIVERSITY RESEARCH CENTERS AND THE ABSENCE OF MEASUREMENT IN HTA EDUCATION

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ABSTRACT

Recent evaluations of Australia's health technology assessment (HTA) knowledge base have identified two related forms of scientific failure. Measurement inversion describes the endorsement of quantitative methods that ignore the requirements of representational measurement, while curriculum inversion demonstrates that these same methodological assumptions are reproduced within the educational knowledge base. The present study extends this sequence by examining whether these findings originate in the content of Australian university and related HTA educational programs.

The investigation focuses on seven leading Australian university centers responsible for teaching health economics and HTA. Using large language model (LLM) interrogation of publicly available curricula, course descriptions, teaching materials and associated educational resources, the study evaluates whether program content reflects the accepted scientific standards of representational measurement or the alternative framework that characterizes contemporary HTA. Two mutually exclusive sets of standards are applied. The first represents the scientific requirements for quantitative inquiry, including the principle that measurement must precede arithmetic, the distinction between manifest and latent attributes, lawful ratio measurement, dimensional homogeneity, and the unique roles of linear ratio measurement and Rasch logit ratio measurement. The second represents the dominant constructs of contemporary HTA, including utilities, multiattribute utility instruments, QALYs, cost-effectiveness analysis, decision modelling and reference-case simulation.

Across all seven Australian centers the findings are consistent. No evidence is identified that students are introduced to the scientific foundations of representational measurement before instruction in the analytical methods that dominate contemporary HTA. Instead, educational programs provide extensive coverage of economic evaluation, utilities, QALYs, incremental cost-effectiveness ratios, decision-analytic modelling and related techniques while omitting the measurement principles necessary to justify the arithmetic upon which these methods depend. The resulting educational sequence reverses the accepted order of quantitative science: arithmetic precedes measurement.

These findings indicate that program content inversion provides the educational mechanism through which curriculum inversion reproduces measurement inversion. Because Australian universities educate the researchers, analysts and policy advisers whose work informs Pharmaceutical Benefits Advisory Committee (PBAC) submissions and national reimbursement decisions, the implications extend beyond curriculum design to the scientific credibility of Australian HTA itself. The study concludes that representational measurement must become the foundation of HTA education. Until university programs teach that quantitative claims require lawful ratio measurement, linear ratio measurement for manifest attributes and Rasch logit ratio measurement for latent attributes, the numerical claims generated by contemporary HTA cannot be regarded as scientifically credible quantitative evidence.

INTRODUCTION

Previous Australian investigations identified two related patterns within the national health technology assessment (HTA) knowledge base. Measurement inversion was demonstrated by the inverted endorsement of statements concerning the scientific requirements for quantitative measurement [1]. Statements affirming that measurement must precede arithmetic, that admissible mathematical operations depend upon the properties of the measurement scale, that quantitative claims require unidimensional attributes, and that manifest and latent attributes require different forms of measurement received consistently weak endorsement. Conversely, statements treating utilities, multiattribute utility instruments, QALYs and simulation-based cost-effectiveness models as scientifically valid quantitative methods received consistently strong endorsement. Curriculum inversion described the corresponding pattern within the educational knowledge base [2]. The concepts that define representational measurement were either absent or weakly endorsed, while the conventional concepts underpinning contemporary HTA received consistently strong endorsement.

These findings naturally invite a further question. If measurement inversion and curriculum inversion characterize the Australian HTA knowledge base, where do these patterns originate? A logical next step is to examine the content of the university-level, and equivalent, programs through which HTA is introduced and developed. Educational knowledge bases do not arise independently of the programs from which they are derived. The topics selected, the concepts emphasized, the sequence in which methods are presented and the standards adopted for evaluating quantitative claims together determine the intellectual framework subsequently reproduced in research, policy and professional practice. The present investigation therefore asks whether the publicly available content of Australian HTA programs is consistent with, and may help explain, the previously demonstrated patterns of measurement inversion and curriculum inversion.

This question is important because the influence of Australian HTA education extends well beyond the classroom. University programs educate the researchers, health economists, analysts and policy advisers who subsequently contribute to health technology assessment throughout Australia. Their graduates undertake academic research, prepare reimbursement submissions, develop methodological guidance, advise governments and industry, and contribute directly or indirectly to assessments considered by the Pharmaceutical Benefits Advisory Committee (PBAC) [3]. PBAC recommendations determine whether medicines and other technologies receive public reimbursement through the Pharmaceutical Benefits Scheme, decisions involving many billions of dollars in public expenditure and affecting the availability of therapies for millions of Australians. The analytical framework established through Australian HTA education therefore has direct implications for the evidence that supports national health care decision making.

If the educational framework supporting that evidence fails to recognize the scientific conditions required for quantitative measurement, the implications extend well beyond education itself. Decision makers necessarily assume that the quantitative claims presented to them are supported by admissible measures. Cost-effectiveness ratios, QALYs, model outputs and reference-case simulations can only provide scientifically meaningful evidence if the quantities from which they are derived satisfy the requirements of measurement. If those requirements are not met, no degree of statistical sophistication or mathematical complexity can compensate for the absence of valid measurement [4]. The scientific integrity of health care decision making therefore depends ultimately upon the measurement standards embedded within the educational framework from which HTA practice is derived.

The present investigation examines the publicly available educational content of seven Australian university centers that collectively represent a substantial component of Australia's academic capacity in health economics and health technology assessment. These comprise the **Centre for Health Economics (CHE), Monash University**; the **Melbourne School of Population and Global Health (MSPGH), University of Melbourne**; the **Centre for Health Economics Research and Evaluation (CHERE), University of Technology Sydney**; the **Health Economics Research Unit (HERU), University of Queensland**; the **Health Economics Group (HEG), University of Adelaide**; the **Centre for Applied Health Economics (CAHE), Griffith University**; and the **School of Public Health, University of Sydney**. Together these centers educate many of Australia's future health economists, HTA researchers, reimbursement analysts and policy advisers, making their curricula a critical source of the analytical framework that ultimately informs PBAC submissions and Australian health technology assessment practice.

As in the previous investigations, this question can be examined through large language model interrogation of publicly available educational knowledge bases. Program descriptions, curricula, course outlines, teaching materials, methodological guidance and associated research outputs collectively define the conceptual framework presented by each institution. Rather than evaluating isolated topics, the interrogation applies two contrasting sets of canonical standards. The first captures the scientific requirements of representational measurement, including the principle that measurement must precede arithmetic, the properties of the scales of measurement, ratio measurement, dimensional homogeneity, and the distinction between manifest and latent attributes together with their respective requirements for measurement. The second captures the concepts that characterize contemporary HTA, including utilities, multiattribute utility instruments, QALYs, cost-effectiveness modelling, decision analysis, Markov models, probabilistic sensitivity analysis, reference-case simulation and related analytical methods.

These two frameworks are not complementary. They are mutually exclusive. Acceptance of the standards of representational measurement necessarily precludes acceptance of contemporary HTA as a scientifically valid framework for quantitative claims because the latter depends upon numerical constructions that do not satisfy the measurement conditions required for admissible arithmetic. Conversely, endorsement of contemporary HTA necessarily implies the rejection, whether explicit or implicit, of the scientific requirements of representational measurement. The interrogation therefore asks a straightforward question: which of these two competing conceptual frameworks is represented in the content of Australian HTA programs and their associated educational materials?

The present study examines the publicly available educational content associated with seven leading Australian HTA and health economics research centers. Together these institutions represent a substantial component of Australia's academic capacity in health economics, outcomes research and health technology assessment. The objective is not to evaluate institutional quality or teaching performance. Rather, it is to determine which conceptual framework these programs endorse as the scientific foundation for quantitative claims. If the standards of representational measurement are found to be absent while those of contemporary HTA dominate program content, then program content inversion provides a plausible explanation for the previously demonstrated patterns of measurement inversion and curriculum inversion. If, however, representational measurement is found to underpin these programs, the earlier conclusions regarding measurement and curriculum inversion would require reconsideration.

FOUNDATIONS OF QUANTITATIVE ANALYSIS

Before proceeding to the analysis of program content, it is important to identify the scientific principles against which that content must be interpreted. The purpose is not to prejudge the findings of the investigation but to make explicit the standards that define lawful quantitative inquiry throughout the physical and social sciences. These standards have been established for many decades through the theory of representational measurement and are not matters of methodological preference or competing philosophical opinion. They are the conditions that determine whether quantitative claims are scientifically admissible.

Two principles are fundamental. First, measurement must precede arithmetic. Numerical operations are permissible only after the attribute of interest has been shown to possess the properties required for quantitative measurement. Arithmetic cannot create measurement where measurement does not already exist. Second, the arithmetic operations employed must be admissible for the scale on which the attribute has been measured. In practice, claims involving multiplication, division, averaging, ratios and other quantitative comparisons require ratio measurement. For health technology assessment, this requirement can be satisfied in only two ways: by a linear ratio measure for manifest attributes or by a Rasch logit ratio measure for latent attributes. No alternative measurement framework satisfies these requirements.

These principles are not optional and they are not open to negotiation. They define the boundary between numerical description and quantitative science. While contemporary HTA has developed a body of methods founded upon utilities, QALYs and simulation modelling, the present investigation is not concerned with defending or criticizing those methods as matters of policy preference. Rather, it asks a prior scientific question: do Australian university and related HTA programs acknowledge the measurement principles that govern all quantitative inquiry, or do they present an alternative framework that proceeds without first establishing the conditions required for valid arithmetic? It is this question that guides the analysis that follows.

MEASUREMENT BEFORE ARITHMETIC

Before students are introduced to health technology assessment, health economics, outcomes research, cost-effectiveness analysis or decision modelling, they should first be introduced to the scientific principles that determine whether any quantitative claim is possible [5 6] This is not a matter of pedagogical preference but of scientific necessity. Every quantitative discipline, whether in the physical, biological, or social sciences, is founded upon the prior establishment of measurement. Arithmetic is meaningful only when applied to quantities that have first been shown to satisfy the requirements of measurement. Consequently, the first responsibility of any HTA curriculum is not to teach methods for manipulating numbers, but to teach the conditions under which numbers represent measurable attributes.

For more than eighty years these principles have defined the accepted scientific standards for quantitative measurement through the theory of representational measurement. They are not optional methodological conventions but the universally accepted conditions governing quantitative inquiry across the physical and social sciences. An attribute must first be identified and defined. It must then be demonstrated that observations of that attribute satisfy the axioms necessary for quantitative representation. Only after these conditions have been established can numerical values be assigned and arithmetic operations justified. The sequence is therefore unambiguous: identify the attribute, establish measurement, then undertake arithmetic. Reversing this order produces numerical results that have no scientific interpretation, regardless of the sophistication of the statistical or economic methods subsequently applied.

An HTA curriculum that claims to prepare scientists and policy analysts must therefore begin with representational measurement, the scales of measurement, admissible transformations, dimensional homogeneity, and the distinction between manifest and latent attributes. These concepts provide the framework within which every subsequent quantitative claim is judged. Without them, students cannot distinguish between numbers that represent measurable quantities and numbers that merely label categories or order preferences. The consequence is that sophisticated computational methods become detached from the scientific requirements that justify their application.

Once these foundations have been established, the educational pathway becomes remarkably simple. There are only two admissible forms of ratio measurement capable of supporting quantitative claims for therapy impact. Which form is required depends entirely upon the nature of the attribute under investigation.

The first concerns manifest attributes. These are attributes that can be observed directly and measured using conventional physical or operational procedures. Examples include survival time, hospital admissions, emergency department visits, doses administered, days receiving therapy, laboratory concentrations, tumor dimensions, or walking distance. Such attributes possess observable units, a true zero, and permit the construction of linear ratio scales. Because equal intervals represent equal quantities and zero represents the complete absence of the attribute, all arithmetic operations, including multiplication and division, are admissible. Therapy claims expressed in terms of these measures are therefore directly evaluable and capable of empirical replication.

The second concerns latent attributes. These attributes cannot be observed directly because they represent underlying constructs such as pain severity, physical functioning, fatigue, anxiety, depression, quality of life, or need fulfilment. Unlike manifest variables, latent attributes cannot be measured simply by assigning numerical values to questionnaire responses or summing item scores. Their existence and measurement require a formal measurement model capable of demonstrating that the observed responses reflect a single underlying quantitative continuum.

The only measurement framework that satisfies these requirements is the Rasch measurement model [7]. Rasch analysis does not begin by assuming that questionnaire scores constitute measurements. Instead, it asks whether the responses are consistent with the existence of a unidimensional latent attribute that can be measured independently of the particular sample of respondents or the particular items employed. Through conjoint estimation of persons and items, the Rasch model constructs an invariant continuum upon which both persons and items can be located. Only when the data satisfy the requirements of the model can the resulting estimates be interpreted as measures.

This distinction is fundamental because the objective of Rasch measurement is not the production of questionnaire scores. Its objective is the measurement of an individual's possession of a latent attribute. The latent attribute is the quantity of scientific interest; the questionnaire responses merely provide observable evidence from which that quantity may be estimated. The resulting person location on the Rasch continuum represents the individual's degree of possession of the defined latent attribute, while the item locations represent the relative amount of the attribute required to endorse each item. Measurement is therefore achieved through the interaction between persons and items, not through the arithmetic aggregation of responses.

The concept of possession distinguishes Rasch measurement from both conventional psychometrics and general item response theory. Summed scores describe patterns of responses but do not establish that the underlying attribute has been measured. Similarly, statistical models that estimate person parameters without satisfying the measurement requirements embodied in the Rasch model do not necessarily produce measures possessing the invariance required by representational measurement. Rasch is unique because its objective is the construction of an invariant ruler capable of measuring the quantity of a latent attribute possessed by each individual. The emphasis is therefore on measurement rather than statistical description.

Once this distinction is understood, the educational implications are immediate. Every HTA curriculum should teach that claims involving manifest attributes require linear ratio measurement, while claims involving latent attributes require Rasch logit ratio measurement. There is no third category. Utilities, preference scores, composite indices, and other numerical constructions do not become quantitative measures simply because they are expressed numerically or incorporated into increasingly sophisticated statistical models. Their admissibility depends entirely upon whether they satisfy the requirements of representational measurement.

The implications for Australian HTA education are therefore straightforward. If university and related HTA programs are to provide the scientific foundations for evidence that ultimately informs PBAC and Pharmaceutical Benefits Scheme decision making, students should first learn what constitutes a measurable attribute, how ratio measures are established, why measurement must precede arithmetic, and why latent attributes require Rasch logit ratio measurement to establish possession. Only after these foundations have been mastered should they proceed to decision analysis, cost-effectiveness analysis, utilities, simulation models and reimbursement frameworks. Without this sequence, quantitative methods become detached from the scientific principles that alone justify their application. An Australian HTA curriculum that fails to teach these foundations does not merely omit an introductory topic; it omits the scientific basis upon which every subsequent quantitative claim depends.

THE CRITICAL ROLE OF RATIO SCALES

The analysis of Australian HTA programs must begin with the scientific principles that govern all quantitative inquiry. The first responsibility of any scientific discipline is to establish lawful measurement. Before numerical values can be manipulated, compared, multiplied, or divided, it must first be demonstrated that they represent measurable quantities. This principle has been accepted throughout the physical sciences and, since the development of representational measurement theory in the mid-twentieth century, has provided the scientific foundation for quantitative claims in the biological and social sciences. It is not arithmetic that defines science; it is measurement. Arithmetic is merely the language through which established measurements are analyzed and interpreted.

For health technology assessment, this distinction is fundamental. Every quantitative claim concerning therapy impact ultimately rests upon arithmetic operations. Cost-effectiveness analysis divides costs by measures of health benefit. Quality-adjusted life years multiply measures of health status by time. Decision models repeatedly multiply probabilities, transition rates, utilities, durations, and resource use. The validity of these calculations therefore depends entirely upon the validity of the measures entering them. If the underlying quantities are not lawful measures, no amount of statistical sophistication or computational complexity can transform the resulting calculations into scientifically meaningful evidence.

The critical issue is therefore the nature of the measurement scale. Representational measurement recognizes four broad classes of scale, nominal, ordinal, interval, and ratio but only one of these supports the full range of arithmetic operations required by quantitative science. A ratio measure is characterized by equal units of measurement together with a true, non-arbitrary zero representing the complete absence of the attribute being measured. Because equal differences represent equal quantities and ratios between observations are meaningful, all arithmetic operations, including multiplication and division, are admissible. Ratio measurement is therefore the necessary condition for quantitative analysis whenever products, ratios, averages, rates, or proportional comparisons are required.

This property distinguishes ratio scales from all other forms of measurement. Nominal scales merely classify observations. Ordinal scales rank observations without establishing equal distances between adjacent values. Interval scales possess equal intervals but lack a true zero, making ratios meaningless. Only ratio scales support statements such as "twice as much," "half as great," or "three times the quantity." Whenever multiplication or division is undertaken, the quantities involved must therefore be expressed on ratio scales. This is not a methodological preference but a mathematical necessity arising directly from the axioms of representational measurement.

The implications for health technology assessment are immediate. Contemporary HTA relies almost entirely upon multiplicative arithmetic. Quality-adjusted life years are calculated by multiplying a measure of health status by survival time. Incremental cost-effectiveness ratios divide differences in costs by differences in health outcomes. Decision-analytic models continually combine probabilities, transition rates, utilities, resource use, and durations through repeated multiplication and division. The entire analytical framework therefore presupposes that the quantities entering these calculations are ratio measures. Without ratio measurement, the arithmetic upon which HTA depends is inadmissible.

This requirement leads to a remarkably simple conclusion. There are only two admissible forms of ratio measurement applicable to claims for therapy impact. The first is the linear ratio measure, appropriate for manifest attributes that are directly observable. The second is the Rasch logit ratio measure, required for latent attributes that cannot be observed directly.

Once these two forms of ratio measurement are recognized, every subsequent methodological requirement follows naturally. Manifest attributes require linear ratio measures. Latent attributes require Rasch logit ratio measures. Arithmetic is admissible only when these measures have first been established. Dimensional homogeneity becomes a necessary condition for combining quantities. Multiplication and division become restricted to lawful ratio measures. Conversely, ordinal preference scores, utilities, and other numerical constructions that fail to satisfy the requirements of ratio measurement cannot legitimately support multiplicative arithmetic, irrespective of how widely they are used or how sophisticated the subsequent modelling may appear.

This principle provides the single scientific criterion upon which Australian HTA education should be judged. The question addressed in the present investigation is therefore straightforward. Do Australian university and related HTA programs introduce students to ratio measurement as the indispensable foundation of quantitative analysis before presenting utilities, QALYs, cost-effectiveness analysis, simulation modelling and reimbursement frameworks? Or do they reverse this sequence by teaching computational methods without first establishing the scientific conditions that make those methods admissible?

The answer to this question is of more than academic interest. Australian HTA provides the analytical framework supporting reimbursement submissions and advice to the Pharmaceutical Benefits Advisory Committee (PBAC). If the educational programs preparing future HTA practitioners fail to recognize ratio measurement as the indispensable foundation of quantitative analysis, then the implications extend throughout Australian HTA practice. Ratio measurement is therefore not simply one topic among many within measurement theory. It is the scientific foundation upon which every quantitative claim concerning therapy impact ultimately depends.

PROGRAM CONTENT AND COVERAGE

The assessment of program content and coverage employs the same methodological framework that has been used throughout this series of investigations to evaluate measurement inversion and curriculum inversion. In each case, the analytical instrument was the structured interrogation of artificial intelligence large language models (LLMs). The underlying principle remains unchanged. Rather than relying upon subjective interpretation of educational material, the LLM is used to interrogate a defined knowledge base against an explicit set of scientific criteria derived from the axioms of representational measurement together with the standards and constructs that characterize contemporary HTA.

In the previous investigations of measurement inversion and curriculum inversion, the interrogations were based upon a series of canonical statements representing either scientifically correct or scientifically incorrect propositions concerning measurement. Each statement was evaluated in terms of the extent to which it was endorsed by the institutional knowledge base. Endorsement was expressed as a canonical probability ranging from complete rejection to complete acceptance, with corresponding normalized logit values providing a common quantitative scale. The resulting endorsement profiles allowed direct comparison of institutions, agencies and educational programs, identifying the extent to which each knowledge base supported or rejected the scientific principles required for quantitative measurement.

The knowledge base interrogated in those earlier studies was defined broadly. It comprised the publicly accessible body of information associated with the institution under investigation, including research publications, methodological guidance, educational material, policy documents, technical reports, websites, teaching resources and other documentary evidence. The objective was to determine whether the institution, viewed as a whole, endorsed the principles of representational measurement or, alternatively, exhibited measurement inversion through the endorsement of numerical constructs that failed the requirements for lawful measurement.

The present assessment applies exactly the same interrogation methodology but with a more narrowly defined knowledge base. Rather than considering the complete institutional knowledge base, the focus is restricted to the educational programs offered by each research center. The knowledge base therefore comprises course descriptions, program outlines, syllabi where available, workshop descriptions, educational objectives, teaching modules, reading lists and other publicly available material describing the structure and content of the educational programs. The objective is not to evaluate institutional research activity or methodological publications but to determine what students are actually taught.

The interrogation is consequently more focused than those undertaken previously. Instead of examining the general endorsement of measurement principles across an institution, the analysis seeks to establish whether the educational content presented to students includes the scientific foundations required for quantitative measurement. The central question is whether representational measurement is taught before students are introduced to the numerical methods that characterize contemporary health technology assessment.

The assessment rests upon the presence or absence of educational content representing the accepted theory of measurement. The benchmark is provided by the ten essential topics that define the scientific foundations of HTA education. These encompass representational measurement, scales of measurement, the principle that measurement precedes arithmetic, the axioms of representational measurement, the distinction between manifest and latent attributes, linear ratio measurement for manifest attributes, Rasch logit ratio measurement for latent attributes, possession of latent attributes as the defining objective of Rasch measurement, admissible arithmetic and dimensional homogeneity, and the application of these principles in evaluating therapy claims. Collectively, these topics define the minimum scientific content that should precede instruction in health technology assessment methods.

These foundational topics are contrasted with the subjects that dominate contemporary HTA education. These include utilities and preference measurement, quality-adjusted life years, cost-effectiveness analysis, incremental cost-effectiveness ratios, decision trees, Markov models, microsimulation, probabilistic sensitivity analysis, value-of-information analysis and related modelling techniques. The purpose is not to deny the existence or importance of these methods, but to determine whether they are presented only after the scientific conditions required for quantitative measurement have been established.

The distinction is critical. In the earlier investigations, endorsement probabilities demonstrated whether institutional knowledge bases accepted or rejected the principles of representational measurement. In the present investigation, the question is more direct: does the educational program teach these principles at all? If the scientific foundations of measurement are absent, while conventional HTA methods occupy the curriculum, the educational sequence has been inverted. Students are introduced to arithmetic, modelling and decision analysis before they are taught the conditions under which those procedures are scientifically admissible.

This progression from measurement inversion, to curriculum inversion, to program content inversion provides a coherent framework for evaluating HTA education. Measurement inversion identifies failure to recognize the scientific requirements for quantitative claims. Curriculum inversion demonstrates that these requirements are not embedded within educational programs. Program content inversion identifies the immediate cause of that failure: the absence of explicit teaching of the scientific foundations of measurement within the programs themselves. It is this final level of analysis that forms the focus of the present investigation.

CONTENT AND COVERAGE ASSESSMENT FRAMEWORK

For the purposes of the content assessment, the educational knowledge base was defined more broadly than the brief program or course descriptions typically presented on institutional websites. Rather, the interrogation encompassed all publicly available material that defined the educational content of each program. This included program descriptions, learning objectives, curriculum outlines, lists of courses and modules, individual course descriptions, module summaries, syllabi where available, recommended reading lists, workshop and seminar descriptions, teaching resources, faculty descriptions of educational content, related educational webpages, and any supplementary material specifically associated with the educational program. Collectively, these sources provided the evidential basis for determining both the scope and the scientific content of the educational offerings available to prospective and current students.

The assessment was deliberately confined to educational material. It did not evaluate the broader research activities of the center, its publication record, methodological research, policy reports, or faculty scholarship unless these materials were explicitly incorporated into, or directly linked with, the educational program itself. The objective was not to determine what individual investigators might know or publish concerning measurement theory, but rather to establish what students are expected to learn through the formal educational activities offered by each center.

The first stage of the assessment focused exclusively on the scientific foundations of measurement. The question was not whether the educational material referred to measurement in a general or descriptive sense, but whether it explicitly presented the concepts required to support lawful quantitative analysis. Particular attention was given to the ten essential topics that define the minimum scientific content of an HTA curriculum: representational measurement, scales of measurement, the principle that measurement precedes arithmetic, the axioms of representational measurement, the distinction between manifest and latent attributes, linear ratio measurement for manifest attributes, Rasch logit ratio measurement for latent attributes, possession of latent attributes as the defining objective of Rasch measurement, admissible arithmetic and dimensional homogeneity, and the recognition that quantitative evaluation of therapy claims rests exclusively upon these two admissible forms of ratio measurement.

The second stage of the assessment examined the extent to which the programs covered the methods that characterize contemporary HTA. These included preference elicitation, multiattribute utility instruments, quality-adjusted life years, cost-effectiveness analysis, incremental cost-effectiveness ratios, decision trees, Markov models, microsimulation, probabilistic sensitivity analysis, value-of-information analysis, budget impact analysis, and related techniques that dominate present-day HTA practice.

The relationship between these two stages of the assessment is central to the present investigation. The issue is not whether contemporary HTA methods are taught as they are expected to be but whether they are taught only after students have acquired the scientific principles that determine when quantitative claims are permissible. If a curriculum provides comprehensive instruction in modelling, economic evaluation, and decision analysis while offering little or no instruction in representational measurement and ratio measurement, then the sequence required by quantitative science has been reversed. Arithmetic has displaced measurement as the foundation of analysis.

The resulting content profile therefore provides a direct assessment of program content inversion. Programs that teach the scientific requirements for lawful measurement before introducing HTA applications conform to the expected standards of quantitative science. Programs that omit these foundations while emphasizing utilities, QALYs, cost-effectiveness analysis, and simulation modelling exhibit program content inversion. It is this inversion that provides the immediate educational mechanism through which curriculum inversion and, ultimately, measurement inversion, are reproduced within health technology assessment.

The two components of the assessment are, by construction, mutually exclusive. Acceptance of the principles of representational measurement necessarily determines the admissibility of subsequent quantitative methods. A curriculum that explicitly teaches ratio measurement, the distinction between manifest and latent attributes, admissible arithmetic, dimensional homogeneity, and the two lawful forms of ratio measurement would have no scientific basis for treating ratio-free numerical constructions as quantitative measures. Once measurement precedes arithmetic is accepted as a foundational principle, the analytical methods subsequently taught must conform to those measurement requirements. The scientific foundations therefore determine, rather than merely accompany, the methods that follow.

Conversely, where there is no evidence that a curriculum recognizes the principles of representational measurement, no scientific constraints exist to prevent the adoption of the ratio-free analytical structures that characterize contemporary HTA. Utilities, multiattribute preference instruments, QALYs, incremental cost-effectiveness ratios, and reference-case simulation models can then be introduced without any prior consideration of whether the quantities involved satisfy the requirements for ratio measurement. The omission of representational measurement therefore provides the educational conditions under which these methods become accepted as legitimate analytical tools. Program content inversion is thus not simply the absence of one body of knowledge and the presence of another; it represents two fundamentally incompatible conceptions of quantitative science. One requires that arithmetic be constrained by lawful measurement. The other permits arithmetic to proceed independently of measurement, thereby institutionalizing measurement inversion within the educational program.

ASSESSMENT RESULTS

A separate assessment is presented for each of the seven research centers included in this investigation. Each assessment applies the common content and coverage framework described in the previous section and is based upon the publicly available educational materials defining the center's educational programs. The objective is to determine whether the scientific foundations of representational measurement are explicitly embedded within the educational content and whether these foundations precede instruction in analytical frameworks for HTA.

Each assessment is presented in a common format to facilitate direct comparison across centers. The first component examines evidence for the presence or absence of the essential principles of representational measurement, with particular emphasis on ratio measurement, the distinction between manifest and latent attributes, and the recognition that lawful quantitative claims require either linear ratio measures or Rasch logit ratio measures. The second component examines the extent to which the program emphasizes the conventional analytical methods of contemporary HTA, including utilities, QALYs, cost-effectiveness analysis, decision modelling, simulation methods, and related applications.

Because all centers are evaluated against the same scientific criteria, the resulting assessments provide a consistent basis for identifying similarities and differences in educational content. Of particular interest is whether the programs demonstrate the expected sequence in which measurement precedes arithmetic, or whether they exhibit program content inversion by emphasizing numerical methods in the absence of the scientific principles required to justify their application.

The individual assessments are followed by a comparative summary that identifies the common patterns across all seven centers and considers their implications for HTA education. Collectively, these findings provide the empirical basis for determining whether program content inversion represents isolated institutional variation or a systematic characteristic.

CURRICULUM CONTENT REVIEW

Institution

Monash University
Centre for Health Economics

Purpose

This review evaluates the publicly available curriculum of the Monash University Centre for Health Economics against a single scientific criterion: whether representational measurement is explicitly taught before students are introduced to the quantitative methods of health technology assessment. Particular attention is given to ratio measurement, admissible transformations, dimensional homogeneity, manifest and latent attributes, and Rasch measurement. These are the requirements that must be established before arithmetic operations can support valid quantitative claims concerning therapy impact.

Programs and Courses Reviewed

The review covers the postgraduate health economics and professional education programs offered through the Centre for Health Economics. These include graduate study in Health Economics together with professional education in model-based health economic evaluation.

Courses reviewed include:

- Master of Business (Economics and Health)
- Graduate study in Health Economics
- Model-Based Health Economic Evaluation (Professional Development)
- Health economics and economic evaluation curriculum descriptions

A. REPRESENTATIONAL MEASUREMENT

Topic	Explicitly taught	Course(s)
Representational measurement	No evidence identified	—
Scales of measurement	No evidence identified	—
Measurement precedes arithmetic	No evidence identified	—
Axioms of representational measurement	No evidence identified	—
Ratio measurement	No evidence identified	—
Admissible transformations	No evidence identified	—
Dimensional homogeneity	No evidence identified	—
Manifest and latent attributes	No evidence identified	—
Possession of latent attributes	No evidence identified	—
Rasch measurement	No evidence identified	—
Person-item conjoint measurement	No evidence identified	—
Specific objectivity and invariance	No evidence identified	—
Linear ratio measurement for manifest attributes	No evidence identified	—
Rasch logit ratio measurement for latent attributes	No evidence identified	—

B. CONVENTIONAL HTA FRAMEWORK

Topic	Explicitly taught	Course(s)
Health economics	Yes	Graduate curriculum
Health technology assessment	Yes	Professional and graduate curriculum
Economic evaluation	Yes	Graduate curriculum
Cost-benefit analysis	Yes	Economic evaluation
Cost-effectiveness analysis	Yes	Economic evaluation
Cost-utility analysis	Yes	Economic evaluation
Measurement and valuation of costs and benefits	Yes	Economic evaluation
Valuation of health outcomes	Yes	Economic evaluation
Quality-adjusted life-years	Yes	Economic evaluation
Incremental cost-effectiveness ratios	Yes	Economic evaluation
Discounting	Yes	Economic evaluation
Evaluation of new health technologies	Yes	Graduate curriculum
Prioritization and health decision-making	Yes	Graduate curriculum
PBAC decision methods	Yes	Health economic evaluation
Utilities and preference-based health outcomes	Yes	Health economic evaluation
Decision-analytic or simulation modelling	Yes	Model-Based Health Economic Evaluation
Markov modelling	Yes	Model-Based Health Economic Evaluation
Probabilistic sensitivity analysis	Yes	Model-Based Health Economic Evaluation
Value-of-information analysis	No explicit evidence identified	—

Assessment

The Monash University curriculum displays the same program content inversion identified in the United States and New Zealand. Students receive extensive instruction in health economics, economic evaluation, cost-effectiveness analysis, cost-utility analysis, QALYs, ICERs, decision modelling, Markov models, probabilistic sensitivity analysis and the application of these methods to reimbursement and health policy decisions. Yet no corresponding evidence is identified that they are first introduced to the scientific requirements of representational measurement.

The curriculum therefore teaches students to construct, analyze and interpret quantitative models without first establishing whether the quantities being manipulated satisfy the conditions required for lawful arithmetic. No explicit distinction is made between manifest and latent attributes, no requirement for ratio measurement is stated, and no role is assigned to Rasch measurement in constructing measures of latent attributes.

The result is curriculum inversion. Conventional HTA methods are presented as established quantitative techniques, while the prior scientific question—whether the underlying quantities are lawful measures supporting arithmetic operations—is absent. On the available public evidence, the Monash University curriculum does not challenge the methodological foundations of contemporary HTA. It reproduces them.

CURRICULUM CONTENT REVIEW

Institution

University of Melbourne
Melbourne School of Population and Global Health

Purpose

This review evaluates the publicly available curriculum of the Melbourne School of Population and Global Health against a single scientific criterion: whether representational measurement is explicitly taught before students are introduced to the quantitative methods of health technology assessment. Particular attention is given to ratio measurement, admissible transformations, dimensional homogeneity, manifest and latent attributes, and Rasch measurement. These are the requirements that must be established before arithmetic operations can support valid quantitative claims concerning therapy impact.

Programs and Courses Reviewed

The review covers postgraduate teaching in health economics, economic evaluation and health technology assessment within the Melbourne School of Population and Global Health.

Programs and courses reviewed include:

- Master of Public Health
- Graduate Certificate in Public Health
- Graduate Diploma in Public Health
- Health economics and economic evaluation curriculum
- Health technology assessment teaching materials

A. REPRESENTATIONAL MEASUREMENT

Topic	Explicitly taught	Course(s)
Representational measurement	No evidence identified	—
Scales of measurement	No evidence identified	—
Measurement precedes arithmetic	No evidence identified	—
Axioms of representational measurement	No evidence identified	—
Ratio measurement	No evidence identified	—
Admissible transformations	No evidence identified	—
Dimensional homogeneity	No evidence identified	—
Manifest and latent attributes	No evidence identified	—
Possession of latent attributes	No evidence identified	—
Rasch measurement	No evidence identified	—
Person-item conjoint measurement	No evidence identified	—
Specific objectivity and invariance	No evidence identified	—
Linear ratio measurement for manifest attributes	No evidence identified	—
Rasch logit ratio measurement for latent attributes	No evidence identified	—

B. CONVENTIONAL HTA FRAMEWORK

Topic	Explicitly taught	Course(s)
Health technology assessment	Yes	Public health curriculum
Health economics	Yes	Public health curriculum
Economic evaluation	Yes	Public health curriculum
Cost-benefit analysis	Yes	Economic evaluation
Cost-effectiveness analysis	Yes	Economic evaluation
Cost-utility analysis	Yes	Economic evaluation
Measurement and valuation of costs and benefits	Yes	Economic evaluation
Valuation of health outcomes	Yes	Economic evaluation
Quality-adjusted life-years	Yes	Economic evaluation
Incremental cost-effectiveness ratios	Yes	Economic evaluation
Discounting	Yes	Economic evaluation
Evaluation of new health technologies	Yes	Public health curriculum
PBAC methods	Yes	Health economics curriculum
Utilities and preference-based health outcomes	Yes	Economic evaluation

Topic	Explicitly taught	Course(s)
Decision-analytic modelling	Yes	Health economics curriculum
Markov modelling	Yes	Health economics curriculum
Probabilistic sensitivity analysis	Yes	Health economics curriculum
Value-of-information analysis	No explicit evidence identified	—

Assessment

The University of Melbourne curriculum displays the same program content inversion identified at Monash University, the University of Technology Sydney, the University of Queensland, the University of Adelaide, Griffith University, the New Zealand universities and seven United States centers. Students receive extensive instruction in health economics, health technology assessment, economic evaluation, cost-effectiveness analysis, cost-utility analysis, QALYs, ICERs, decision modelling, Markov modelling and related methods. Yet no corresponding evidence is identified that they are first introduced to the scientific requirements of representational measurement.

The curriculum therefore teaches students how to construct and interpret quantitative models without first establishing whether the quantities being manipulated satisfy the conditions required for lawful arithmetic. No explicit distinction is made between manifest and latent attributes, no requirement for ratio measurement is identified, and no role is assigned to Rasch measurement in constructing measures of latent attributes.

The result is curriculum inversion. Conventional HTA methods are presented as established quantitative techniques while the prior scientific question—whether the underlying quantities are lawful measures supporting arithmetic operations—is absent. On the available public evidence, the University of Melbourne does not challenge the methodological foundations of contemporary HTA. It reproduces them.

CURRICULUM CONTENT REVIEW

Institution

University of Sydney
School of Public Health

Purpose

This review evaluates the publicly available curriculum of the University of Sydney School of Public Health against a single scientific criterion: whether representational measurement is explicitly taught before students are introduced to the quantitative methods of health technology assessment. Particular attention is given to ratio measurement, admissible transformations, dimensional homogeneity, manifest and latent attributes, and Rasch measurement. These are the requirements that must be established before arithmetic operations can support valid quantitative claims concerning therapy impact.

Programs and Courses Reviewed

The review covers postgraduate teaching in health economics, economic evaluation and health technology assessment within the School of Public Health.

Programs and courses reviewed include:

- Master of Public Health
- Graduate Diploma in Public Health
- Graduate Certificate in Public Health
- PUBH5312 – Health Economic Evaluation
- HPOL5000 – Health Policy and Health Economics

A. REPRESENTATIONAL MEASUREMENT

Topic	Explicitly taught	Course(s)
Representational measurement	No evidence identified	—
Scales of measurement	No evidence identified	—
Measurement precedes arithmetic	No evidence identified	—
Axioms of representational measurement	No evidence identified	—
Ratio measurement	No evidence identified	—
Admissible transformations	No evidence identified	—
Dimensional homogeneity	No evidence identified	—
Manifest and latent attributes	No evidence identified	—
Possession of latent attributes	No evidence identified	—
Rasch measurement	No evidence identified	—
Person-item conjoint measurement	No evidence identified	—
Specific objectivity and invariance	No evidence identified	—
Linear ratio measurement for manifest attributes	No evidence identified	—
Rasch logit ratio measurement for latent attributes	No evidence identified	—

B. CONVENTIONAL HTA FRAMEWORK

Topic	Explicitly taught	Course(s)
Health technology assessment	Yes	PUBH5312
Health economics	Yes	HPOL5000, PUBH5312
Economic evaluation	Yes	PUBH5312
Cost-benefit analysis	Yes	PUBH5312
Cost-effectiveness analysis	Yes	PUBH5312
Cost-utility analysis	Yes	PUBH5312
Measurement and valuation of costs and benefits	Yes	PUBH5312
Valuation of health outcomes	Yes	PUBH5312
Quality-adjusted life-years	Yes	PUBH5312
Incremental cost-effectiveness ratios	Yes	PUBH5312
Discounting	Yes	PUBH5312
Evaluation of new health technologies	Yes	PUBH5312
Prioritization and health decision-making	Yes	HPOL5000, PUBH5312
PBAC methods	Yes	PUBH5312
Utilities and preference-based health outcomes	Yes	PUBH5312
Decision-analytic or simulation modelling	Yes	PUBH5312
Markov modelling	No explicit evidence identified	—
Probabilistic sensitivity analysis	No explicit evidence identified	—
Value-of-information analysis	No explicit evidence identified	—

Assessment

The University of Sydney curriculum displays the same program content inversion identified at Monash University, the University of Technology Sydney, the University of Queensland, the University of Adelaide, the University of Melbourne, the New Zealand universities, and the six United States centers. Students are introduced to health economics, economic evaluation, cost-effectiveness analysis, cost-utility analysis, QALYs, ICERs, health technology assessment and the methods employed by the Pharmaceutical Benefits Advisory Committee (PBAC). Yet no corresponding evidence is identified that they are first introduced to the scientific requirements of representational measurement.

The curriculum therefore teaches students how to apply quantitative methods without first establishing whether the quantities being manipulated satisfy the conditions required for lawful arithmetic. No explicit distinction is made between manifest and latent attributes, no requirement for ratio measurement is stated, and no role is assigned to Rasch measurement in constructing measures of latent attributes.

The result is curriculum inversion. Conventional HTA methods are presented as legitimate tools of quantitative analysis, while the prior scientific question—whether the underlying quantities are lawful measures supporting arithmetic operations—is absent. On the available public evidence, the University of Sydney does not challenge the methodological foundations of contemporary HTA. It reproduces them.

CURRICULUM CONTENT REVIEW

Institution

Griffith University
Centre for Applied Health Economics (CAHE)

Purpose

This review evaluates the publicly available curriculum associated with the Griffith University Centre for Applied Health Economics against a single scientific criterion: whether representational measurement is explicitly taught before students are introduced to the quantitative methods of health technology assessment. Particular attention is given to ratio measurement, admissible transformations, dimensional homogeneity, manifest and latent attributes, and Rasch measurement. These are the requirements that must be established before arithmetic operations can support valid quantitative claims concerning therapy impact.

Programs and Courses Reviewed

The review covers postgraduate teaching in health economics, economic evaluation and health technology assessment associated with the Centre for Applied Health Economics and Griffith University's public health and health services programs.

Programs and curriculum reviewed include:

- Master of Public Health
- Graduate Certificate in Public Health
- Graduate Diploma in Public Health
- Health economics curriculum
- Economic evaluation teaching materials

A. REPRESENTATIONAL MEASUREMENT

Topic	Explicitly taught	Course(s)
Representational measurement	No evidence identified	—
Scales of measurement	No evidence identified	—
Measurement precedes arithmetic	No evidence identified	—
Axioms of representational measurement	No evidence identified	—
Ratio measurement	No evidence identified	—
Admissible transformations	No evidence identified	—
Dimensional homogeneity	No evidence identified	—
Manifest and latent attributes	No evidence identified	—
Possession of latent attributes	No evidence identified	—
Rasch measurement	No evidence identified	—
Person-item conjoint measurement	No evidence identified	—
Specific objectivity and invariance	No evidence identified	—
Linear ratio measurement for manifest attributes	No evidence identified	—
Rasch logit ratio measurement for latent attributes	No evidence identified	—

B. CONVENTIONAL HTA FRAMEWORK

Topic	Explicitly taught	Course(s)
Health technology assessment	Yes	Public health curriculum
Health economics	Yes	Public health curriculum
Economic evaluation	Yes	Public health curriculum
Cost-benefit analysis	Yes	Economic evaluation
Cost-effectiveness analysis	Yes	Economic evaluation
Cost-utility analysis	Yes	Economic evaluation
Measurement and valuation of costs and benefits	Yes	Economic evaluation
Valuation of health outcomes	Yes	Economic evaluation
Quality-adjusted life-years	Yes	Economic evaluation
Incremental cost-effectiveness ratios	Yes	Economic evaluation
Discounting	Yes	Economic evaluation
Evaluation of new health technologies	Yes	Public health curriculum
Prioritization and health decision-making	Yes	Public health curriculum
PBAC methods	Yes	Health economics curriculum
Utilities and preference-based health outcomes	Yes	Economic evaluation

Topic	Explicitly taught	Course(s)
Decision-analytic or simulation modelling	Yes	Public health curriculum
Markov modelling	No explicit evidence identified	—
Probabilistic sensitivity analysis	No explicit evidence identified	—
Value-of-information analysis	No explicit evidence identified	—

Assessment

The Griffith University curriculum displays the same program content inversion identified across the other Australian universities, the New Zealand universities, and the six United States centers. Students are introduced to health economics, health technology assessment, economic evaluation, cost-effectiveness analysis, cost-utility analysis, QALYs, ICERs and associated methods of health policy evaluation. Yet no corresponding evidence is identified that they are first introduced to the scientific requirements of representational measurement.

The curriculum therefore teaches students how to apply quantitative methods without first establishing whether the quantities being manipulated satisfy the conditions required for lawful arithmetic. No explicit distinction is made between manifest and latent attributes, no requirement for ratio measurement is identified, and no role is assigned to Rasch measurement in constructing measures of latent attributes.

The result is curriculum inversion. Conventional HTA methods are presented as established quantitative techniques while the prior scientific question, whether the underlying quantities are lawful measures supporting arithmetic operations, is absent. On the available public evidence, Griffith University does not challenge the methodological foundations of contemporary HTA. It reproduces them.

CURRICULUM CONTENT REVIEW

Institution
University of Queensland
Health Economics Research Unit (HERU)

Purpose

This review evaluates the publicly available curriculum associated with the University of Queensland Health Economics Research Unit against a single scientific criterion: whether representational measurement is explicitly taught before students are introduced to the quantitative methods of health technology assessment. Particular attention is given to ratio measurement, admissible transformations, dimensional homogeneity, manifest and latent attributes, and Rasch measurement. These are the requirements that must be established before arithmetic operations can support valid quantitative claims concerning therapy impact.

Programs and Courses Reviewed

The review covers postgraduate teaching in health economics, economic evaluation and health technology assessment associated with the Health Economics Research Unit and the University of Queensland's public health and health services programs.

Programs and curriculum reviewed include:

- Master of Public Health
- Graduate Certificate in Public Health
- Graduate Diploma in Public Health
- Health economics curriculum
- Economic evaluation teaching materials

A. REPRESENTATIONAL MEASUREMENT

Topic	Explicitly taught	Course(s)
Representational measurement	No evidence identified	—
Scales of measurement	No evidence identified	—
Measurement precedes arithmetic	No evidence identified	—
Axioms of representational measurement	No evidence identified	—
Ratio measurement	No evidence identified	—
Admissible transformations	No evidence identified	—
Dimensional homogeneity	No evidence identified	—
Manifest and latent attributes	No evidence identified	—
Possession of latent attributes	No evidence identified	—
Rasch measurement	No evidence identified	—
Person-item conjoint measurement	No evidence identified	—
Specific objectivity and invariance	No evidence identified	—
Linear ratio measurement for manifest attributes	No evidence identified	—
Rasch logit ratio measurement for latent attributes	No evidence identified	—

B. CONVENTIONAL HTA FRAMEWORK

Topic	Explicitly taught	Course(s)
Health technology assessment	Yes	Public health curriculum
Health economics	Yes	Public health curriculum

Topic	Explicitly taught	Course(s)
Economic evaluation	Yes	Public health curriculum
Cost-benefit analysis	Yes	Economic evaluation
Cost-effectiveness analysis	Yes	Economic evaluation
Cost-utility analysis	Yes	Economic evaluation
Measurement and valuation of costs and benefits	Yes	Economic evaluation
Valuation of health outcomes	Yes	Economic evaluation
Quality-adjusted life-years	Yes	Economic evaluation
Incremental cost-effectiveness ratios	Yes	Economic evaluation
Discounting	Yes	Economic evaluation
Evaluation of new health technologies	Yes	Public health curriculum
Prioritization and health decision-making	Yes	Public health curriculum
PBAC methods	Yes	Health economics curriculum
Utilities and preference-based health outcomes	Yes	Economic evaluation
Decision-analytic or simulation modelling	Yes	Public health curriculum
Markov modelling	Yes	Health economics curriculum
Probabilistic sensitivity analysis	Yes	Health economics curriculum
Value-of-information analysis	Yes	Health economics curriculum

Assessment

The University of Queensland Health Economics Research Unit curriculum displays the same program content inversion identified across the other Australian universities, the New Zealand universities, and the six United States centers. Students are introduced to health economics, health technology assessment, economic evaluation, cost-effectiveness analysis, cost-utility analysis, quality-adjusted life-years (QALYs), incremental cost-effectiveness ratios (ICERs), decision-analytic modelling, probabilistic sensitivity analysis and associated methods of health policy evaluation. Yet no corresponding evidence is identified that they are first introduced to the scientific requirements of representational measurement.

The curriculum therefore teaches students how to construct and apply quantitative models without first establishing whether the quantities being manipulated satisfy the conditions required for lawful arithmetic. No explicit distinction is made between manifest and latent attributes, no requirement for ratio measurement is identified, and no role is assigned to Rasch measurement in constructing measures of latent attributes.

The result is curriculum inversion. Conventional HTA methods are presented as established quantitative techniques while the prior scientific question, whether the underlying quantities are lawful measures supporting arithmetic operations is absent. On the available public evidence, the University of Queensland Health Economics Research Unit does not challenge the methodological foundations of contemporary HTA. It reproduces them.

CURRICULUM CONTENT REVIEW

Institution
University of Technology Sydney
Centre for Health Economics Research and Evaluation (CHERE)

Purpose

This review evaluates the publicly available curriculum associated with the University of Technology Sydney Centre for Health Economics Research and Evaluation (CHERE) against a single scientific criterion: whether representational measurement is explicitly taught before students are introduced to the quantitative methods of health technology assessment. Particular attention is given to ratio measurement, admissible transformations, dimensional homogeneity, manifest and latent attributes, and Rasch measurement. These are the requirements that must be established before arithmetic operations can support valid quantitative claims concerning therapy impact.

Programs and Courses Reviewed

The review covers postgraduate teaching in health economics, economic evaluation and health technology assessment associated with CHERE and the University of Technology Sydney's health economics and public health programs.

Programs and curriculum reviewed include:

- Master of Public Health
- Graduate Certificate in Public Health
- Graduate Diploma in Public Health
- Health economics curriculum
- Economic evaluation teaching materials
- Professional education in health technology assessment and health economics

A. REPRESENTATIONAL MEASUREMENT

Topic	Explicitly taught	Course(s)
Representational measurement	No evidence identified	—
Scales of measurement	No evidence identified	—
Measurement precedes arithmetic	No evidence identified	—
Axioms of representational measurement	No evidence identified	—

Topic	Explicitly taught	Course(s)
Ratio measurement	No evidence identified	—
Admissible transformations	No evidence identified	—
Dimensional homogeneity	No evidence identified	—
Manifest and latent attributes	No evidence identified	—
Possession of latent attributes	No evidence identified	—
Rasch measurement	No evidence identified	—
Person-item conjoint measurement	No evidence identified	—
Specific objectivity and invariance	No evidence identified	—
Linear ratio measurement for manifest attributes	No evidence identified	—
Rasch logit ratio measurement for latent attributes	No evidence identified	—

B. CONVENTIONAL HTA FRAMEWORK

Topic	Explicitly taught	Course(s)
Health technology assessment	Yes	Public health curriculum
Health economics	Yes	Public health curriculum
Economic evaluation	Yes	Public health curriculum
Cost-benefit analysis	Yes	Economic evaluation
Cost-effectiveness analysis	Yes	Economic evaluation
Cost-utility analysis	Yes	Economic evaluation
Measurement and valuation of costs and benefits	Yes	Economic evaluation
Valuation of health outcomes	Yes	Economic evaluation
Quality-adjusted life-years	Yes	Economic evaluation
Incremental cost-effectiveness ratios	Yes	Economic evaluation
Discounting	Yes	Economic evaluation
Evaluation of new health technologies	Yes	Public health curriculum
Prioritization and health decision-making	Yes	Public health curriculum
PBAC methods	Yes	Health economics curriculum
Utilities and preference-based health outcomes	Yes	Economic evaluation
Decision-analytic or simulation modelling	Yes	Health economics curriculum
Markov modelling	Yes	Health economics curriculum
Probabilistic sensitivity analysis	Yes	Health economics curriculum

Topic	Explicitly taught	Course(s)
Value-of-information analysis	Yes	Health economics curriculum

Assessment

The University of Technology Sydney Centre for Health Economics Research and Evaluation curriculum displays the same program content inversion identified across the other Australian universities, the New Zealand universities, and the six United States centers. Students are introduced to health economics, health technology assessment, economic evaluation, cost-effectiveness analysis, cost-utility analysis, quality-adjusted life-years (QALYs), incremental cost-effectiveness ratios (ICERs), decision-analytic modelling, Markov models, probabilistic sensitivity analysis and associated methods of health policy evaluation. Yet no corresponding evidence is identified that they are first introduced to the scientific requirements of representational measurement.

The curriculum therefore teaches students how to construct and apply quantitative methods without first establishing whether the quantities being manipulated satisfy the conditions required for lawful arithmetic. No explicit distinction is made between manifest and latent attributes, no requirement for ratio measurement is identified, and no role is assigned to Rasch measurement in constructing measures of latent attributes.

The result is curriculum inversion. Conventional HTA methods are presented as established quantitative techniques while the prior scientific question—whether the underlying quantities are lawful measures supporting arithmetic operations—is absent. On the available public evidence, the University of Technology Sydney Centre for Health Economics Research and Evaluation does not challenge the methodological foundations of contemporary HTA. It reproduces them.

CURRICULUM CONTENT REVIEW

Institution
University of Adelaide
Health Economics Group (HEG)

Purpose

This review evaluates the publicly available curriculum associated with the University of Adelaide Health Economics Group against a single scientific criterion: whether representational measurement is explicitly taught before students are introduced to the quantitative methods of health technology assessment. Particular attention is given to ratio measurement, admissible transformations, dimensional homogeneity, manifest and latent attributes, and Rasch measurement. These are the requirements that must be established before arithmetic operations can support valid quantitative claims concerning therapy impact.

Programs and Courses Reviewed

The review covers postgraduate teaching in health economics, economic evaluation and health technology assessment associated with the Health Economics Group and the University of Adelaide's public health and health policy programs.

Programs and curriculum reviewed include:

- Master of Public Health
- Graduate Certificate in Public Health
- Graduate Diploma in Public Health
- Health economics curriculum
- Economic evaluation teaching materials

A. REPRESENTATIONAL MEASUREMENT

Topic	Explicitly taught	Course(s)
Representational measurement	No evidence identified	—
Scales of measurement	No evidence identified	—
Measurement precedes arithmetic	No evidence identified	—
Axioms of representational measurement	No evidence identified	—
Ratio measurement	No evidence identified	—
Admissible transformations	No evidence identified	—
Dimensional homogeneity	No evidence identified	—
Manifest and latent attributes	No evidence identified	—
Possession of latent attributes	No evidence identified	—
Rasch measurement	No evidence identified	—
Person-item conjoint measurement	No evidence identified	—
Specific objectivity and invariance	No evidence identified	—
Linear ratio measurement for manifest attributes	No evidence identified	—
Rasch logit ratio measurement for latent attributes	No evidence identified	—

B. CONVENTIONAL HTA FRAMEWORK

Topic	Explicitly taught	Course(s)
Health technology assessment	Yes	Public health curriculum
Health economics	Yes	Public health curriculum
Economic evaluation	Yes	Public health curriculum

Topic	Explicitly taught	Course(s)
Cost-benefit analysis	Yes	Economic evaluation
Cost-effectiveness analysis	Yes	Economic evaluation
Cost-utility analysis	Yes	Economic evaluation
Measurement and valuation of costs and benefits	Yes	Economic evaluation
Valuation of health outcomes	Yes	Economic evaluation
Quality-adjusted life-years	Yes	Economic evaluation
Incremental cost-effectiveness ratios	Yes	Economic evaluation
Discounting	Yes	Economic evaluation
Evaluation of new health technologies	Yes	Public health curriculum
Prioritization and health decision-making	Yes	Public health curriculum
PBAC methods	Yes	Health economics curriculum
Utilities and preference-based health outcomes	Yes	Economic evaluation
Decision-analytic or simulation modelling	Yes	Public health curriculum
Markov modelling	No explicit evidence identified	—
Probabilistic sensitivity analysis	No explicit evidence identified	—
Value-of-information analysis	No explicit evidence identified	—

Assessment

The University of Adelaide Health Economics Group curriculum displays the same program content inversion identified across the other Australian universities, the New Zealand universities, and the six United States centers. Students are introduced to health economics, health technology assessment, economic evaluation, cost-effectiveness analysis, cost-utility analysis, QALYs, incremental cost-effectiveness ratios and associated methods of health policy evaluation. Yet no corresponding evidence is identified that they are first introduced to the scientific requirements of representational measurement.

The curriculum therefore teaches students how to apply quantitative methods without first establishing whether the quantities being manipulated satisfy the conditions required for lawful arithmetic. No explicit distinction is made between manifest and latent attributes, no requirement for ratio measurement is identified, and no role is assigned to Rasch measurement in constructing measures of latent attributes.

The result is curriculum inversion. Conventional HTA methods are presented as established quantitative techniques while the prior scientific question whether the underlying quantities are lawful measures supporting arithmetic operations is absent. On the available public evidence, the University of Adelaide Health Economics Group does not challenge the methodological foundations of contemporary HTA. It reproduces them.

OVERALL ASSESSMENT

The curriculum reviews of Australia's leading health economics and health technology assessment research centers reveal a consistent pattern. Across all institutions examined, no evidence was identified that representational measurement is presented as the scientific foundation for quantitative claims. The concepts of ratio measurement, admissible transformations, dimensional homogeneity, the distinction between manifest and latent attributes, and Rasch measurement are absent from the published curricula. Instead, students are introduced directly to health economics, economic evaluation, cost-effectiveness analysis, QALYs, decision modelling and related analytical techniques.

These findings are entirely consistent with previous interrogations of the Australian HTA knowledge base. The major research centers continue to teach and apply the analytical framework that underpins contemporary HTA, including the methodological assumptions embodied in the PBAC Guidelines. At the same time, no evidence has been identified that the substantial critiques of those guidelines from the perspective of representational measurement have been incorporated into teaching or curriculum development. Nor is there evidence that the concepts of curriculum inversion or measurement inversion are recognized as issues requiring academic consideration.

Australia is not unique in this respect. Comparable curriculum reviews undertaken in the United States and New Zealand demonstrate the same pattern. Across all three countries, the educational framework preparing future HTA practitioners consistently introduces quantitative analytical methods before establishing the scientific conditions necessary for lawful quantitative measurement. The consequence is a persistent pattern of curriculum inversion that reproduces, from one generation of practitioners to the next, the measurement inversion that characterizes contemporary health technology assessment.

WHAT ARE STUDENTS NOT BEING TAUGHT?

For students entering Australian HTA programs, the omission of representational measurement is not simply the absence of another topic within an already crowded curriculum. It removes the scientific framework that enables them to distinguish between numbers that represent measurable quantities and numbers that merely describe, rank or summarize observations. Students are taught how to construct increasingly sophisticated economic models, estimate incremental cost-effectiveness ratios, calculate QALYs and undertake probabilistic sensitivity analyses, yet they are not first introduced to the principles that determine whether the quantities entering those calculations are legitimate measures. They therefore acquire computational skills without first acquiring the scientific criteria needed to judge whether those computations are meaningful.

The educational consequence is profound. Without instruction in the scales of measurement and the axioms of representational measurement, students have no framework for asking the most fundamental scientific questions. What type of attribute is being measured? Is it manifest or latent? What scale of measurement has been established? Which arithmetic operations are admissible? Does multiplication require ratio measurement? Has dimensional homogeneity been preserved? If the curriculum never introduces these questions, students cannot be expected to ask them when evaluating published research, preparing reimbursement submissions or undertaking their own investigations.

This places graduates at a significant intellectual disadvantage. They may become highly competent users of established HTA methods while lacking the scientific tools needed to evaluate whether those methods satisfy the requirements of quantitative inquiry. They learn how to apply accepted analytical frameworks but not how to determine whether those frameworks rest upon lawful measurement. The result is an educational process that emphasizes methodological proficiency while neglecting methodological validity.

Universities should equip students not merely to reproduce existing analytical practice but to evaluate it critically against accepted scientific standards. The scales of measurement and the axioms of representational measurement provide precisely those standards. Their omission deprives students of the conceptual framework needed to distinguish between quantitative science and numerical construction. In doing so, the curriculum limits students' ability to question prevailing methodologies and perpetuates the very measurement inversion that these curriculum reviews have identified. A curriculum that omits the scientific foundations of measurement therefore fails not only the discipline but also the students it is intended to educate.

THE IMPLICATIONS OF PROGRAM INVERSION FOR AUSTRALIAN HTA

The seven curriculum content reviews presented in this report reveal a striking degree of consistency. Across Australia's leading university programs in health economics and health technology assessment, no explicit evidence was identified that students are introduced to the scientific foundations of representational measurement before being taught the analytical methods that define contemporary HTA. Concepts fundamental to meaningful quantitative inquiry—including ratio measurement, admissible transformations, dimensional homogeneity, the distinction between manifest and latent attributes, and Rasch measurement—are absent from the publicly available educational content. In contrast, every program provides extensive instruction in economic evaluation, utilities, QALYs, cost-effectiveness analysis, decision-analytic modelling, and related techniques that underpin the current PBAC analytical framework.

These findings demonstrate that curriculum inversion is not confined to an individual university or research center. It characterizes Australian HTA education as a whole. Students are systematically introduced to increasingly sophisticated numerical methods before they are taught the scientific conditions required to justify those methods. Arithmetic precedes measurement; modelling precedes the establishment of lawful quantitative scales; and numerical manipulation is presented before the legitimacy of the quantities being manipulated has been established. The educational system therefore reproduces measurement inversion as a normal feature of professional training rather than identifying it as a fundamental scientific error.

The consequences extend far beyond curriculum design. Australia's universities educate the researchers, analysts, consultants, reimbursement advisers and policy makers who subsequently shape PBAC submissions, government policy, academic research, consulting practice and pharmaceutical evaluation. When representational measurement is absent from that educational foundation, measurement inversion inevitably becomes institutionalized throughout the Australian HTA enterprise. The present reviews therefore identify the educational mechanism through which the contemporary PBAC analytical framework is continually reproduced.

The implications are profound. If representational measurement is accepted, as it has been throughout the physical and social sciences for more than eighty years, as the necessary foundation for quantitative inquiry, then the central constructs of contemporary Australian HTA cannot claim scientific legitimacy. Utilities are not ratio measures. QALYs are not ratio measures. Incremental cost-effectiveness ratios derived from ordinal utilities cannot be interpreted as quantitative evidence, while reference-case simulation models merely extend these measurement failures through increasingly elaborate arithmetic. Numerical sophistication cannot compensate for the absence of lawful measurement. Arithmetic cannot create measurement where measurement does not exist.

These findings also reinforce evidence from the United States and New Zealand. Across all three countries the same educational pattern is observed. Leading universities teach contemporary HTA as though its quantitative foundations were already established, while omitting the scientific principles required to determine whether those foundations exist. This consistency across institutions and countries makes it increasingly difficult to regard measurement inversion as an isolated oversight. Instead, it appears to be an international characteristic of contemporary HTA education.

If representational measurement is accepted as the non-negotiable foundation of quantitative science, then the answer is unavoidable. The same institutions that educate future HTA researchers, analysts and policy advisers without first establishing the conditions required for lawful measurement cannot reasonably claim that the quantitative outputs of their research satisfy those conditions. The absence of ratio measurement from the curriculum is reflected in the analytical framework subsequently employed in research and policy evaluation. Educational inversion becomes research inversion.

This has direct consequences for the interpretation of claims regarding therapy impact. Without lawful ratio measurement there is no scientific justification for the arithmetic operations upon which utilities, QALYs, incremental cost-effectiveness ratios, and reference-case simulation models depend. Their numerical outputs may be internally consistent calculations, but they cannot be regarded as quantitative evidence of therapy value or therapy impact. Arithmetic cannot confer scientific legitimacy on quantities that have never been demonstrated to possess the properties required for arithmetic.

The consequence is that the contemporary Australian HTA framework is ultimately self-defeating. It seeks to quantify therapy impact while failing to establish the single prerequisite upon which all quantitative inference depends: lawful ratio measurement. For more than eighty years representational measurement has established that multiplication, division and proportional comparison are admissible only for ratio measures. Contemporary HTA proceeds as though this principle does not exist. Utilities are treated as ratio measures when they are not; QALYs are treated as quantitative measures when they are not; and increasingly sophisticated simulation models merely propagate these measurement failures through additional layers of arithmetic. The result is not quantitative science but numerical construction.

The curriculum reviews presented in this report lead to an unavoidable conclusion. Until Australia's universities adopt representational measurement as the foundation of HTA education, the research emerging from those institutions will continue to reproduce the same measurement inversion. Claims for therapy impact derived from the contemporary HTA framework cannot be accepted as scientifically credible quantitative evidence because the measurement conditions necessary to support those claims have never been established. The issue is not one of improving existing methods. It is the necessity of replacing a framework built upon arithmetic without measurement with one in which measurement once again precedes arithmetic. To be specific: should Australian universities continue to teach quantitative methods in HTA that do not satisfy the scientific requirements for quantitative measurement?

The responsibility for addressing this position rests first with Australia's universities. Universities are entrusted with defining, preserving and transmitting the scientific standards that underpin their disciplines. Universities are entrusted with defining, preserving and transmitting the scientific. In every quantitative science, measurement precedes arithmetic. For more than eighty years, representational measurement has established the conditions under which quantitative claims are scientifically admissible. These principles are not optional methodological preferences; they define the boundary between quantitative science and numerical construction.

The curriculum reviews presented here indicate that Australia's leading HTA teaching and research centers do not recognize that boundary in the content of their educational programs. By omitting representational measurement while teaching utilities, QALYs, cost-effectiveness analysis and simulation modelling as though they possess established quantitative legitimacy, universities have placed both their teaching and much of their subsequent HTA research outside the accepted standards of normal science. The issue is not simply that an important topic has been overlooked. It is that the scientific foundation upon which every subsequent quantitative claim depends has been omitted.

THE NECESSARY TRANSFORMATION OF PROGRAM CONTENT

Once the scientific constraints imposed by ratio measurement are recognized, the implications for health technology assessment education become immediate and unavoidable. The seven Australian university research centers reviewed in this report cannot continue to present their existing curricula as scientifically adequate. Their programs introduce students to health economics, health technology assessment, economic evaluation, cost-effectiveness analysis, cost-utility analysis, quality-adjusted life-years (QALYs), incremental cost-effectiveness ratios

(ICERs), decision-analytic modelling and associated quantitative methods while omitting the scientific conditions that make quantitative analysis possible. This is not a deficiency that can be corrected by adding new topics or expanding existing modules. It is a structural failure in which arithmetic is taught before measurement. Until that sequence is reversed, these curricula cannot satisfy the accepted standards of quantitative science.

The difficulty is fundamental. Before arithmetic operations can be performed it must first be established that the quantities concerned are lawful measures and that the mathematical operations applied to them are admissible. Where multiplication and division are involved, this requires ratio measurement. For manifest attributes this means linear ratio measurement. For latent attributes it requires Rasch logit ratio measurement. Unless these conditions are satisfied, arithmetic operations are inadmissible irrespective of the sophistication of the statistical methods, simulation models or economic analyses subsequently employed. Neither institutional acceptance nor four decades of routine practice can alter the mathematical properties of the scales on which quantitative claims depend.

The consequence is that transformation is not a matter of educational preference but scientific necessity. Every university program preparing students for health technology assessment must begin with representational measurement, the axioms of fundamental measurement, scales of measurement, admissible transformations, dimensional homogeneity, unidimensional attributes, and the distinction between manifest and latent attributes. Students must understand why measurement precedes arithmetic, why ratio measurement alone supports multiplication and division, why manifest and latent attributes require different approaches to measurement, and why Rasch measurement provides the unique solution for constructing ratio measures of latent attributes. Only after these foundations have been established should students proceed to economic evaluation, decision modelling, observational evaluation, formulary assessment and claims for therapy impact. Existing HTA methods should themselves become subjects for critical scientific evaluation against these standards rather than being presented as accepted quantitative methodologies.

The seven Australian research centers therefore face a straightforward choice. They may continue to teach the existing HTA paradigm and accept that it does not satisfy the accepted requirements for quantitative measurement, or they may reconstruct their curricula around the principles of representational measurement and restore measurement as the indispensable prerequisite for arithmetic. There is no third alternative. Once the requirements of quantitative science are recognized, the present curriculum becomes scientifically unsustainable.

To facilitate this transition, Maimon Research has developed a comprehensive nine-unit curriculum that reconstructs health technology assessment from the foundations of representational measurement. The program begins with measurement rather than arithmetic and proceeds systematically through the construction of lawful quantitative claims for both manifest and latent attributes before addressing health economics, therapy evaluation and formulary assessment. A complete description of the curriculum, together with supporting teaching materials and implementation guidance, is available at on the Maimon Research website [8].

CONCLUSION

Representational measurement is the indispensable foundation of quantitative science. The curriculum reviews presented here demonstrate that this foundation is absent from the publicly available teaching frameworks of Australia's leading university-based health technology assessment research centers. Students are introduced to health economics, economic evaluation, QALYs, ICERs and decision-analytic modelling without first being taught the scientific conditions required for lawful quantitative claims. The result is program inversion: arithmetic is taught before measurement.

Once the established axioms of representational measurement and the indispensable role of ratio measurement are recognized, the contemporary framework of health technology assessment collapses. This is not because a new standard has been introduced, but because the scientific standards governing quantitative measurement have been established for more than sixty years and were simply ignored in the development of HTA. Quantitative claims require ratio measures: linear ratio measures for manifest attributes and Rasch logit ratio measures for latent attributes. None of the constructs that define contemporary HTA, including utilities, quality-adjusted life-years (QALYs), incremental cost-effectiveness ratios (ICERs), and the decision-analytic simulation models built upon them satisfy these requirements. They therefore have no standing as quantitative measures or quantitative claims. They are not legitimate scientific constructs that can be revised or replaced by more sophisticated versions of the same methodology. They are redundant artifacts of a measurement framework that ignored the long-established scientific conditions required for quantitative measurement and quantitative claims.

Their continued use in university teaching, HTA research, reimbursement submissions and health policy perpetuate measurement inversion. The responsibility for correcting this failure rests with Australian universities and their affiliated HTA research centers. Their first duty is not to preserve a failed analytical framework but to ensure that what they teach, investigate and publish satisfies the accepted standards of quantitative science. This requires a fundamental reconstruction of program content in which representational measurement becomes the necessary prerequisite for all quantitative analysis. Until that transformation occurs, Australian HTA education and the research it generates will remain outside the accepted standards of normal quantitative science.

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