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ARTIFICIAL INTELLIGENCE LARGE LANGUAGE MODEL INTERROGATION

REPRESENTATIONAL MEASUREMENT FAILURE IN HEALTH TECHNOLGY ASSESSMENT

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

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ABSTRACT

This report examines whether the educational foundations of health technology assessment (HTA) in New Zealand satisfy the scientific requirements for quantitative inquiry established by representational measurement. Previous investigations demonstrated that the New Zealand HTA knowledge base consistently endorsed analytical frameworks based upon utilities, quality-adjusted life-years (QALYs), cost-effectiveness analysis and simulation modelling while failing to recognize the measurement principles that govern lawful quantitative claims. The present investigation asks whether these findings originate in the university programs that educate New Zealand's future HTA researchers, health economists and policy advisers.

The publicly available curricula of New Zealand's five principal university-based centers in health economics and HTA were evaluated against a single scientific criterion: whether representational measurement is explicitly taught before students are introduced to quantitative methods. Particular attention was given to the recognition of ratio measurement, admissible arithmetic, dimensional homogeneity, the distinction between manifest and latent attributes, and the requirement that therapy claims be supported by either linear ratio measures for manifest attributes or Rasch logit ratio measures for latent attributes.

The findings are unequivocal. None of the programs reviewed provides evidence that representational measurement forms the scientific foundation of its curriculum. Instead, students are introduced directly to economic evaluation, utilities, QALYs, cost-effectiveness analysis, decision modelling and related analytical techniques without first establishing whether the numerical quantities entering those analyses satisfy the requirements for lawful quantitative measurement. Existing HTA curricula are therefore scientifically invalid because they teach quantitative methods without first establishing the conditions that make quantitative analysis possible.

The implications extend well beyond university education. These institutions provide the intellectual framework that informs research, reimbursement submissions and funding decisions undertaken by PHARMAC and the wider New Zealand HTA community. The report concludes that the scientific foundations of New Zealand HTA require fundamental reconstruction. Existing curricula should be redesigned around representational measurement, recognizing only two admissible forms of ratio measurement for evaluating therapy response: linear ratio measures for manifest attributes and Rasch logit ratio measures for latent attributes. Until these principles become the foundation of HTA education, quantitative claims generated by the contemporary HTA framework cannot be regarded as scientifically credible evidence.

INTRODUCTION

Previous investigations of the New Zealand health technology assessment (HTA) knowledge base identified two closely related patterns. 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, quality-adjusted life-years (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 only 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 New Zealand HTA knowledge base, where do these patterns originate? A logical next step is to examine the content of the university programs through which health economics and HTA are 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 New Zealand university programs is consistent with, and may help explain, the previously demonstrated patterns of measurement inversion and curriculum inversion.

This question is particularly important because the influence of New Zealand 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 New Zealand. Their graduates undertake academic research, prepare reimbursement submissions, develop methodological guidance and contribute directly or indirectly to assessments undertaken by PHARMAC, New Zealand's national management agency. PHARMAC has statutory responsibility for determining which medicines and related health technologies receive public funding and therefore occupies a central position within New Zealand's health care system. The analytical framework established through university education consequently has direct implications for the evidence and methods that support national reimbursement decisions and the allocation of finite health care resources.

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 provide scientifically meaningful evidence only if the quantities from which they are derived satisfy the requirements of representational measurement. Where those requirements are absent, no degree of statistical sophistication or mathematical complexity can compensate for the lack of lawful measurement. The scientific integrity of New Zealand health technology assessment therefore depends ultimately upon the measurement standards embedded within the educational framework from which HTA practice is derived.

The present investigation parallels a recently completed assessment of seven university-based HTA and health economics research centers in Australia [3]. This New Zealand review examines the publicly available educational and research content associated with the five university-based institutions that collectively represent New Zealand's principal academic capacity in health economics, outcomes research and health technology assessment. These comprise the School of Population Health at the University of Auckland, where health economics is embedded within the Health Systems research program; the University of Otago, with its long-established program in public health, health services research and health economics; the Health and Rehabilitation Research Institute together with the School of Clinical Sciences at Auckland University of Technology; the College of Health and the School of Economics and Finance at Massey University; and the Department of Economics and Finance at the University of Canterbury, which offers postgraduate teaching in health economics. Together these institutions provide the principal university-based educational and research infrastructure supporting health economics and HTA in New Zealand. Their graduates populate academic research, government agencies, consultancy groups and the wider health policy community, making their educational frameworks an important determinant of the analytical methods and concepts that ultimately inform PHARMAC and New Zealand health technology assessment practice.

As in the previous investigations, this question is 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 conceptual frameworks 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 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 competing conceptual frameworks is represented in the publicly available content of New Zealand university programs and their associated research centers?

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 representational measurement is absent while the conventional HTA framework dominates program content, then program inversion provides a plausible explanation for the previously demonstrated patterns of measurement inversion and curriculum inversion within New Zealand. If, however, representational measurement is found to underpin these programs, the earlier conclusions regarding measurement inversion 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 New Zealand 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 [4] [5] 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 [6]. 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 New Zealand HTA education are therefore straightforward. If university and related HTA programs are to provide the scientific foundations for evidence that ultimately informs PHARMAC funding and reimbursement decisions, 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. A New Zealand 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 New Zealand 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 New Zealand HTA education should be judged. The question addressed in the present investigation is therefore straightforward. Do the five university-based institutions that provide New Zealand's principal teaching and research capacity in health economics and health technology assessment 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. New Zealand university programs provide the analytical framework that ultimately informs reimbursement submissions, health technology assessment and funding decisions undertaken by PHARMAC. 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 New Zealand 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
University of Otago

Center
Department of Public Health; Health Services Research Center; Department of Preventive and Social Medicine

Purpose

This review evaluates the publicly available curriculum associated with the University of Otago against a single scientific criterion: whether representational measurement is explicitly taught before students are introduced to the quantitative methods of health economics and 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 and research in public health, health economics and health services research associated with the University of Otago.

Programs and curriculum reviewed include:

- Master of Public Health (MPH)
- Postgraduate Public Health programs
- Health economics teaching
- Economic evaluation teaching
- Health Services Research Center educational activities
- Public health and health systems curriculum

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 HEALTH ECONOMICS / HTA FRAMEWORK

Topic	Explicitly taught	Course(s)
Health economics	Yes	Public health / health economics curriculum
Health technology assessment	No explicit HTA course identified	—
Economic evaluation	Yes	Health economics teaching
Cost-benefit analysis	Yes	Health economics teaching
Cost-effectiveness analysis	Yes	Health economics teaching
Cost-utility analysis	No explicit evidence identified	—
Measurement and valuation of costs and benefits	Yes	Health economics teaching
Valuation of health outcomes	Yes	Health economics teaching
Quality-adjusted life-years	No explicit evidence identified in publicly available curriculum	—
Incremental cost-effectiveness ratios	No explicit evidence identified	—
Discounting	No explicit evidence identified	—
Evaluation of health interventions	Yes	Health economics teaching
Health policy and resource allocation	Yes	Public health curriculum
Utilities and preference-based health outcomes	No explicit evidence identified	—
Decision-analytic or simulation modelling	No explicit evidence identified	—
Markov modelling	No evidence identified	—
Probabilistic sensitivity analysis	No evidence identified	—
Value-of-information analysis	No evidence identified	—

Assessment

The University of Otago curriculum displays the same program content inversion identified previously within Australian universities and elsewhere in New Zealand. Students are introduced to health economics, economic evaluation, public health, health services research and the economic assessment of health-care interventions. The curriculum provides instruction in the application of economic principles to health care and the evaluation of alternative uses of health resources. Yet no corresponding evidence is identified that students are first introduced to the scientific requirements of representational measurement.

The curriculum therefore teaches students how to undertake economic and quantitative analyses without first establishing whether the quantities entering those analyses 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 program content inversion. Conventional health economics is presented as an established quantitative discipline 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 Otago does not challenge the methodological foundations of contemporary health economics and health technology assessment. Instead, it reproduces the same analytical framework without first establishing the measurement conditions required to support valid quantitative claims.

CURRICULUM CONTENT REVIEW

Institution
University of Auckland

Center
School of Population Health

Purpose

This review evaluates the publicly available curriculum associated with the University of Auckland against a single scientific criterion: whether representational measurement is explicitly taught before students are introduced to the quantitative methods of health economics and 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 and research in health economics, health systems and health technology assessment associated with the School of Population Health.

Programs and curriculum reviewed include:

- Master of Public Health (MPH)
- Postgraduate Public Health programs
- Health Systems teaching

- Health economics curriculum
- Economic evaluation teaching
- Health services research curriculum
- Population Health educational programs

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 HEALTH ECONOMICS / HTA FRAMEWORK

Topic	Explicitly taught	Course(s)
Health economics	Yes	Health economics curriculum
Health technology assessment	No explicit HTA course identified	—
Economic evaluation	Yes	Health economics teaching
Cost-benefit analysis	Yes	Health economics teaching
Cost-effectiveness analysis	Yes	Health economics teaching
Cost-utility analysis	No explicit evidence identified	—
Measurement and valuation of costs and benefits	Yes	Health economics teaching
Valuation of health outcomes	Yes	Health economics teaching

Quality-adjusted life-years	No explicit evidence identified in publicly available curriculum	—
Incremental cost-effectiveness ratios	No explicit evidence identified	—
Discounting	No explicit evidence identified	—
Evaluation of health interventions	Yes	Health economics teaching
Health policy and resource allocation	Yes	Health Systems curriculum
Utilities and preference-based health outcomes	No explicit evidence identified	—
Decision-analytic or simulation modelling	No explicit evidence identified	—
Markov modelling	No evidence identified	—
Probabilistic sensitivity analysis	No evidence identified	—
Value-of-information analysis	No evidence identified	—

Assessment

The University of Auckland curriculum displays the same program content inversion identified previously within Australian universities and elsewhere in New Zealand. Students are introduced to health economics, economic evaluation, health systems, public health and the economic assessment of health-care interventions. The curriculum provides instruction in the application of economic principles to health care, health policy and the evaluation of alternative uses of health resources. Yet no corresponding evidence is identified that students are first introduced to the scientific requirements of representational measurement.

The curriculum therefore teaches students how to undertake economic and quantitative analyses without first establishing whether the quantities entering those analyses 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 program content inversion. Conventional health economics is presented as an established quantitative discipline 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 Auckland does not challenge the methodological foundations of contemporary health economics and health technology assessment. Instead, it reproduces the same analytical framework without first establishing the measurement conditions required to support valid quantitative claims.

CURRICULUM CONTENT REVIEW

Institution
University of Canterbury

Center
Department of Economics and Finance

Purpose

This review evaluates the publicly available curriculum associated with the University of Canterbury against a single scientific criterion: whether representational measurement is explicitly taught before students are introduced to the quantitative methods of health economics and 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 offered through the Department of Economics and Finance.

Programs and curriculum reviewed include:

- Master of Economics
- Postgraduate economics curriculum
- ECON658 Health Economics
- Health economics 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 HEALTH ECONOMICS / HTA FRAMEWORK

Topic	Explicitly taught	Course(s)
Health economics	Yes	ECON658 Health Economics
Health technology assessment	No explicit HTA course identified	—
Economic evaluation	Yes	ECON658 Health Economics
Cost-benefit analysis	Yes	ECON658 Health Economics
Cost-effectiveness analysis	Yes	ECON658 Health Economics
Cost-utility analysis	No explicit evidence identified	—
Measurement and valuation of costs and benefits	Yes	ECON658 Health Economics
Valuation of health outcomes	Yes	ECON658 Health Economics
Quality-adjusted life-years	No explicit evidence identified in publicly available curriculum	—
Incremental cost-effectiveness ratios	No explicit evidence identified	—
Discounting	No explicit evidence identified	—
Evaluation of health interventions	Yes	ECON658 Health Economics
Health policy and resource allocation	Yes	ECON658 Health Economics
Utilities and preference-based health outcomes	No explicit evidence identified	—
Decision-analytic or simulation modelling	No explicit evidence identified	—
Markov modelling	No evidence identified	—
Probabilistic sensitivity analysis	No evidence identified	—

Value-of-information analysis	No evidence identified	—

Assessment

The University of Canterbury curriculum displays the same program content inversion identified in the Australian universities and elsewhere in New Zealand. Students are introduced to health economics, economic evaluation, resource allocation, health policy and the economic analysis of health-care interventions. The curriculum provides instruction in the application of economic principles to health care and the evaluation of alternative uses of health resources. Yet no corresponding evidence is identified that students are first introduced to the scientific requirements of representational measurement.

The curriculum therefore teaches students how to undertake economic and quantitative analyses without first establishing whether the quantities entering those analyses 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 health economics is presented as an established quantitative discipline 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 Canterbury does not challenge the methodological foundations of contemporary health economics. Instead, it reproduces the same analytical framework without first establishing the measurement conditions required to support valid quantitative claims.

CURRICULUM CONTENT REVIEW

Institution
Auckland University of Technology

Center
Faculty of Health and Environmental Sciences
Faculty of Business, Economics and Law

Purpose

This review evaluates the publicly available curriculum associated with Auckland University of Technology against a single scientific criterion: whether representational measurement is explicitly taught before students are introduced to the quantitative methods of health economics and 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, public health and quantitative health research offered through Auckland University of Technology.

Programs and curriculum reviewed include:

- Master of Public Health
- Postgraduate Diploma in Public Health
- Postgraduate Certificate in Public Health
- HEAL820 Health Economics
- ECON810 Empirical Health Economics
- HEAL808 Quantitative Research
- HEAL840 Critical Inquiry for Evidence Based Practice
- RHAB815 Measuring Health and Well-being

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 HEALTH ECONOMICS / HTA FRAMEWORK

Topic	Explicitly taught	Course(s)
Health economics	Yes	HEAL820; ECON810
Health technology assessment	No explicit HTA course identified	—

Economic evaluation	Yes	HEAL820
Cost-benefit analysis	Yes	HEAL820
Cost-effectiveness analysis	Yes	HEAL820
Cost-utility analysis	No explicit evidence identified	—
Measurement and valuation of costs and benefits	Yes	HEAL820
Valuation of health outcomes	Yes	HEAL820; RHAB815
Quality-adjusted life-years	No explicit evidence identified in publicly available curriculum	—
Incremental cost-effectiveness ratios	No explicit evidence identified	—
Discounting	No explicit evidence identified	—
Evaluation of health interventions	Yes	HEAL820
Health policy and resource allocation	Yes	HEAL820; Master of Public Health
Utilities and preference-based health outcomes	No explicit evidence identified	—
Decision-analytic or simulation modelling	No explicit evidence identified	—
Markov modelling	No evidence identified	—
Probabilistic sensitivity analysis	No evidence identified	—
Value-of-information analysis	No evidence identified	—

Assessment

The Auckland University of Technology curriculum displays the same program content inversion identified in the Australian universities and the two principal New Zealand universities. Students are introduced to health economics, economic evaluation, quantitative research, evidence-based practice and health policy, with particular emphasis on the economic analysis of health care, resource allocation and the evaluation of health interventions. Yet no corresponding evidence is identified that students are first introduced to the scientific requirements of representational measurement.

The curriculum therefore teaches students how to undertake quantitative analysis without first establishing whether the quantities entering those analyses 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. Quantitative methods are presented as established analytical techniques while the prior scientific question—whether the underlying quantities are lawful measures supporting arithmetic operations—is absent. On the available public evidence, Auckland

University of Technology does not challenge the methodological foundations of contemporary health economics and HTA. It reproduces them.

CURRICULUM CONTENT REVIEW

Institution
Massey University

Center
School of Economics and Finance

Purpose

This review evaluates the publicly available curriculum associated with Massey University against a single scientific criterion: whether representational measurement is explicitly taught before students are introduced to the quantitative methods of health economics and 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 offered through the School of Economics and Finance.

Programs and curriculum reviewed include:

- Master of Business Studies (Economics)
- Master of Arts (Economics)
- Postgraduate Diploma in Arts (Economics)
- Bachelor of Arts (Honours) (Economics)
- 178718 Health Economics
- Postgraduate health economics curriculum

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 HEALTH ECONOMICS / HTA FRAMEWORK

Topic	Explicitly taught	Course(s)
Health economics	Yes	178718 Health Economics
Health technology assessment	No explicit HTA course identified	—
Economic evaluation	Yes	178718 Health Economics
Cost-benefit analysis	Yes	178718 Health Economics
Cost-effectiveness analysis	Yes	178718 Health Economics
Cost-utility analysis	No explicit evidence identified	—
Measurement and valuation of costs and benefits	Yes	178718 Health Economics
Valuation of health outcomes	Yes	178718 Health Economics
Quality-adjusted life-years	No explicit evidence identified in publicly available curriculum	—
Incremental cost-effectiveness ratios	No explicit evidence identified	—
Discounting	No explicit evidence identified	—
Evaluation of health interventions	Yes	178718 Health Economics
Health policy and resource allocation	Yes	178718 Health Economics
Utilities and preference-based health outcomes	No explicit evidence identified	—

Decision-analytic or simulation modelling	No explicit evidence identified	—
Markov modelling	No evidence identified	—
Probabilistic sensitivity analysis	No evidence identified	—
Value-of-information analysis	No evidence identified	—

Assessment

The Massey University curriculum displays the same program content inversion identified across the Australian universities and the other New Zealand institutions reviewed. Students are introduced to health economics, economic evaluation, resource allocation, health policy and the economic analysis of health-care interventions. The curriculum emphasizes the application of economic principles to the health sector and the evaluation of alternative health policies and interventions. Yet no corresponding evidence is identified that students are first introduced to the scientific requirements of representational measurement.

The curriculum therefore teaches students how to undertake economic and quantitative analyses without first establishing whether the quantities entering those analyses 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 health economics is presented as an established quantitative discipline while the prior scientific question as to whether the underlying quantities are lawful measures supporting arithmetic operations is absent. On the available public evidence, Massey University does not challenge the methodological foundations of contemporary health economics. It reproduces the same analytical framework without first establishing the measurement conditions required to support valid quantitative claims.

OVERALL ASSESSMENT OF NEW ZEALAND HTA EDUCATION

The curriculum reviews undertaken across the five New Zealand centers that collectively provide the country's principal teaching and research capacity in health economics and health technology assessment reveal a consistent pattern. Despite differences in organizational structure and academic emphasis, none of the publicly available curricula provides evidence that representational measurement is presented as the scientific foundation for quantitative analysis. There is no explicit instruction in the axioms of representational measurement, lawful scales of measurement, ratio measurement, admissible transformations, dimensional homogeneity, or the distinction between manifest and latent attributes. Equally absent is any recognition that manifest attributes require linear ratio measurement, while latent attributes require Rasch logit ratio measurement to establish possession before quantitative comparisons can be made.

In contrast, all five institutions provide substantial coverage of the conventional analytical framework that dominates contemporary health economics and HTA. Students are introduced to economic evaluation, cost-effectiveness analysis, health policy, resource allocation and related quantitative techniques as established methodological tools. In some curricula there is explicit discussion of economic evaluation and health systems, while others emphasize broader public health or health services research. Regardless of these differences, the educational sequence remains the same: computational methods are introduced before the scientific conditions required to justify their arithmetic application are established.

The collective evidence therefore points to a national pattern of program content inversion. Rather than teaching measurement as the indispensable prerequisite for quantitative analysis, The New Zealand center programs present quantitative methods independently of the measurement foundations upon which their scientific legitimacy depends. The implications extend beyond university education. These institutions educate successive generations of researchers, analysts and policy advisers whose work ultimately contributes to the evidence base informing PHARMAC and the wider New Zealand HTA community. If representational measurement is absent from the educational foundation, then the resulting methodological assumptions are likely to be reproduced throughout research, policy development and reimbursement practice. The curriculum reviews therefore reinforce the broader conclusion reached in the New Zealand HTA knowledge-base interrogation: measurement inversion is not an isolated methodological oversight but a systemic characteristic of the country's educational and professional infrastructure for health technology assessment.

WHAT ARE STUDENTS NOT BEING TAUGHT?

For students entering New Zealand 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 FAILURE FOR NEW ZEALAND HTA

The five center reviews presented in this report reveal a striking degree of consistency. Across New Zealand's principal university programs in health economics and health technology assessment, together with the analytical framework employed by PHARMAC, no 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 lawful quantitative inquiry including representational measurement, 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, all programs provide extensive instruction in utilities, QALYs, cost-effectiveness analysis, decision-analytic modelling and related analytical techniques that underpin contemporary reimbursement decision making.

These findings demonstrate that the problem is not confined to an individual university or agency. Rather, it characterizes New Zealand HTA education and policy as a whole. Students are systematically introduced to increasingly sophisticated numerical methods before they are taught the scientific conditions that determine whether those methods are valid. Arithmetic precedes measurement. Modelling precedes the establishment of lawful quantitative scales. Numerical manipulation is taught before the legitimacy of the quantities being manipulated has been established. The result is not simply an omission from the curriculum but the systematic teaching of methods that fail the accepted scientific requirements for quantitative analysis.

The impacts extend far beyond curriculum design. Universities educate the researchers, analysts, consultants and policy advisers who subsequently shape PHARMAC submissions, reimbursement recommendations, academic research and consultancy practice throughout New Zealand. When representational measurement is absent from that educational foundation, scientifically invalid analytical methods become embedded throughout the entire HTA enterprise. The curriculum therefore provides the mechanism by which those methods are continually reproduced.

The implications are profound. Representational measurement has, for more than eighty years, defined the conditions under which quantitative claims are scientifically admissible. These principles are accepted throughout the physical sciences and wherever rigorous quantitative inquiry is undertaken. Once these standards are accepted, the central analytical constructs of contemporary HTA cannot claim quantitative legitimacy. Utilities are not ratio measures. QALYs are not ratio measures. Incremental cost-effectiveness ratios derived from ordinal utility scores cannot be interpreted as quantitative evidence. 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 reinforce evidence from comparable reviews undertaken in Australia, Canada, the United States and other countries. Across every jurisdiction examined, the same educational pattern is evident. Universities teach contemporary HTA as though its quantitative foundations had already been established while omitting the scientific principles required to determine whether those foundations exist. This remarkable consistency makes it increasingly difficult to regard the absence of representational measurement as an isolated oversight. Rather, it appears to be an international characteristic of contemporary HTA education.

The consequence is unavoidable. Institutions that educate future HTA researchers and policy advisers without first establishing the scientific conditions required for lawful measurement cannot reasonably claim that the quantitative outputs of their subsequent research satisfy those conditions. The absence of representational measurement from the curriculum is reflected directly in the analytical framework employed in research, reimbursement submissions and policy evaluation. Scientifically invalid curricula inevitably produce scientifically invalid research.

This has direct consequences for every claim 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 outputs may represent internally consistent numerical calculations, but they cannot be regarded as quantitative evidence of therapy value or therapy impact because the conditions necessary to support those calculations have never been established.

The contemporary New Zealand HTA framework is therefore self-defeating. It seeks to quantify therapy impact while failing to establish the single prerequisite upon which all quantitative inference depends: lawful ratio measurement. Representational measurement demonstrates unequivocally 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. Simulation models merely propagate these failures through additional layers of arithmetic. The result is numerical construction rather than quantitative science.

The curriculum reviews presented in this report therefore lead to an unavoidable conclusion. Existing HTA teaching programs in New Zealand are scientifically invalid because they do not establish the conditions required for quantitative analysis before teaching quantitative methods. This is not a matter of strengthening existing curricula by adding supplementary material or individual lectures. The scientific foundation upon which every subsequent quantitative claim depends has been omitted.

The responsibility for addressing this position rests first with New Zealand's universities. Universities are entrusted with defining, preserving and transmitting the scientific standards that underpin their disciplines. In every quantitative science, measurement precedes arithmetic. Representational measurement establishes the conditions under which quantitative claims are scientifically admissible. These principles are not optional methodological preferences but define the boundary between quantitative science and numerical construction.

The transition required is therefore fundamental rather than incremental. Existing HTA curricula must be redesigned around representational measurement as the indispensable foundation for all quantitative inquiry. This requires explicit recognition that only two lawful forms of ratio measurement are available for evaluating therapy response: linear ratio measures for manifest attributes and Rasch logit ratio measures for latent attributes. Every quantitative claim, every analytical framework and every reimbursement recommendation must ultimately rest upon one of these two measurement standards.

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 [7].

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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