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REPRESENTATIONAL MEASUREMENT FAILURE IN HEALTH TECHNOLGY ASSESSMENT

UNITED STATES: IS THE HTA CURRICULUM AN EDUCATION IN SCIENCE OR TECHNICAL TRAINING?

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ABSTRACT

Health technology assessment (HTA) has become firmly institutionalized throughout the United States through graduate programs, university research centers and professional education in health economics and outcomes research. Across this educational framework, students are introduced to utilities, quality-adjusted life-years (QALYs), incremental cost-effectiveness ratios (ICERs), economic evaluation, decision modelling and related analytical methods that define contemporary HTA practice. The existence of an established curriculum, however, raises a more fundamental educational question: does the standard HTA curriculum provide a university education in quantitative science or primarily technical training in the application of an inherited analytical methodology?

This paper addresses that question by examining the scientific foundations that should characterize a university curriculum in a quantitative discipline. Drawing upon Karl Popper's concept of the evolution of objective knowledge, it argues that universities have a responsibility not merely to transmit established methods but to educate students in the scientific principles through which knowledge advances by criticism, empirical evaluation and potential refutation. For HTA, these principles are provided by representational measurement, including measurement preceding arithmetic, attribute definition, scale theory, lawful ratio measurement, admissible arithmetic, dimensional homogeneity, the distinction between manifest and latent attributes, Rasch logit ratio measurement for latent variables, and the formulation of credible, empirically evaluable, independently replicable and potentially falsifiable claims.

The paper synthesizes evidence from successive interrogations of the United States HTA knowledge base, curriculum assessments and program-content reviews. These investigations consistently demonstrate measurement inversion, curriculum inversion and program-content inversion. Representational measurement is largely absent from the educational framework, while utilities, QALYs, economic evaluation, ICERs and simulation modelling are comprehensively represented. Students therefore learn how to apply the established HTA methodology before they are taught the scientific principles necessary to determine whether its quantitative claims satisfy the accepted standards of lawful measurement.

The paper argues that this educational sequence transforms HTA from a university science into a technically sophisticated professional methodology. The contemporary curriculum successfully prepares graduates for formulary assessment, reimbursement analysis, market access and other administrative decision-making activities, but it does not first provide the scientific framework required to evaluate the quantitative legitimacy of those activities. Once representational measurement is introduced, the inherited analytical framework itself becomes the object of scientific investigation rather than unquestioned technical instruction.

The conclusion is that universities should no longer regard representational measurement as an optional addition to existing HTA curricula. It provides the scientific framework by which the

curriculum itself must be evaluated. If HTA is to retain its place as a university-based quantitative discipline, its educational foundation must be reconstructed around the principles of lawful measurement and the continuing evolution of objective knowledge rather than the technical application of an inherited analytical methodology.

INTRODUCTION

Health technology assessment (HTA) has, over more than four decades, become firmly established within universities throughout the United States. Graduate programs, research centers, colleges of pharmacy, schools of public health, schools of medicine and associated professional training programs collectively provide the educational pathway through which successive generations of students enter health economics, outcomes research and health technology assessment. Although individual institutions differ in emphasis, the underlying curriculum is remarkably consistent. Students are introduced to utilities, quality-adjusted life-years (QALYs), incremental cost-effectiveness ratios (ICERs), economic evaluation, decision analysis, reference-case simulation, uncertainty analysis and increasingly sophisticated modelling techniques as the accepted analytical methods of contemporary HTA. The curriculum is therefore organized around teaching students how to apply an established quantitative methodology.

This raises a fundamental educational question. What is the purpose of a university curriculum in HTA? Is it to educate students in the scientific principles governing quantitative inquiry, or is it primarily to train students in the technical application of an inherited analytical framework? These are fundamentally different educational objectives. A university education begins with the scientific principles that determine whether quantitative claims are possible. Technical training begins with accepted analytical methods and teaches students how to apply them competently. The distinction becomes critical when the scientific foundations of those methods themselves become the subject of sustained examination.

Institutional acceptance should not be confused with scientific legitimacy. A methodology does not become science because it has been taught for four decades, embedded within university curricula, endorsed by research centers or adopted by successive generations of practitioners. Scientific legitimacy depends upon a prior requirement: the methods being taught must satisfy the accepted standards governing lawful quantitative measurement. That question has received comparatively little explicit attention because the contemporary HTA curriculum has become epistemically closed. Its organizing assumptions are presented as established knowledge rather than propositions open to scientific evaluation. Students are taught how to use the inherited analytical framework, but not how to determine whether its quantitative foundations satisfy the standards of representational measurement.

This epistemic closure explains why the curriculum has continued to evolve technically while remaining largely unchanged scientifically. New statistical methods, Bayesian approaches, increasingly sophisticated simulation models, artificial intelligence, machine learning and computational advances have all been incorporated into contemporary HTA. Yet these developments refine the technical performance of the inherited analytical framework rather than addressing the prior scientific question upon which that framework depends: do the quantities entering these analyses possess the measurement properties required to support the arithmetic being performed?

Previous interrogations of the United States HTA knowledge base, together with curriculum reviews and program-content assessments, consistently demonstrate the consequences of this educational orientation. Representational measurement, measurement preceding arithmetic, ratio measurement, admissible arithmetic, dimensional homogeneity, the distinction between manifest and latent attributes and Rasch measurement receive little explicit recognition within the standard curriculum, while utilities, QALYs, ICERs, economic evaluation and reference-case simulation are comprehensively represented. The curriculum therefore functions primarily as technical instruction within an inherited analytical methodology rather than as education in quantitative science [1] .

The purpose of this paper is to examine that distinction. It asks whether the standard United States HTA curriculum satisfies the educational responsibilities normally associated with university teaching in a quantitative discipline or whether it is principally concerned with training students to apply an established methodological framework. Once representational measurement is introduced as the scientific criterion governing quantitative claims, the curriculum itself becomes the object of scientific evaluation [2] [3] . The question is therefore no longer simply what students are taught. It is whether they are being educated in the scientific principles governing quantitative inquiry or trained in the technical application of an inherited analytical tradition.

1. WHAT SHOULD BE THE SCIENTIFIC FOUNDATION OF A UNIVERSITY CURRICULUM IN HEALTH TECHNOLOGY ASSESSMENT?

The defining responsibility of a university is not merely to transmit established knowledge but to educate students in the evolution of objective knowledge. As Karl Popper argued, scientific knowledge advances through a continuing process of problems, conjectures, criticism and attempted refutation [4] [5]. No scientific theory enjoys permanent authority. Every explanation remains provisional, open to empirical challenge and replacement should a superior explanation emerge. The university therefore occupies a unique position within society. Its purpose is not simply to prepare technically competent practitioners but to educate students in the scientific process through which knowledge itself develops. Students should understand not only the accepted theories of a discipline but also the evidence supporting those theories, the criticisms that have been advanced against them, and the competing explanations that seek to replace them. Without this process there is no scientific education. There is only the transmission of established professional practice.

Technical training has a fundamentally different objective. It assumes that the underlying analytical framework has already been established and concentrates upon developing competence in its application. Students learn accepted methods, analytical procedures, software, professional guidance and practical techniques. Whether those methods themselves continue to satisfy the accepted standards of science is generally outside the scope of technical instruction. Technical education therefore prepares practitioners. University education prepares scientists capable of participating in the continuing evolution of objective knowledge.

This distinction is fundamental for health technology assessment. If HTA is presented as a university-based quantitative discipline, students should first be introduced to the scientific principles governing quantitative inquiry before they encounter the analytical methods that depend upon those principles. They should understand how quantitative knowledge is created, how competing explanations are evaluated, and why every quantitative claim must remain open to empirical evaluation, independent replication and potential falsification. Only after these scientific foundations have been established should students be introduced to economic evaluation, utilities, quality-adjusted life-years (QALYs), incremental cost-effectiveness ratios (ICERs), decision analysis, simulation modelling and the other analytical methods of contemporary HTA. A curriculum that reverses this sequence may produce technically competent analysts, but it cannot claim to have provided an education in normal quantitative science.

Representational measurement provides the scientific foundation for that education. It establishes the principles that determine whether quantitative claims are possible before specifying the analytical methods used to support them. These principles are not methodological preferences unique to HTA. They have governed meaningful quantitative inquiry for decades.

The first principle is that measurement precedes arithmetic. Numerical operations cannot create measurement where measurement does not already exist. Students should therefore understand that the scientific problem begins with measurement rather than with mathematical manipulation.

The second principle is that every quantitative investigation begins with an attribute. The attribute whose change is to be evaluated must first be identified and defined before any attempt is made to measure it. Students should therefore learn to distinguish between manifest attributes, which are directly observable, and latent attributes, which require a measurement model. This distinction determines every subsequent stage of quantitative inquiry. Contemporary HTA has largely reversed this scientific sequence by organizing its curriculum around analytical methods rather than around the attributes whose change those methods are intended to evaluate.

The third principle is that arithmetic is constrained by the properties of the measurement scale. Students should understand the hierarchy of nominal, ordinal, interval and ratio scales, together with admissible transformations and dimensional homogeneity. Multiplication, division and ratio formation require lawful ratio measurement. Numerical convenience cannot override these scientific constraints.

The fourth principle follows directly from the nature of the attribute itself. Manifest and latent attributes require different approaches to measurement. Manifest attributes such as survival time, hospital admissions, emergency department visits, treatment administrations or medication possession may support lawful linear ratio measurement where a defined unit and non-arbitrary zero exist. Latent attributes such as pain, fatigue, depression, physical functioning or need fulfilment cannot be observed directly and require construction of an invariant quantitative continuum through Rasch measurement.

The fifth principle is that only two lawful measurement systems are required for claims of therapy impact. Manifest attributes require linear ratio measurement. Latent attributes require Rasch logit ratio measurement based upon person-item conjoint measurement, invariance, specific objectivity and the assessment of attribute possession. There is no third class of therapy-impact measure because every claim concerns either a manifest or a latent attribute.

The sixth principle is that scientific claims must be formulated so that they are capable of empirical evaluation. Students should therefore learn how to construct protocols specifying the target population, comparator, attribute of interest, lawful measurement instrument, observation period, success criterion and explicit falsification rule. Claims that cannot subsequently be evaluated against observation remain hypotheses rather than scientific evidence.

Taken together, these principles establish the scientific foundation of a university curriculum in HTA. They also define the educational sequence that such a curriculum should follow. Students first learn how quantitative knowledge develops, how lawful measurement is established, how attributes determine the appropriate measurement system, how arithmetic is constrained by measurement, and how scientific claims are formulated and evaluated. Only then should they be introduced to the analytical techniques of contemporary HTA. Once this scientific sequence has been established, utilities, QALYs, ICERs, decision models and simulation techniques cease to be accepted technical procedures and become scientific propositions whose legitimacy can be evaluated against the accepted standards of representational measurement.

This provides the benchmark against which the contemporary United States HTA curriculum is assessed. The question is not whether students are taught sophisticated analytical methods. They clearly are. The question is whether they first receive an education in the scientific principles governing quantitative inquiry or whether they are trained primarily in the technical application of an inherited analytical methodology. If representational measurement is absent while the technical framework of contemporary HTA is comprehensively represented, the curriculum no longer reflects the Popperian evolution of objective knowledge. Instead, it becomes a technically accomplished but epistemically closed system in which accepted methods are transmitted without first exposing them to the scientific standards by which every quantitative discipline should be judged.

The purpose of a university curriculum is therefore not to preserve an inherited methodology but to prepare students to participate in the continuing evolution of objective knowledge. The emergence of representational measurement as a challenge to the scientific foundations of HTA is precisely the kind of development that universities should welcome. Whether that challenge is ultimately accepted or rejected is a matter for scientific inquiry. Ensuring that students understand the challenge, the evidence upon which it rests and its implications for the discipline is an educational responsibility.

The practical question naturally follows: if representational measurement defines the scientific foundation of a university HTA curriculum, how should the transition be achieved? The challenge is educational rather than merely methodological. Most faculty currently teaching HTA, health economics and outcomes research were themselves educated within the inherited analytical framework. Their expertise lies in the technical methods that have defined the discipline for more than four decades. Reconstruction therefore requires more than replacing one analytical technique with another. It requires a structured educational pathway through which faculty and students can progressively reconsider the scientific foundations of the discipline itself.

Such a pathway is now available. The Maimon Research nine-unit transition program was developed specifically to support the transition from the legacy HTA framework to one grounded in representational measurement [6]. Beginning with the principle that measurement precedes arithmetic, the program progresses systematically through attribute definition, scales of measurement, admissible arithmetic, dimensional homogeneity, the distinction between manifest and latent attributes, lawful linear ratio measurement, Rasch logit ratio measurement, attribute possession, and finally the formulation of credible, empirically evaluable, independently replicable and potentially falsifiable claims of therapy impact. Each unit builds upon the preceding one so that quantitative methods are introduced only after the scientific conditions necessary to support them have been established.

The significance of this program extends beyond its individual content. It demonstrates that reconstruction of the HTA curriculum is educationally feasible. Representational measurement need not remain an abstract philosophical critique of contemporary HTA. It can be translated into a coherent curriculum that restores the scientific sequence required for quantitative inquiry. The objective is not to append a measurement module to an otherwise unchanged HTA course while leaving its analytical structure intact. It is to reorganize the curriculum around the principles of lawful measurement so that attributes determine measurement, measurement determines arithmetic, and arithmetic supports only those therapy-impact claims that satisfy the accepted standards of normal quantitative science.

2. IS THE CONTEMPORARY UNITED STATES HTA CURRICULUM: SCIENCE OR TECHNICAL TRAINING?

If the previous section describes the scientific responsibilities of a university curriculum, the question immediately becomes whether the contemporary United States HTA curriculum satisfies those responsibilities. Does it educate students in the evolution of objective knowledge through criticism, conjecture, empirical evaluation and potential refutation, or does it train students in the competent application of an inherited analytical framework? These are fundamentally different educational objectives. One prepares scientists capable of extending and challenging knowledge. The other prepares practitioners capable of applying accepted methods. The evidence accumulated from successive interrogations of the United States HTA knowledge base indicates that the contemporary curriculum overwhelmingly reflects the latter objective.

Rather than beginning with the scientific principles governing quantitative measurement, the standard HTA curriculum begins with the technical methods that characterize contemporary health economics and outcomes research. Students are introduced to health economics, economic evaluation, utilities, quality-adjusted life-years (QALYs), cost-effectiveness analysis, incremental cost-effectiveness ratios (ICERs), decision analysis, reference-case simulation, uncertainty analysis, budget-impact modelling and related analytical techniques before they encounter the scientific principles required to determine whether those methods satisfy the accepted standards of lawful measurement. Representational measurement, measurement preceding arithmetic, admissible arithmetic, dimensional homogeneity, the distinction between manifest and latent attributes, and Rasch measurement occupy little or no explicit place within the organizing framework of the curriculum. The scientific foundations that should determine whether these methods are quantitatively admissible are therefore absent or treated as epistemically irrelevant.

This conclusion is not based upon isolated examples or anecdotal observation. It emerges consistently from successive interrogations of the United States HTA knowledge base. Measurement inversion interrogations employing twenty-four canonical statements demonstrate systematic endorsement of propositions supporting utilities, QALYs, economic evaluation and the conventional HTA analytical framework while giving consistently weak endorsement to the propositions that should define every quantitative science. Curriculum interrogations similarly demonstrate curriculum inversion, where graduate education introduces students to the analytical framework of contemporary HTA before providing them with the scientific principles necessary to determine whether the arithmetic underpinning that framework is lawful. Program-content assessments of university research centers reach the same conclusion. Across these educational and research environments, representational measurement is consistently absent while the methods of contemporary HTA are comprehensively represented. The evidence therefore points not to isolated institutional deficiencies but to a coherent national educational framework.

Viewed from a Popperian perspective, the implications are profound. Students are introduced to accepted methods, but they are not first equipped with the scientific principles necessary to subject those methods themselves to criticism. The curriculum therefore transmits established knowledge without exposing that knowledge to the process through which objective knowledge evolves. Scientific criticism becomes external to the curriculum rather than integral to it. Students learn how to operate within the inherited framework, but they are not taught how that framework itself should be examined, challenged, modified or, if necessary, replaced. The Popperian process through which scientific knowledge advances by conjecture and refutation is therefore largely absent from the educational structure of contemporary HTA.

There should be no misunderstanding concerning the achievements of the contemporary curriculum. It succeeds in producing technically competent practitioners capable of undertaking the analyses required within the existing HTA enterprise. Graduates learn how to estimate utilities, construct QALYs, calculate ICERs, undertake economic evaluations, build decision and simulation models, perform uncertainty analyses and prepare submissions for formulary committees, reimbursement agencies, integrated health systems, pharmaceutical manufacturers and market-access organizations. The curriculum is therefore highly effective if its objective is to prepare analysts for one-off technology assessments and formulary decision making within the conventions of the existing HTA framework.

That objective, however, is fundamentally different from the educational mission of a university. Universities do not exist merely to train technically competent practitioners for the immediate needs of employers or healthcare decision makers. Their primary responsibility is to educate students in the evolution of objective knowledge. Students should therefore understand not only how accepted analytical methods are applied, but also the scientific principles by which those methods are evaluated, criticized, modified or ultimately replaced. Technical competence concerns the application of an inherited methodology. Scientific education concerns understanding whether that methodology itself satisfies the accepted standards of quantitative science.

The consequences of this distinction become immediately apparent once representational measurement is introduced into the curriculum. Students no longer ask simply how utilities should be estimated, QALYs calculated or ICERs interpreted. They ask whether utilities constitute lawful measures, whether QALYs satisfy the requirements of ratio measurement, whether ICERs are scientifically meaningful ratios, whether simulation models generate empirically evaluable claims, and whether the quantities entering these analyses possess the measurement properties required for the arithmetic performed. These are not questions concerning technical competence. They are questions concerning the scientific legitimacy of the discipline itself. The curriculum therefore changes from a sequence of accepted analytical techniques into an object of scientific investigation.

The issue is therefore not whether the contemporary United States HTA curriculum produces graduates who can competently apply the methods of HTA. It clearly does. The issue is whether competence in applying an inherited analytical framework should be regarded as equivalent to education in quantitative science. The evidence presented here suggests that it should not. A curriculum that teaches students how to construct utilities, QALYs, ICERs and simulation models before teaching them the scientific principles that determine whether those constructs satisfy the accepted standards of lawful measurement is not educating scientists. It is providing technical instruction within an established analytical methodology organized around measurement inversion and sustained by epistemic closure.

Once representational measurement becomes part of the curriculum, the educational question changes fundamentally. The issue is no longer simply: How should HTA be performed? It becomes: Should the inherited analytical framework continue to be taught as university quantitative science? That question does not challenge the technical competence of HTA practitioners. It challenges the scientific status of the curriculum itself. It is to that question that universities, research centers and the wider HTA community must now respond.

3. SHOULD THE CONTEMPORARY UNITED STATES HTA CURRICULUM BE TAUGHT AS SCIENCE?

The central question posed by this paper is not whether the contemporary United States HTA analytical framework has become an established technical discipline. It clearly has. Universities throughout the United States have developed sophisticated graduate programs, research centers have expanded rapidly, pharmaceutical manufacturers, consulting organizations, integrated health systems and government agencies recruit graduates with specialized HTA skills, and professional organizations have established an extensive educational infrastructure supporting the discipline. The issue is fundamentally different. Can universities continue to present the contemporary HTA analytical framework as a scientifically valid quantitative discipline once it is examined against the accepted standards of representational measurement?

The answer does not depend upon whether utilities, quality-adjusted life-years (QALYs), cost-effectiveness analysis, incremental cost-effectiveness ratios (ICERs) or simulation modelling have proved useful in supporting formulary decisions, reimbursement recommendations or healthcare resource allocation. Administrative usefulness does not establish scientific validity, nor does widespread institutional acceptance. Universities do not determine scientific status by counting practitioners, publications or years of successful application. Scientific disciplines are judged by the principles governing their methods. The relevant question is therefore whether the quantitative constructs underpinning contemporary HTA satisfy the accepted standards of lawful measurement before the arithmetic upon which they depend is performed.

This distinction between administrative usefulness and scientific legitimacy is fundamental. Healthcare systems necessarily require methods that support reimbursement and resource-allocation decisions. Contemporary HTA undoubtedly provides a widely accepted administrative framework for those purposes. Universities, however, are held to a different standard. Their responsibility is not simply to prepare graduates capable of operating within existing decision-making systems. Their responsibility is to educate students in the scientific principles governing quantitative inquiry and to prepare them to contribute to the continuing evolution of objective knowledge. The educational standard is therefore necessarily higher than the operational requirements of formulary committees or reimbursement agencies.

The evidence presented throughout the preceding investigations provides a consistent answer. Measurement inversion demonstrates that the scientific propositions defining lawful measurement receive weak endorsement, while propositions supporting utilities, QALYs, economic evaluation and the conventional HTA analytical framework receive strong endorsement. Curriculum inversion demonstrates that students are introduced to these analytical methods before learning the scientific principles required to evaluate them. Program-content inversion demonstrates that university teaching and research comprehensively represent the methods of contemporary HTA while omitting representational measurement as the scientific foundation for quantitative analysis. These are not independent findings. They describe the same educational framework viewed from complementary perspectives.

The implications are profound. It is sometimes suggested that the problem could be resolved by introducing an additional lecture or short module on representational measurement into existing HTA programs. This proposal fundamentally misunderstands the role of measurement within quantitative science. Representational measurement is not another analytical technique that can simply be added to an already crowded curriculum. It is the scientific framework that determines whether every subsequent quantitative method is itself admissible. It therefore evaluates the curriculum rather than complements it.

Once students understand lawful measurement, the central constructs of the contemporary HTA analytical framework immediately become objects of scientific scrutiny. They no longer ask merely how to estimate a utility score; they ask whether utilities are lawful quantitative measures. They no longer ask how to calculate a QALY; they ask whether multiplying an ordinal preference score by time satisfies the requirements of ratio measurement. They no longer ask how to construct an ICER; they ask whether both numerator and denominator are lawful ratio measures capable of supporting ratio formation. They no longer judge decision models or simulation models solely by their technical sophistication; they ask whether the quantities entering those models possess the measurement properties required for the arithmetic performed and whether the resulting claims are credible, empirically evaluable, independently replicable and capable of potential falsification.

This is precisely why representational measurement cannot be treated as another methodological option within HTA. It changes the level at which scientific discussion occurs. Instead of comparing one economic model with another, one simulation technique with another or one statistical method with another, it asks whether the quantitative framework itself satisfies the accepted standards governing meaningful measurement. The discussion therefore moves beyond methodology to the philosophy of science. The curriculum itself becomes the object of scientific investigation.

At that point the relationship between representational measurement and the contemporary HTA curriculum changes fundamentally. The two cannot coexist as complementary scientific frameworks because they begin from incompatible first principles. Representational measurement requires that measurement governs arithmetic. Contemporary HTA assumes the legitimacy of arithmetic without first demonstrating that the quantities involved possess the measurement properties necessary to support the operations performed. Once students understand that measurement precedes arithmetic, the inherited analytical framework ceases to function as unquestioned scientific knowledge and instead becomes a series of scientific conjectures open to criticism, empirical evaluation and possible refutation. In Popperian terms, the curriculum re-enters the process through which objective knowledge evolves.

This distinction exposes the fundamental difference between scientific education and technical training. Technical training prepares students to function effectively within an established analytical framework. Scientific education equips students to determine whether that framework itself satisfies the accepted standards of quantitative science and to participate in its continuing development. The contemporary HTA curriculum clearly succeeds in the first objective. It prepares graduates to undertake economic evaluations, construct cost-effectiveness models, prepare formulary submissions, support reimbursement decisions and contribute effectively to the existing HTA enterprise. What it does not first do is provide students with the scientific principles necessary to determine whether those activities constitute lawful quantitative science.

The educational consequences are therefore unavoidable. Universities may continue to teach the contemporary HTA analytical framework as the historical methodology upon which much current formulary assessment, reimbursement analysis and market-access practice has been constructed. They may continue to regard it as a technically sophisticated administrative decision framework. What they cannot legitimately claim, once the standards of representational measurement are understood, is that it constitutes a university education in quantitative science. A university curriculum is expected to contribute to the evolution of objective knowledge through criticism, empirical evaluation and potential refutation. A curriculum whose central quantitative constructs have not first demonstrated lawful measurement cannot fulfil that responsibility.

Universities therefore face a choice only in the narrow administrative sense. Scientifically, the issue has already been defined. Representational measurement is not another topic that can be incorporated into the existing HTA curriculum while leaving its structure unchanged. It is the scientific framework by which the curriculum itself is judged. Once students understand that measurement precedes arithmetic, that multiplication, division and ratio formation require lawful ratio measures, that attributes determine the appropriate measurement framework, and that scientific claims must be credible, empirically evaluable, independently replicable and capable of potential falsification, the central constructs of the inherited HTA framework immediately become objects of scientific scrutiny rather than accepted analytical methods.

The conclusion therefore follows directly. The contemporary HTA curriculum survives only because it remains epistemically closed to the scientific principles capable of evaluating its own quantitative foundations. Once that epistemic closure is removed, the curriculum becomes part of the normal scientific process through which all established theories are exposed to criticism, empirical evaluation and possible replacement. Universities may choose to continue teaching the inherited HTA methodology as technical instruction for contemporary administrative practice. They should no longer present it as education in quantitative science unless and until its central quantitative constructs demonstrate that they satisfy the accepted standards of lawful measurement. That is not a matter of educational preference. It is the ordinary expectation of normal science.

CONCLUSION

This paper has not questioned whether the contemporary United States HTA analytical framework has become an established technical methodology. It clearly has. Over more than four decades it has developed into a highly organized analytical framework comprising utilities, quality-adjusted life-years (QALYs), incremental cost-effectiveness ratios (ICERs), economic evaluation, reference-case simulation, uncertainty analysis and increasingly sophisticated modelling techniques. These methods are now embedded throughout universities, research centres, healthcare organizations, consulting firms, government agencies and the pharmaceutical industry. Students can therefore be trained to apply them competently and consistently in support of formulary assessment, reimbursement decisions and market-access activities.

That, however, is not the defining purpose of a university education.

A university exists to educate students in the evolution of objective knowledge rather than simply train them in established professional techniques. As Popper argued, scientific knowledge advances through criticism, conjecture, empirical evaluation and the continual testing of accepted explanations. Students should therefore first understand the scientific principles governing quantitative inquiry before they are introduced to the analytical methods that depend upon those principles. In HTA this requires education in representational measurement, lawful ratio measurement, admissible arithmetic, dimensional homogeneity, the distinction between manifest and latent attributes, and the requirement that scientific claims be credible, empirically evaluable, independently replicable and capable of potential falsification. Only then should students be introduced to the analytical methods of contemporary HTA.

The evidence presented throughout this series of investigations demonstrates that the contemporary United States HTA curriculum reverses this scientific sequence. Students are introduced to an established analytical methodology before they are provided with the scientific principles required to determine whether that methodology satisfies the accepted standards of quantitative science. The curriculum therefore functions primarily as technical instruction within an inherited analytical framework rather than as education in the scientific foundations of quantitative inquiry.

The educational consequences follow directly. Once students understand representational measurement, the central constructs of the contemporary HTA framework immediately become objects of scientific examination. They no longer ask simply how to estimate utilities, calculate QALYs or construct ICERs. They ask whether utilities are lawful measures, whether QALYs satisfy the requirements of ratio measurement, whether ICERs represent meaningful quantitative ratios, and whether the outputs of decision models are capable of empirical evaluation and potential falsification. These are not peripheral methodological questions. They concern the scientific status of the discipline itself.

For this reason, representational measurement cannot be incorporated into the existing curriculum as another methodological topic. It is not an additional analytical technique. It is the scientific framework by which the curriculum itself is evaluated. Once measurement is required to precede arithmetic, every subsequent quantitative construct must demonstrate that it satisfies the accepted standards governing lawful measurement. The curriculum itself therefore becomes an object of scientific inquiry.

The question facing universities is consequently no longer whether the contemporary HTA curriculum should be refined, updated or supplemented. Nor is it whether the analytical framework has proved administratively useful in supporting healthcare decision making. Administrative usefulness and scientific legitimacy are fundamentally different questions. Universities exist to educate students in quantitative science, not simply to prepare technically competent practitioners for existing administrative systems. Their responsibility is therefore to ensure that students understand the scientific principles by which accepted methodologies are judged and to participate in the continuing evolution of objective knowledge rather than merely reproduce inherited professional practice.

The conclusion follows naturally. If the contemporary United States HTA curriculum is to retain its place within university education as a quantitative science, it must first demonstrate that its central analytical constructs satisfy the accepted standards of representational measurement. If those standards cannot be met, the curriculum should continue to be taught only for what it demonstrably is: an historically important and technically sophisticated methodology for contemporary administrative decision making, rather than as the scientific foundation of health technology assessment. The long-term future of HTA therefore lies not in further technical refinement of the inherited framework but in its reconstruction around the ordinary principles of normal science: define the attribute, establish lawful measurement, determine the admissible arithmetic, formulate credible and empirically evaluable claims, and allow those claims to be subjected to criticism, replication and potential refutation. That is how objective knowledge advances. It is also what university education should be expected to provide.

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