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REPRESENTATIONAL MEASUREMENT FAILURE IN HEALTH TECHNOLGY ASSESSMENT

UNITED STATES: RETURNING HEALTH TECHNOLOGY ASSESSMENT TO NORMAL SCIENCE

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ABSTRACT

Health technology assessment (HTA) has become institutionalized through university graduate programs, research centers, professional organizations and healthcare agencies as the dominant framework for economic evaluation and healthcare decision making. Students are routinely introduced to utilities, quality-adjusted life-years (QALYs), incremental cost-effectiveness ratios (ICERs), decision modelling and reference-case simulation as the accepted quantitative methods of the discipline. Recent investigations of national HTA agencies, university curricula, research centers and program-content knowledge bases, however, have identified a consistent pattern of measurement inversion, curriculum inversion and program-content inversion in which the principles of lawful measurement receive little explicit recognition while the methods of contemporary HTA are

comprehensively represented.

This paper examines the educational implications of that finding. It argues that representational measurement has progressed beyond the status of an isolated methodological critique and now constitutes a documented scientific challenge to the quantitative foundations of contemporary HTA. Unlike routine curriculum revision, representational measurement does not propose another analytical technique to supplement the existing framework. It returns HTA to the accepted standards of normal quantitative science by requiring that attributes be defined before measurement, measurement precede arithmetic, arithmetic be constrained by the properties of the measurement scale, and scientific claims be credible, empirically evaluable, independently replicable and capable of potential falsification. The paper further argues that every therapy-impact claim concerns either a manifest attribute requiring lawful linear ratio measurement or a latent attribute requiring Rasch logit ratio measurement, providing a coherent scientific framework that has been largely absent from contemporary HTA.

The paper considers the resulting responsibilities of universities and university-based research groups. It argues that higher education is distinguished from technical training by its commitment to scientific inquiry, critical evaluation and openness to competing explanations. Universities are not required to endorse representational measurement or reject the inherited HTA framework. They do, however, have a responsibility to inform students that a substantial scientific challenge now exists, explain the principles upon which that challenge rests, and provide the evidence necessary for informed academic judgement. Once representational measurement is recognized as a return to the accepted standards of normal quantitative science, remaining silent is no longer an academically neutral position. The duty to inform therefore becomes an essential responsibility of university education and a necessary step in returning HTA to lawful quantitative science.

INTRODUCTION

The preceding paper concluded that the contemporary health technology assessment (HTA) curriculum functions primarily as technical instruction within an inherited analytical methodology rather than as education in quantitative science [1]. Across university programs, research centers and associated teaching, students are introduced to utilities, quality-adjusted life-years (QALYs), incremental cost-effectiveness ratios (ICERs), decision modelling and reference-case simulation before they encounter the scientific principles required to determine whether these methods satisfy the accepted standards of representational measurement [2 3] . Measurement inversion, curriculum inversion and program-content inversion therefore describe not isolated institutional weaknesses but a coherent educational framework in which arithmetic precedes measurement rather than measurement determining arithmetic. Once representational measurement is introduced as the organizing scientific principle, the curriculum itself becomes the object of scientific evaluation. More importantly, the apparent complexity of contemporary HTA is replaced by a return to the familiar standards of normal quantitative science: attributes must first be defined, lawful measurement established, arithmetic constrained by the properties of the measurement scale, and scientific claims required to be credible, empirically evaluable, independently replicable and capable of potential falsification.

This conclusion raises a question extending well beyond curriculum design. What responsibilities do universities and university research groups have once a substantial scientific challenge to the foundations of their discipline has been systematically articulated? Universities are not technical training institutes whose primary purpose is to transmit established professional methods. Their defining responsibility is to educate students in the scientific principles governing a discipline, expose them to significant competing explanations where these exist, and provide the intellectual framework within which evidence can be critically evaluated. Scientific progress has never depended upon preserving inherited methodologies because they are widely accepted. It has depended upon subjecting those methodologies to continual examination against accepted scientific standards. The issue is therefore no longer whether representational measurement constitutes an important challenge to contemporary HTA. The cumulative evidence now demonstrates that it does. The educational question is whether universities can continue presenting the inherited analytical framework without informing students that its quantitative foundations have become the subject of sustained scientific scrutiny.

This responsibility does not require universities or faculty to endorse representational measurement, abandon contemporary HTA or accept every criticism directed at utilities, QALYs or reference-case simulation. Academic education does not require agreement; it requires openness, critical inquiry and informed evaluation. Once a coherent scientific alternative has emerged, students should be informed that it exists, understand the principles upon which it rests, and be given the opportunity to evaluate its implications for the discipline they are studying. This obligation is particularly important because representational measurement does not propose another competing analytical method. It returns HTA to the ordinary scientific principles governing every quantitative discipline. The challenge is therefore not one of technical innovation but of determining whether the inherited analytical framework satisfies the standards of lawful measurement that should have preceded it.

The present paper examines that responsibility. It argues that the cumulative evidence now available from national HTA agencies, university curricula, research centers, professional organizations and program-content interrogations has moved representational measurement well beyond the status of an isolated theoretical critique. It now constitutes a documented challenge to the quantitative foundations of contemporary HTA. Under these circumstances, universities should reasonably expect prospective students to ask searching questions concerning the scientific assumptions underlying the curriculum they are being invited to study. More importantly, universities should be prepared to answer those questions. Doing nothing is no longer an academically neutral position. Whether institutions ultimately accept, reject or modify representational measurement is a matter for continuing scientific investigation. Ignoring its existence or failing to inform students that such a challenge has emerged is inconsistent with the educational responsibilities of higher education. The issue is therefore no longer simply whether representational measurement changes HTA. It is whether universities committed to scientific inquiry have a responsibility to return HTA to the standards of normal science and to ensure that their students are fully informed of the challenge that now confronts the discipline.

1. THE IMPORTANCE OF THE LAWFUL MEASUREMENT CHALLENGE IN HEALTH TECHNOLOGY ASSESSMENT

For many years the scientific foundations of contemporary health technology assessment (HTA) attracted remarkably little critical attention. Debate focused instead on technical refinement. New statistical methods, increasingly sophisticated simulation models, Bayesian approaches, real-world evidence, artificial intelligence, machine learning and computational advances were introduced as successive improvements to an analytical framework whose underlying quantitative assumptions were rarely questioned. The accepted methods of utilities, quality-adjusted life-years (QALYs), incremental cost-effectiveness ratios (ICERs), cost-effectiveness analysis and reference-case simulation came to be regarded as established scientific instruments rather than as quantitative constructs whose measurement properties required independent demonstration. Discussion therefore concentrated on improving the performance of the framework rather than examining whether its arithmetic satisfied the accepted requirements of lawful measurement.

That position has now changed. Over the past several years, a coherent challenge has emerged based upon the principles of representational measurement. The central proposition is both simple and fundamental: measurement must precede arithmetic. Every quantitative claim depends upon the measurement properties of the quantities entering the analysis. Multiplication requires ratio measurement. Arithmetic must respect admissible transformations and dimensional homogeneity. Manifest and latent attributes require different measurement strategies. These are not methodological preferences unique to HTA. They are long-established scientific principles governing quantitative inquiry across the natural and social sciences.

The challenge is also constructive rather than merely critical. Representational measurement does not seek to replace one technical methodology with another or introduce a more sophisticated analytical framework. It returns HTA to the ordinary standards that govern every quantitative science. Scientific investigation begins by defining the attribute of interest, establishing the lawful form of measurement appropriate to that attribute, determining the arithmetic admissible for that measurement, and formulating claims that are credible, empirically evaluable, independently replicable and capable of potential falsification. These principles have guided quantitative inquiry for decades. Their application to HTA therefore represents a return to normal science rather than the creation of a new scientific paradigm

The significance of this challenge extends beyond theoretical measurement. It addresses the quantitative legitimacy of the central analytical constructs upon which contemporary HTA depends. If utilities are not lawful ratio measures, then multiplying them by time cannot create a meaningful quantitative measure of therapy benefit. If the denominator of an incremental cost-effectiveness ratio fails to satisfy the requirements of ratio measurement, the resulting ratio cannot acquire scientific legitimacy through increasingly sophisticated arithmetic. Likewise, simulation models, however technically accomplished, cannot compensate for deficiencies in the measurement properties of the quantities from which their outputs are constructed. The challenge therefore concerns the scientific foundations of HTA rather than the technical execution of its established methods.

The importance of attributes has likewise become apparent. Contemporary HTA has largely organized itself around analytical techniques with utilities, QALYs, ICERs and decision models rather than around the attributes whose change is to be measured. Once the attribute becomes the starting point, the measurement problem becomes remarkably straightforward. Every therapy-impact claim is for either a manifest attribute, which requires lawful linear ratio measurement, or a latent attribute, which requires Rasch logit ratio measurement. No third category is required. The distinction between manifest and latent attributes therefore provides the organizing framework that has been largely absent from contemporary HTA and explains why questions of lawful measurement have remained outside the discipline for more than four decades. The defining mistake of contemporary HTA was not the adoption of utilities or QALYs. It was beginning with analytical methods rather than with the attributes whose measurement those methods purported to represent.

Importantly, this challenge is no longer confined to theoretical discussion. A substantial body of evidence has accumulated through systematic interrogations of national HTA agencies, professional organizations, university curricula, research centers and publicly available program-content knowledge bases across multiple countries. These investigations consistently demonstrate weak recognition of representational measurement and the principles governing lawful quantitative measurement, accompanied by strong endorsement of the conventional HTA analytical framework. Comparable findings have now been reported across Australia, Canada, New Zealand, the United States and numerous international and regional HTA organizations. Curriculum reviews and program-content assessments likewise demonstrate that graduate education comprehensively teaches utilities, QALYs, cost-effectiveness analysis and decision modelling while giving little or no explicit attention to measurement preceding arithmetic, ratio measurement, admissible arithmetic, dimensional homogeneity or Rasch measurement.

The importance of these findings lies not simply in their consistency but in their implications for higher education. The challenge can no longer be dismissed as an isolated theoretical objection or a difference of methodological opinion. It has become a documented scientific critique directed at the quantitative foundations of an internationally established discipline. Whether individual investigators ultimately accept or reject its conclusions is not the immediate issue. The issue is that the challenge now exists, is supported by an expanding body of scholarship, and raises questions concerning the scientific legitimacy of methods that occupy a central place in graduate education, research, professional guidance and healthcare decision making.

This changes the educational landscape fundamentally. Universities are no longer confronted simply with competing methodological preferences within HTA. They are confronted with a challenge that asks whether the discipline itself satisfies the accepted standards of normal quantitative science. Doing nothing is therefore no longer an academically neutral position. Universities may ultimately accept, reject or modify representational measurement, but they cannot reasonably continue teaching the inherited framework as though this challenge had never been made. Once a documented scientific critique questions the quantitative foundations of an established discipline and offers a coherent alternative grounded in accepted principles of measurement, students are entitled to know that the challenge exists. The responsibility of the university is no longer merely to transmit an inherited analytical methodology. It is to ensure that students understand the scientific assumptions upon which that methodology rests, the challenge that now confronts those assumptions, and the evidence upon which competing conclusions may be judged. It is this educational responsibility that provides the foundation for the discussion that follows.

2. THE RESPONSIBILITY OF THE UNIVERSITY

Universities occupy a unique position within society because their primary responsibility is not simply to transmit established knowledge but to educate students in the principles by which knowledge is created, evaluated and, where necessary, replaced. This responsibility is particularly important in quantitative disciplines. Students should not merely learn how to apply accepted analytical techniques. They should understand the scientific assumptions upon which those techniques depend and acquire the ability to evaluate whether those assumptions satisfy accepted scientific standards. A university education differs fundamentally from technical training because it develops independent scientific judgement rather than competence in the application of an inherited methodology.

This distinction becomes especially important when a discipline encounters a challenge to its scientific foundations. Throughout the history of science, established theories have been questioned, refined and, in some cases, replaced. Universities have never fulfilled their educational mission by shielding students from these developments. On the contrary, they have been expected to expose students to significant scientific controversies, explain the competing evidence and allow students to evaluate alternative explanations using accepted scientific principles. This process does not require universities to endorse every new theory or reject every established methodology. It requires only that students understand the existence of the challenge, the evidence supporting it, and the reasons advanced both for and against its acceptance.

Health technology assessment has now reached precisely this point. The question is no longer whether representational measurement constitutes a coherent scientific challenge to the quantitative foundations of HTA. A substantial and growing body of scholarship now questions the measurement status of utilities, QALYs, incremental cost-effectiveness ratios and reference-case simulation while proposing an alternative framework grounded in representational measurement, lawful ratio scales and empirically evaluable claims. This challenge has been documented across national HTA agencies, professional organizations, university curricula, research centers and program-content knowledge bases in multiple countries. Whether individual faculty members ultimately agree with these conclusions is secondary. The educational issue is that the challenge now exists and concerns the scientific legitimacy of the methods students are expected to master.

The responsibilities of universities become particularly important because this is unlike the routine methodological debates that characterize most scientific disciplines. It questions the scientific foundations upon which contemporary HTA has been constructed over more than four decades. During that period universities have developed graduate curricula, research centers, textbooks, doctoral programs, professional training and methodological guidance around utilities, QALYs, cost-effectiveness analysis, decision modelling and reference-case simulation. Thousands of peer-reviewed publications, reimbursement submissions and policy recommendations have been produced within this analytical framework. The present challenge therefore extends far beyond criticism of individual methods. It asks whether the measurement assumptions supporting the entire quantitative framework satisfy the accepted standards governing lawful measurement.

The implications are correspondingly extensive. If representational measurement is accepted as the governing scientific standard, the issue is not simply how future HTA should be taught. Existing curricula, textbooks, methodological guidance and published research all become open to re-examination because the measurement properties of their central quantitative constructs have themselves become the subject of scientific investigation. Few disciplines encounter challenges that simultaneously affect graduate education, research, professional practice and healthcare policy. The present debate therefore concerns the scientific foundations of HTA rather than the refinement of individual analytical techniques.

Paradoxically, the challenge itself is conceptually straightforward because it represents a return to the standards of normal quantitative science rather than the introduction of a new scientific paradigm. Scientific inquiry begins by defining the attribute of interest. Measurement precedes arithmetic. The properties of the measurement scale determine which mathematical operations are admissible. Scientific claims should be credible, empirically evaluable, independently replicable and capable of potential falsification. These principles are not innovations introduced by representational measurement. They have governed quantitative inquiry for decades. Their application to HTA simply restores the scientific sequence that should have preceded the development of the discipline.

The importance of attributes illustrates this point. Contemporary HTA has largely organized itself around analytical techniques with utilities, QALYs, ICERs and simulation models rather than around the attributes whose change those techniques are intended to represent. Once the attribute again becomes the starting point, the measurement problem becomes remarkably simple. Every therapy-impact claim is for either a manifest attribute, requiring lawful linear ratio measurement, or a latent attribute, requiring Rasch logit ratio measurement based upon unidimensionality, invariance and specific objectivity. No third class of therapy-impact measure is required. The absence of attributes from the conceptual framework of HTA explains why the distinction between manifest and latent attributes, and the different measurement systems appropriate to each, remained largely outside the discipline for more than forty years.

This responsibility should not be interpreted as an accusation that universities or faculty have knowingly disregarded representational measurement. Most instructors teach the framework within which they themselves were educated. Contemporary HTA has been transmitted through graduate programs, textbooks, journals, professional organizations and established research practice across successive generations of scholars. It is therefore unsurprising that the same analytical framework has been reproduced throughout the discipline. The emergence of representational measurement changes that educational context. What could previously be regarded as the accepted quantitative framework must now be recognized as one competing scientific interpretation whose assumptions are open to examination.

Universities therefore acquire a responsibility that extends beyond the routine delivery of established curricula. Prospective students should be informed that the quantitative foundations of contemporary HTA are now the subject of substantial scientific scrutiny. They should understand that an alternative framework has been proposed, that it returns HTA to the accepted standards of normal quantitative science, and that it reaches conclusions fundamentally different from those of the legacy paradigm. Education does not require students to accept those conclusions. It requires that they understand the challenge before committing themselves to mastering an analytical framework whose scientific foundations have become contested.

Doing nothing is therefore no longer an academically neutral position. Universities and university research groups may ultimately accept, reject or modify the representational measurement framework, but they cannot legitimately continue teaching the inherited HTA paradigm as though this challenge had never been made. Once a coherent scientific critique questions the quantitative foundations of an established discipline and proposes a constructive alternative grounded in accepted scientific principles, the responsibility of higher education is clear. Students and researchers should be informed that the challenge exists, understand the evidence upon which it rests, and be given the opportunity to evaluate its implications for themselves. Universities exist not to preserve a forty-year analytical legacy but to educate scholars capable of determining whether that legacy satisfies the standards of normal quantitative science.

3. WHY THIS CHALLENGE CANNOT BE TREATED AS AN ORDINARY CURRICULUM REVISION

The challenge presented by representational measurement differs fundamentally from the routine curriculum revisions that characterize most academic disciplines. Universities regularly update courses to accommodate new statistical techniques, revised clinical guidelines, improved computational methods, artificial intelligence, machine learning or advances in analytical methodology. Such developments refine an existing scientific framework while leaving its underlying assumptions intact. Representational measurement is fundamentally different. It does not propose another analytical technique to be incorporated into the existing HTA curriculum. It questions whether the quantitative framework upon which that curriculum has been constructed satisfies the accepted standards governing lawful measurement. Consequently, the issue is not curriculum enhancement but the scientific status of the curriculum itself.

This distinction is important because contemporary HTA represents more than forty years of intellectual development. During that period universities established graduate programs, research centers, doctoral training, textbooks, journals, professional organizations and methodological guidance around a common analytical framework built upon utilities, quality-adjusted life-years (QALYs), incremental cost-effectiveness ratios (ICERs), cost-effectiveness analysis, decision modelling and reference-case simulation. Thousands of peer-reviewed publications, reimbursement submissions and healthcare policy decisions have relied upon these constructs.

Entire academic careers have been devoted to refining their application. The present challenge therefore extends far beyond criticism of individual analytical methods. It asks whether the measurement assumptions supporting the entire quantitative framework satisfy the accepted standards of representational measurement.

The implications are therefore cumulative rather than incremental. If representational measurement is accepted as the governing scientific standard, the consequences extend backwards as well as forwards. Existing curricula require reconsideration. Established textbooks require re-evaluation. Methodological guidance becomes open to review. Published research must be reconsidered, not because it employed inappropriate statistical methods, but because the measurement status of the quantities entering those analyses is itself brought into question. Few scientific disciplines encounter challenges whose implications extend simultaneously across education, research, professional guidance, reimbursement policy and professional practice.

Paradoxically, the challenge itself is conceptually straightforward because it represents a return to the accepted standards of normal quantitative science rather than the introduction of a new scientific paradigm. Its central propositions have been accepted within measurement theory for decades. Measurement precedes arithmetic. Arithmetic is constrained by the properties of the measurement scale. Multiplication and division require ratio measurement. Scientific claims should be credible, empirically evaluable, independently replicable and capable of potential falsification. These are not methodological innovations. They are the ordinary principles governing quantitative inquiry across the natural and social sciences. Their application to HTA therefore restores the scientific sequence that should always have governed the discipline.

The simplicity of the challenge also reflects a more fundamental issue. Contemporary HTA organized itself around analytical methods rather than around the attributes whose change it sought to evaluate. Utilities, QALYs, ICERs and decision models became the organizing framework of the discipline, while the prior scientific question of what attribute is being measured largely disappeared. Once the attribute again becomes the starting point, the measurement problem becomes remarkably straightforward. Every therapy-impact claim is with either a manifest attribute, requiring lawful linear ratio measurement, or a latent attribute, requiring Rasch logit ratio measurement based upon unidimensionality, invariance and specific objectivity. No third class of therapy-impact measure is required. The absence of attributes from the conceptual framework of HTA explains why the distinction between manifest and latent attributes, and the different measurement systems appropriate to each, remained largely outside the discipline for more than four decades.

This simplicity creates an unusual educational dilemma. Many HTA faculty possess extensive expertise in health economics, outcomes research, epidemiology, biostatistics, decision science and economic evaluation, yet comparatively few have received formal training in representational measurement. Graduate education has traditionally emphasized statistical analysis, economic modelling, comparative effectiveness research and healthcare decision making while giving comparatively little attention to the scientific foundations of measurement itself. Consequently, concepts such as admissible transformations, dimensional homogeneity, lawful ratio measurement, and the distinction between manifest and latent attributes remain unfamiliar to many experienced investigators. This observation should not be interpreted as criticism of individual scholars. Rather, it reflects the historical development of the discipline. Faculty have generally taught the analytical framework within which they themselves were educated.

For this reason, the present challenge cannot be addressed simply by adding a lecture on measurement theory to an otherwise unchanged curriculum. Representational measurement is not another topic alongside utilities, QALYs or decision modelling. It establishes the scientific criteria by which those constructs are themselves evaluated. Once students understand that measurement precedes arithmetic and that arithmetic is constrained by the properties of lawful measurement, they inevitably begin asking whether the central constructs of contemporary HTA satisfy those requirements. The curriculum therefore becomes internally inconsistent. Students are first taught the principles governing lawful quantitative measurement and are then introduced to analytical methods whose compatibility with those principles has become the very issue under scientific examination. The contradiction lies not in the students' questions but in the coexistence of two fundamentally different scientific frameworks.

The challenge is therefore one of scientific transition rather than incremental curriculum revision. Universities cannot resolve it by expanding the existing curriculum while leaving its organizing assumptions unchanged. They must determine whether representational measurement is simply another optional topic or whether it constitutes the scientific framework that determines the admissibility of every quantitative claim made within HTA. If the latter is accepted, the implications extend throughout the curriculum because every subsequent analytical method must first satisfy the standards of lawful measurement.

To support this transition, the Maimon Research nine-unit program provides a structured pathway from the inherited HTA framework to one organized around representational measurement [4] . It begins with the principle that measurement must precede arithmetic and progressively examines the definition of attributes, scales of measurement, admissible mathematical operations, dimensional homogeneity, and the distinction between manifest and latent attributes. It then considers the two forms of measurement required to support quantitative therapy-impact claims: linear ratio measurement for manifest attributes and Rasch logit ratio measurement for latent attributes. Particular attention is given to the construction and evaluation of Rasch measurement systems, the concept of attribute possession, and the requirement that claims be empirically evaluable and capable of falsification. The purpose is not to add measurement theory to the existing HTA curriculum, but to demonstrate how the curriculum itself must change once lawful measurement becomes its organizing scientific principle.

The intended outcome is therefore a reconstruction of how HTA problems are formulated, taught and evaluated. Participants should be able to begin with a clearly defined attribute rather than with an analytical technique; determine whether that attribute is manifest or latent; identify the measurement requirements appropriate to it; establish whether the resulting measure possesses the properties necessary to support the proposed arithmetic; and formulate therapy-impact claims that can be tested against empirical evidence. From this perspective, utilities, QALYs, mapping algorithms and reference-case simulation models are not accepted simply because they are established components of contemporary HTA. They must first demonstrate that the numerical values they employ satisfy the measurement requirements necessary for the operations performed upon them. The nine-unit program is thus designed to provide faculty and practitioners with both the scientific framework and the practical tools required to replace measurement inversion with an HTA paradigm in which measurement determines arithmetic, and quantitative claims are constrained by the standards of normal science.

Doing nothing is therefore no longer an academically defensible option. Universities and research groups cannot continue teaching the inherited HTA framework as though this challenge had never been made. Nor can they reasonably avoid informing students because the implications extend across four decades of teaching, research and professional practice. The cumulative evidence documenting measurement inversion, curriculum inversion and program-content inversion has fundamentally altered the educational landscape. Universities may ultimately accept, reject or modify representational measurement, but silence is no longer an academically neutral position. Once a coherent challenge to the scientific foundations of an established discipline has been systematically articulated and supported by an expanding body of scholarship, higher education has a responsibility to expose that challenge to critical examination. Universities exist to educate students in scientific inquiry, not to preserve inherited analytical traditions. The appropriate response to a foundational scientific challenge is not avoidance but investigation.

4. STUDENT EXPECTATIONS OF HEALTH TECHNOLOGY ASSESSMENT

The emergence of representational measurement as a documented challenge to the scientific foundations of health technology assessment fundamentally changes the expectations that prospective students should bring to graduate education. Students entering an HTA or health economics program should reasonably expect to receive more than technical instruction in an established analytical methodology. They should expect to understand the scientific principles upon which that methodology rests, the evidence supporting those principles, and the existence of substantial scientific challenges that call those principles into question. A university education differs fundamentally from professional training because it equips students to evaluate knowledge critically rather than simply apply established techniques. Once the quantitative foundations of HTA have become the subject of sustained scientific scrutiny, students are entitled to know that this scrutiny exists.

Students should therefore expect that the scientific foundations of quantitative measurement will be presented before they are introduced to the analytical methods of contemporary HTA. They should understand why measurement must precede arithmetic, why multiplication and division require ratio measurement, how the properties of measurement scales constrain admissible arithmetic, why dimensional homogeneity is required for meaningful quantitative claims, and why manifest and latent attributes require fundamentally different approaches to measurement. They should understand that every therapy-impact claim begins with the identification of an attribute and that only two lawful measurement systems are available: linear ratio measurement for manifest attributes and Rasch logit ratio measurement for latent attributes. These are not peripheral theoretical topics. They establish the scientific conditions that determine whether every subsequent analytical method is capable of supporting meaningful quantitative claims.

A prospective student should therefore be entitled to ask a series of straightforward scientific questions before deciding whether to undertake advanced study in HTA or HEOR.

- **Where in the curriculum are the principles of representational measurement introduced before health economics, economic evaluation and decision modelling?**
- **How are the scientific requirements of measurement preceding arithmetic explained and applied?**
- **Where are scales of measurement, admissible arithmetic and dimensional homogeneity taught?**
- **How are manifest and latent attributes distinguished, and why do they require different approaches to measurement?**
- **Why are linear ratio measurement and Rasch logit ratio measurement presented as the two lawful approaches to measuring therapy impact—or, if they are not presented, why are they omitted?**
- **What evidence demonstrates that utilities, QALYs and incremental cost-effectiveness ratios satisfy the accepted standards governing lawful quantitative measurement?**
- **How are students introduced to the scientific challenge posed by representational measurement, and what evidence is presented both for and against it?**
- **If representational measurement is omitted from the curriculum, what scientific justification is offered for that omission?**

These are not adversarial questions. They are the natural questions of students seeking to understand the scientific foundations of the discipline they are about to study. Universities should welcome such questions because they reflect precisely the critical inquiry that higher education is intended to encourage.

Students should also expect openness concerning the implications of the challenge. If representational measurement is accepted as the governing scientific framework, many of the analytical methods that currently define HTA necessarily become subjects for critical scientific re-evaluation. Universities should not avoid discussing these implications because they affect long-established teaching, research traditions or accepted professional practice. One of the defining characteristics of higher education is that established ideas remain open to critical examination. Students should therefore see scientific disciplines progressing through the continuous evaluation of evidence, the testing of assumptions and the willingness to modify inherited frameworks when better scientific explanations emerge.

The educational expectations of students extend well beyond individual courses. Graduate education prepares future faculty members, researchers, journal editors, consultants, pharmaceutical scientists, HTA practitioners and healthcare policy advisers. If students complete advanced training without ever encountering the scientific challenge presented by representational measurement, the inherited analytical framework will simply be reproduced through another generation of teaching, research and professional practice. Measurement inversion is then perpetuated not because competing scientific explanations have been critically examined and rejected, but because students were never informed that such an alternative scientific framework existed.

Ultimately, the expectations of prospective students are neither unreasonable nor revolutionary. Students are not asking universities to abandon contemporary HTA before they enroll; nor are they asking faculty to reject four decades of methodological development. Their expectations are considerably more modest and entirely consistent with the purpose of higher education. They are entitled to know that a substantial scientific challenge now exists, to understand the principles upon which that challenge rests, and to evaluate for themselves whether the curriculum they are being invited to study satisfies the accepted standards of normal quantitative science. Universities rightly expect students to exercise critical judgement. Students are equally entitled to expect that universities will provide the scientific information necessary to exercise that judgement intelligently. Once that principle is accepted, the duty to inform is no longer optional. It becomes an essential condition of responsible university education.

CONCLUSION

This paper has argued that the emergence of representational measurement as a documented challenge to the scientific foundations of health technology assessment (HTA) fundamentally changes the responsibilities of universities and university-based research groups. The issue is no longer whether contemporary HTA represents an established analytical framework. It clearly does. Over more than four decades, graduate programs, research centers, professional organizations, journals, textbooks and healthcare agencies have developed an extensive educational and research enterprise founded upon utilities, quality-adjusted life-years (QALYs), incremental cost-effectiveness ratios (ICERs), economic evaluation and increasingly sophisticated decision modelling. The issue is whether the scientific assumptions supporting that enterprise should continue to be presented to students as though they were beyond question when a substantial challenge to their measurement foundations has now been systematically documented.

Unlike routine methodological debates, representational measurement questions the scientific legitimacy of the arithmetic upon which contemporary HTA depends. It is therefore not another analytical technique that can simply be incorporated into an existing curriculum while leaving the remainder unchanged. Once measurement precedes arithmetic becomes the governing scientific principle, the curriculum itself becomes the object of scientific evaluation. Students naturally begin asking whether the quantities entering utilities, QALYs, ICERs and simulation models possess the measurement properties necessary to support the arithmetic performed. Those questions are not disruptive. They are precisely the questions that universities should encourage because they concern the scientific foundations of the discipline itself.

Paradoxically, the challenge is both profound and remarkably simple. It does not require a new mathematics, more sophisticated computational methods or another generation of statistical refinement. It represents a return to the accepted standards of normal quantitative science. Scientific claims should be credible, empirically evaluable, independently replicable and capable of potential falsification. Measurement must precede arithmetic. Arithmetic is constrained by the properties of the measurement scale. Once the target attribute has been identified and defined, the remainder of the scientific process follows naturally. The appropriate measurement system is determined by the nature of the attribute, admissible arithmetic follows from the properties of that measurement system, and therapy-impact claims become capable of empirical evaluation, independent replication and potential falsification. Contemporary HTA largely reversed this scientific sequence by beginning with analytical methods rather than with the attributes whose change those methods purported to represent.

The fact that these principles have received little explicit attention within contemporary HTA should not be interpreted as an individual failure on the part of faculty or researchers. Most have taught the framework within which they themselves were educated. The present challenge questions an intellectual tradition extending across more than forty years of graduate education, research, methodological guidance and professional practice. Its implications therefore reach beyond individual courses or institutions to the scientific foundations of the discipline itself. Precisely because the consequences are so extensive, doing nothing is no longer an academically defensible response. Universities may ultimately accept, reject or modify the representational measurement framework, but they cannot legitimately ignore its existence or fail to inform students that such a challenge now forms part of the scientific literature.

The responsibility of the university is therefore clear. Higher education is distinguished from technical training by its commitment to critical inquiry, scientific openness and intellectual honesty. Prospective students are entitled to be informed when substantial scientific challenges arise concerning the discipline they are proposing to study. They should understand not only the inherited analytical framework but also the existence of competing scientific interpretations, the evidence supporting each, and the reasons why those interpretations differ. Without that knowledge, informed academic choice becomes impossible. Universities need not decide scientific controversies on behalf of their students, but they do have a responsibility to ensure that students understand the questions being asked, the evidence upon which those questions rest, and the implications of the competing answers.

The opportunity created by representational measurement is therefore constructive rather than destructive. Its objective is not to dismantle health technology assessment but to reconstruct it upon the principles that govern every mature quantitative science. The path forward is neither obscure nor technically complex. It begins by restoring the attribute to its central place within scientific inquiry, distinguishing clearly between manifest and latent attributes, selecting the lawful measurement system appropriate to each, restricting arithmetic to that permitted by the resulting measure, and ensuring that every therapy-impact claim is credible, empirically evaluable, independently replicable and capable of potential falsification. Once this scientific sequence is restored, HTA ceases to be defined primarily by inherited analytical techniques and instead becomes organized around the ordinary principles of quantitative inquiry.

The issue is therefore no longer whether representational measurement deserves a place within HTA. The issue is whether HTA wishes to remain a discipline organized around inherited analytical conventions or return to the accepted standards of normal science. Universities need not answer that question in advance for their students. They do, however, have an educational responsibility to ensure that students understand the question, the evidence upon which it rests, and the consequences of the competing answers. Returning HTA to normal science is therefore more than a methodological transition. It is an educational obligation and, ultimately, a reaffirmation of the university's fundamental commitment to scientific inquiry.

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