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REPRESENTATIONAL MEASUREMENT FAILURE IN HEALTH TECHNOLGY ASSESSMENT

CALIFORNIA: REQUIRED PROGRAM CONTENT FOR A GRADUATE COURSE IN HTA

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ABSTRACT

Graduate students entering health technology assessment (HTA), health economics or *quantitative therapy evaluation should expect more than technical proficiency in established analytical methods. They should be taught the scientific principles required to determine whether numerical claims constitute measures, whether the arithmetic performed upon them is admissible and whether resulting therapy-impact claims can contribute to objective knowledge. This paper examines that expectation in the context of California graduate education.*

Previous assessment of six major California university affiliated HTA and health-economics environments identified a striking program-content inversion: 0/17 topics defining representational measurement were explicitly recognized as scientific foundations, compared with 20/20 topics representing contemporary HTA and health economics. *This contrast is particularly significant given California's exceptional concentration of quantitative expertise. It suggests that sophisticated analytical teaching and research have developed without an identifiable prior framework establishing the measurement status of the quantities being analyzed.*

Twenty topics are proposed as the minimum scientific content required for graduate education in quantitative therapy evaluation. They progress from attribute definition and measurement preceding arithmetic through scale properties, admissible transformations, ratio measurement and dimensional homogeneity to the separate requirements for manifest and latent attributes. The destination is two measurement pathways for therapy-impact claims: linear ratio measurement for manifest attributes and Rasch logit ratio measurement for latent attributes, followed by prospective empirical evaluation, replication and potential falsification.

The implications extend beyond curriculum revision. Faculty may have inherited an HTA framework in which representational measurement was absent; that explains the historical omission but cannot justify transmitting it to another generation. California universities therefore face an educational responsibility: graduate students must be given the measurement knowledge required to evaluate, challenge and, where necessary, reject inherited quantitative methods. A nine-unit transformation framework is described to support faculty and institutions in making this transition. The central question is unavoidable: once measurement failure has been exposed, can universities reasonably continue teaching it?

INTRODUCTION

Graduate education in the United States is expensive. A prospective student considering advanced study in health technology assessment (HTA), health economics or quantitative therapy evaluation is being asked to commit tuition fees, considerable time and an important part of his or her future career to the program selected. The student is therefore entitled to ask a straightforward question before enrolling: what scientific capabilities will this program actually give me? If the objective is to acquire expertise in quantitative therapy evaluation, the answer should extend beyond proficiency in established analytical techniques. The student should expect to be taught the scientific requirements that determine whether a numerical claim concerning therapy impact is a measure, whether the arithmetic performed upon it is admissible and whether the resulting claim can contribute to the growth of objective knowledge.

This question has particular relevance in California. Previous assessment of the publicly available program-content knowledge base associated with six major California university affiliated HTA, health-economics, outcomes-research, health-policy and related quantitative health-research environments identified a striking separation between representational measurement and the established quantitative framework of HTA and health economics [1]. Using the fixed program-content framework, none of the 17 topics defining representational measurement was identified as an explicit scientific foundation, while all 20 topics characterizing the established HTA and health-economics framework were represented. The result was 0/17 versus 20/20.

An informed prospective student should be aware of this finding. California contains some of the most prominent universities, academic medical centers and quantitative health-research environments in the United States. The decision to enroll should therefore not rest simply upon institutional reputation or the existence of courses and research programs in health economics, pharmacoeconomics, outcomes research, economic evaluation, comparative effectiveness research, decision science or related quantitative methods. Nor should the publication records of faculty or the technical sophistication of the methods being taught be taken as evidence that the scientific foundations of measurement are necessarily addressed. The 0/17 result raises a prior question: does the proposed graduate education provide the body of measurement knowledge required to determine whether the quantitative operations encountered in therapy evaluation are scientifically meaningful?

The starting point should be elementary but non-negotiable: measurement precedes arithmetic. Before numbers are added, subtracted, multiplied, divided or incorporated into any further quantitative analysis, the attribute represented by those numbers must be defined and their measurement properties established. Students should understand the distinction between assigning numbers and creating measures; nominal, ordinal, interval and ratio scales; admissible transformations; the axioms of representational measurement; the requirements for ratio measurement; and dimensional homogeneity. These are not specialist topics to be appended to an otherwise complete quantitative curriculum. They determine what arithmetic is permissible in the first place.

The curriculum must then address the measurement of therapy impact itself. This requires an explicit distinction between manifest and latent attributes. Manifest attributes are directly observable and, where the necessary measurement conditions are satisfied, can support linear ratio measurement. Latent attributes such as pain, fatigue, anxiety or physical functioning cannot be directly observed and require construction of a measurement continuum. For these attributes, students should understand Rasch person-item conjoint measurement, construction of the logit ruler, unidimensionality, fit, local independence, ordered thresholds, differential item functioning, invariance, specific objectivity and attribute possession. These concepts provide a measurement pathway from observed responses to defensible quantitative claims concerning changes in a latent attribute.

The destination of graduate education in quantitative therapy evaluation should therefore be clear. Students should understand that there are two allowable measurement forms for therapy-impact claims: linear ratio measurement for manifest attributes and Rasch logit ratio measurement for latent attributes. They should be able to identify the target attribute, determine whether it is manifest or latent, establish the appropriate measurement pathway and formulate a quantitative therapy-impact claim whose measurement status can be defended. A collection of statistical and analytical techniques is not a substitute for this capability.

There is an equally important scientific destination. Therapy-impact claims should meet the requirements of normal science. They should be stated prospectively, expressed using defensible measures, empirically evaluable, open to replication and capable of falsification. A graduate should understand that the purpose of quantitative analysis is not simply to generate numerical results but to formulate claims that can be confronted by evidence and can succeed or fail. Measurement provides the necessary bridge between observation and the creation of objective knowledge.

Against this standard, the California 0/17 versus 20/20 finding assumes particular importance. It does not demonstrate an absence of quantitative teaching or expertise. Quite the reverse: the 20/20 result demonstrates the breadth and sophistication of the existing California quantitative program-content knowledge base. That makes the 0/17 finding more, rather than less, consequential. An extensive analytical structure has developed without, as far as can be ascertained from publicly available program content, an identifiable representational-measurement framework establishing the status of the quantities being analyzed and the admissibility of the arithmetic performed upon them. California therefore presents the same fundamental problem identified elsewhere: extensive instruction and research in quantitative analysis without an identifiable prior foundation in the science of quantitative measurement.

For the prospective student, the issue is practical rather than abstract. Graduate education represents a substantial purchase of knowledge and capability. Before committing money, time and career opportunity, an informed student should establish whether the proposed program provides the scientific foundations necessary for quantitative therapy evaluation. Institutional reputation cannot answer that question. Neither can faculty publication records, methodological sophistication or the longevity of the methods being taught. The question must be answered by the content of the education itself.

The purpose of this paper is therefore to identify 20 topics that an informed student should expect a graduate program to address and to explain why each is essential. Together they provide a straightforward standard against which a prospective student can ask: if I enroll in this program, will I be educated in the measurement and evaluation of therapy impact according to the requirements of normal science, and if not, what exactly am I paying to learn?

PROGRAM CONTENT RESULTS

The earlier assessment of the California university affiliated HTA and health-economics research-center knowledge base provides the immediate background to the present paper. The result followed the now familiar pattern: representational measurement was effectively absent from publicly identifiable program content, while the established methods of contemporary HTA and health economics were comprehensively represented. There is no need to reproduce those results here. The importance of the California finding lies not in its uniqueness but in its consistency with the evidence accumulated elsewhere.

The same pattern has emerged from investigations of measurement inversion, curriculum inversion and program-content inversion in the United States and internationally. Across agencies, research centers, university programs and the wider HTA knowledge base, the principles of representational measurement receive little or no identifiable recognition [2] [3] . Measurement preceding arithmetic, admissible transformations, ratio measurement, dimensional homogeneity, the distinction between manifest and latent attributes, and the requirements for constructing measures of latent attributes are largely absent. At the same time, extensive quantitative structures have developed that presume that the numerical values upon which they operate possess the properties required to support the arithmetic being performed.

The cumulative evidence suggests something more serious than the omission of a few topics from graduate curricula. There appears to be little evidence within the HTA discipline of a systematic understanding, or even awareness, of representational measurement as the scientific foundation for quantitative claims. This conclusion is supported not by a single interrogation, university or jurisdiction but by the remarkable consistency of findings across different forms of assessment and different institutional settings. California should therefore be viewed as one expression of a much wider epistemic failure rather than an isolated educational problem.

Indeed, the California result is particularly important because of the size, standing and sophistication of its academic health-research environment. California contains internationally prominent universities, medical schools, schools of public health, pharmacy programs and university-affiliated research centers engaged in health economics, pharmacoeconomics, outcomes research, comparative effectiveness research, health-services research, economic evaluation and healthcare policy. The absence of representational measurement cannot therefore readily be attributed to limited academic infrastructure, insufficient methodological expertise or lack of quantitative sophistication. The contrast is precisely the opposite: extensive analytical sophistication exists alongside an apparent absence of the measurement framework required to establish the quantitative status of the numbers being analyzed**.**

The historical implication is substantial. Graduate programs in HTA, health economics, pharmacoeconomics, outcomes research and related quantitative health disciplines have been educating successive generations of practitioners for approximately three decades without, as far as can be established from the accumulated evidence, placing representational measurement at the foundation of quantitative therapy evaluation. Students have been trained in increasingly sophisticated analytical methods without first being required to establish the measurement status of the numbers entering those analyses. The result has been the institutional reproduction of measurement failure: faculty teach the framework in which they themselves were trained, graduates become practitioners and future faculty, and the same assumptions are transmitted to the next generation.

That history may explain how the omission persisted. It cannot justify continuing to reproduce it**.** Once the measurement failure has been identified and documented, universities have a different responsibility to the students they educate. Another generation should not be taught arithmetic without first being provided with the scientific knowledge required to determine whether that arithmetic is admissible. The epistemic inheritance of faculty cannot be allowed to become automatically the scientific inheritance of their students.

This history gives particular importance to the question of required graduate program content. The objective is not to add another specialist topic called "measurement" to an already crowded curriculum. Nor is it sufficient to devote a lecture to scales of measurement while leaving the remainder of the quantitative program unchanged. If representational measurement establishes the conditions under which quantitative claims and mathematical operations are meaningful, it must provide the **organizing scientific framework** for the course. Measurement must precede arithmetic not only as a proposition taught to students but as the principle governing everything that follows.

The 20 topics that follow are proposed on that basis. Together they describe the minimum body of knowledge that an informed student should expect a graduate program in quantitative HTA to address. They begin with measurement preceding arithmetic and proceed through attribute definition, scale properties, admissible transformations, ratio measurement and dimensional homogeneity to the separate requirements for measuring manifest and latent attributes. They culminate in the two allowable measurement forms for therapy-impact claims, the\linear ratio measurement for manifest attributes and Rasch logit ratio measurement for latent attribute**s** with the requirement that such claims meet the standards of normal science through empirical evaluation, replication and potential falsification.

The question for California graduate programs is therefore not whether these topics would provide useful additions to existing teaching. It is whether a course claiming to educate students in quantitative HTA can reasonably omit them. The accumulated evidence of measurement inversion, curriculum inversion and program-content inversion suggests that this question has not previously occupied the position it requires within graduate education. After three decades of training students within an analytical framework that, as far as publicly identifiable program content demonstrates, lacks this measurement foundation, the question can no longer be avoided: should California universities continue teaching another generation of students quantitative methods without first teaching them the scientific standards required to determine whether those methods are lawful?

TWENTY ESSENTIAL TOPICS FOR A GRADUATE PROGRAM IN QUANTITATIVE THERAPY EVALUATION

The following 20 topics represent a coherent body of knowledge rather than a menu from which individual subjects might be selected. Each contributes to the progression from defining an attribute, through establishing a measure, to constructing an empirically evaluable therapy-impact claim. An informed prospective student should therefore establish whether these topics are addressed in the graduate program being considered.

1. Measurement must precede arithmetic

Why this is essential. Measurement establishes the properties of the numerical representation before arithmetic is undertaken. Those properties determine which mathematical operations are admissible. Arithmetic cannot retrospectively transform numbers into measures or supply measurement properties that were never demonstrated. A graduate student in quantitative therapy evaluation should therefore understand from the outset that the scientific sequence is attribute definition, measurement and only then arithmetic. Reversing this sequence substitutes numerical manipulation for measurement and undermines the quantitative status of subsequent claims.

2. Definition of the target attribute before measurement

Why this is essential. Every therapy-impact claim concerns an attribute. Before selecting an instrument, assigning numbers or performing arithmetic, the student must be able to state precisely what is to be measured. Survival, hospital utilization, pain, fatigue and physical functioning represent different attributes and may require different measurement approaches. Failure to define the attribute creates ambiguity about what the resulting numbers represent. Attribute definition is therefore the necessary starting point for selecting a measure and constructing a defensible therapy-impact claim.

3. The distinction between numerical assignment and measurement

Why this is essential. Numbers may be assigned to observations for identification, ordering, classification or convenience without creating a quantitative measure. The fact that responses are represented by integers does not establish equal units, a meaningful zero or permissible arithmetic. Graduate students must therefore understand the difference between producing a numerical score and measuring an attribute. Without this distinction, numerical representations can acquire an appearance of quantitative precision while lacking the properties required to support the mathematical operations subsequently performed upon them.

4. Nominal, ordinal, interval and ratio scales

Why this is essential. The traditional hierarchy of measurement scales identifies fundamentally different numerical structures. Nominal values classify, ordinal values establish order, interval scales support meaningful differences, and ratio scales additionally support meaningful ratios where their defining requirements are satisfied. These distinctions are not introductory terminology to be mentioned and forgotten. They determine what can legitimately be done with numerical values. A graduate should be able to identify the scale properties of a proposed measure before deciding which arithmetic operations are meaningful.

5. Admissible transformations and permissible arithmetic

Why this is essential. A measurement scale is characterized by transformations that preserve the empirical relationships represented by its numerical assignments. These admissible transformations determine which mathematical statements remain invariant and therefore meaningful. Understanding this relationship prevents students from assuming that every mathematical operation available in software is scientifically permissible. Graduate education in quantitative therapy evaluation should establish the connection between scale structure, admissible transformation and arithmetic so that students can justify the operations applied to measures rather than simply calculate numerical results.

6. The axioms and requirements of representational measurement

Why this is essential. Representational measurement requires numerical relationships to represent corresponding empirical relationships in the attribute being measured. This depends upon conditions such as ordering, additivity, solvability, cancellation and related requirements appropriate to the measurement structure. These principles distinguish measurement from arbitrary numerical assignment. A graduate should understand why measurement requires evidence that the numerical system faithfully represents an empirical relational system. Without this foundation, there is no scientific basis for claiming that assigned numbers possess the quantitative properties attributed to them.

7. The requirements for ratio measurement

Why this is essential. Ratio measurement permits the widest range of arithmetic operations required for quantitative therapy-impact claims, but those operations are justified only when the defining properties of the scale have been established. Students should understand the requirements for invariant units, an appropriate non-arbitrary zero and meaningful ratio comparisons. Statements involving multiplication, division, proportions or claims that one quantity is twice another depend upon these properties. Ratio measurement should therefore be understood as a scientific requirement, not simply another label in a hierarchy of scales.

8. Dimensional homogeneity

Why this is essential. Quantities cannot be combined meaningfully merely because they are represented numerically. The dimensions represented by those quantities must be identified and the proposed arithmetic must preserve dimensional coherence. Dimensional homogeneity provides an elementary safeguard against constructing numerical expressions whose components have incompatible quantitative meanings. Graduate students should be able to examine every proposed therapy-impact calculation and ask what dimensions are being combined, what the resulting quantity represents and whether the operation produces a scientifically interpretable measure rather than an arbitrary numerical construction.

9. The distinction between manifest and latent attributes

Why this is essential. Therapy evaluation involves both directly observable and latent attributes. Hospital days, treatment administrations and survival time are manifest; pain, fatigue, anxiety and physical functioning are latent and cannot be directly observed. This distinction determines the appropriate measurement pathway. A graduate should not approach both categories with the same measurement strategy. Recognizing whether an attribute is manifest or latent is therefore a pivotal decision: it determines how a ruler can be constructed and how a quantitative therapy-impact claim can subsequently be expressed.

10. Linear ratio measurement for manifest attributes

Why this is essential. Manifest attributes capable of direct quantitative representation can be measured using linear ratio scales when the necessary properties of unit and zero are satisfied. Examples may include days hospitalized, treatment administrations or units of resource utilization. Students should understand how such measures are defined, why their units remain invariant and what arithmetic they support. This provides the first of the two measurement pathways required for therapy evaluation and establishes how changes in directly observable attributes can support meaningful quantitative therapy-impact claims.

11. Construction of therapy-impact claims for manifest attributes

Why this is essential. Measurement becomes scientifically useful when it supports an evaluable claim. Students should learn how a manifest attribute is translated into a protocol-defined therapy-impact claim specifying the target population, comparator, timeframe, unit of measurement and expected outcome. The claim should state in advance what observation would support or fail to support it. This moves graduate education beyond descriptive numerical analysis to hypothesis-driven therapy evaluation in which a measured impact is capable of being independently assessed, replicated and potentially rejected by empirical evidence.

12. Why ordinal observations and summed scores do not constitute latent measures

Why this is essential. Questionnaire response categories commonly represent ordered observations, but assigning integers to those categories does not establish equal intervals between them. Adding such integers together does not, by itself, create a measure with invariant units. Graduate students working with patient-reported outcomes must understand this distinction. Otherwise, arithmetic performed on summed scores may be interpreted as measurement without the necessary quantitative structure having been demonstrated. Recognizing the limitations of ordinal observations is the starting point for legitimate measurement of latent attributes.

13. Rasch person–item conjoint measurement

Why this is essential. Latent attributes cannot be directly observed and require a measurement framework capable of constructing a quantitative continuum. Rasch measurement locates persons and items conjointly on the same latent-attribute scale, providing a basis for transforming ordered observations into measures. Graduate students should understand the logic of this relationship rather than treating Rasch as merely another statistical technique. Its importance lies in constructing a ruler for an otherwise unobservable attribute so that differences in attribute possession can support quantitative therapy-impact claims.

14. Construction of a Rasch logit measurement continuum

Why this is essential. Understanding Rasch measurement requires more than knowing its name or operating software. Students should learn how response data are used to estimate person and item locations, how the provisional continuum is constructed and how logits provide the common metric upon which persons and items are located. This establishes the practical bridge between ordinal observations and latent measurement. A graduate should understand where the resulting measures come from, what they represent and why construction of the ruler precedes its use in evaluating therapy impact.

15. Requirements for a defensible Rasch ruler

Why this is essential. A fitted Rasch model does not automatically establish a defensible measurement instrument. Students should understand the empirical requirements that the ruler must satisfy, including unidimensionality, item fit, local independence, ordered response thresholds, differential item functioning, targeting and stability. These requirements test whether the proposed instrument behaves as a measurement system rather than merely providing a statistical description of response data. A graduate should therefore be capable of evaluating whether a proposed latent ruler meets the conditions necessary for quantitative interpretation.

16. Invariance and specific objectivity

Why this is essential. A fundamental objective of measurement is that comparisons should not depend arbitrarily upon the particular measuring instrument or sample used. Rasch specific objectivity requires person comparisons to remain invariant across appropriate items and item comparisons across appropriate persons, subject to the requirements of the measurement model. Students should understand why this property is central to constructing a defensible latent measure. Without appropriate invariance, observed differences may reflect characteristics of the instrument or sample rather than differences in possession of the target attribute.

17. Attribute possession on a Rasch logit scale

Why this is essential. The purpose of latent measurement is to determine the extent to which a person possesses the specified attribute. Once a defensible Rasch ruler has been constructed, the person's response pattern locates that individual on the latent continuum. Graduate students should understand this concept of attribute possession because it changes the focus from questionnaire scores to measures of the attribute itself. Therapy impact can then be expressed as a change in possession rather than simply as a numerical change in an aggregated response score.

18. Therapy-impact claims for changes in latent-attribute possession

Why this is essential. A latent measure should ultimately support an empirically evaluable claim about therapy impact. Students should learn how changes in attribute possession are specified prospectively for a defined population, comparator and timeframe using the Rasch logit measure. The claim must identify the expected change and the evidence that would count against it. This connects latent measurement directly to hypothesis testing and replication. Rasch measurement thereby becomes part of a scientific protocol for evaluating therapy impact rather than an isolated psychometric exercise.

19. The two allowable measurement forms for quantitative therapy-impact claims

Why this is essential. A coherent graduate curriculum should bring the preceding measurement principles together into two pathways for quantitative therapy-impact claims: **linear ratio measurement for manifest attributes and Rasch logit ratio measurement for latent attributes**. The student should understand why the nature of the attribute determines which pathway is appropriate and why other numerical representations cannot simply be assumed to constitute measures. A graduate should leave able to identify the attribute, select the appropriate measurement form and defend the quantitative status of the resulting claim.

20. The requirements of normal science

Why this is essential. Quantitative therapy evaluation should culminate in claims capable of participating in normal scientific inquiry. The attribute must be defined, the measure must satisfy appropriate measurement requirements, and the claim must specify the population, comparator, timeframe and predicted therapy impact. Most importantly, the claim must be empirically evaluable, open to replication and capable of falsification. A graduate program should therefore produce students able not merely to generate numbers, but to construct quantitative claims that can succeed or fail when confronted by evidence. The 20 topics described above imply more than revision of a syllabus.

FACULTY AND STUDENTS

For California universities and university-affiliated research centers**,** they require a change in the relationship between faculty, students and the quantitative framework that has traditionally defined graduate education in HTA, health economics, pharmacoeconomics and outcomes research. If measurement becomes the organizing principle of therapy evaluation, both faculty and students enter a post-legacy environment in which established methods can no longer be accepted simply because they are familiar, widely used or institutionally supported. Every quantitative claim must instead begin with the attribute, satisfy the requirements of measurement and employ only arithmetic justified by the properties of the measure.

For California faculty, this presents an unusual academic challenge. Many current teachers and researchers were themselves educated within programs in which representational measurement was absent. They subsequently developed research careers, publications, teaching materials and professional relationships within the same framework. The evidence from measurement inversion, curriculum inversion and program-content inversion suggests that this omission has been reproduced across successive generations. Faculty cannot therefore be expected to correct the problem merely by being told that measurement should receive greater emphasis. The first requirement is acquisition of a body of knowledge that, for many, was not part of their own graduate education.

This should not be interpreted as a criticism of faculty competence within the framework in which they were trained. California possesses exceptional expertise in economic evaluation, statistics, epidemiology, decision analysis, health-services research, comparative effectiveness research, outcomes research and related quantitative methods. Indeed, the breadth of that expertise makes the measurement problem more significant rather than less. Expertise in these areas does not automatically provide expertise in representational measurement. The post-legacy challenge requires faculty themselves to examine attributes, scales, admissible transformations, ratio measurement, dimensional homogeneity, manifest and latent attributes, Rasch measurement, specific objectivity and attribute possession. Only then can these principles be incorporated coherently into graduate teaching.

The responsibility extends well beyond adding a lecture or module entitled *Measurement*. If students are taught that measurement precedes arithmetic, that proposition must have consequences throughout the course. If they are taught that scale properties determine admissible operations, those restrictions must subsequently be respected. If manifest and latent attributes require different measurement pathways, assignments, research projects and assessments must reflect that distinction. Representational measurement cannot occupy one week of a California graduate course and then disappear while the remainder of the curriculum proceeds unchanged. Integration rather than acknowledgement is the standard.

Faculty must also be prepared for a different type of classroom. Students who understand representational measurement should be encouraged to ask elementary but potentially disruptive questions: *What is the attribute? Is this a measure or merely a score? What is the scale type? Where is the zero? Are the units invariant? What transformations are admissible? Does the proposed arithmetic preserve dimensional homogeneity? Is the attribute manifest or latent? If latent, how was the ruler constructed?* These questions should not be regarded as challenges to faculty authority. They are precisely the questions that graduate education in quantitative science should encourage.

The responsibility of the California graduate student is correspondingly greater. Students should not approach HTA as a collection of procedures to be mastered, reproduced and subsequently applied in academic, industry or policy settings. They should expect to understand why a quantitative operation is scientifically admissible before performing it. The objective is not proficiency in software or conformity with an established analytical template, but the ability to construct and defend a quantitative claim. Students should therefore be prepared to challenge their own assumptions, identify measurement failures and reject numerical operations that cannot be justified by the properties of the measure.

The post-legacy curriculum also provides students with a much clearer destination. Therapy evaluation begins by defining the target attribute and determining whether it is manifest or latent. For manifest attributes, the student should be able to construct or identify an appropriate linear ratio measure. For latent attributes, the student should understand the construction and evaluation of a Rasch logit ratio measure and the assessment of attribute possession. These are not simply two additional analytical techniques. They constitute the two measurement pathways through which quantitative therapy-impact claims can be constructed.

The final obligation shared by faculty and students is to return quantitative therapy evaluation to the requirements of normal science. Claims should be specified prospectively and expressed in terms that permit empirical evaluation. They should be open to replication and, critically, capable of falsification. Failure is therefore not something to be avoided by constructing increasingly elaborate analytical systems. A claim that fails when confronted by evidence contributes to knowledge because it can be rejected, revised or replaced. Faculty should teach this process; students should expect to participate in it.

Transition to a post-legacy environment will inevitably be demanding in California precisely because the existing academic infrastructure is so substantial and deeply established. Major universities, academic medical centers, schools of public health, pharmacy programs and university-affiliated research centers have invested decades in graduate education, research programs, doctoral supervision, publications and professional networks constructed within the contemporary quantitative framework. These cannot be reconstructed overnight. Nor should faculty simply be expected to discard decades of accumulated expertise. The immediate requirement is different: established quantitative methods must be reconsidered against the standards of measurement that should have preceded them. Those that satisfy the requirements can be retained; those that do not must either be reconstructed or abandoned.

That is precisely where the responsibility of the university becomes important. California universities are not required to accept the conclusions advanced here without criticism. Faculty should be encouraged to challenge representational measurement, the proposed distinction between manifest and latent measurement pathways, and the conclusions drawn for contemporary HTA. Academic disagreement is entirely appropriate. What cannot be defended is the continued education of graduate students in quantitative therapy evaluation without exposing them to the body of measurement knowledge necessary to understand and participate in that challenge. Academic freedom protects criticism and disagreement; it does not justify excluding from graduate education the scientific standards required to determine whether the arithmetic being taught is admissible.

This responsibility has become still more immediate because the measurement failure of contemporary HTA has now been systematically documented. Measurement inversion, curriculum inversion and program-content inversion have repeatedly identified the same separation between representational measurement and the established HTA framework. Faculty may reasonably argue that these principles were absent from their own education. That explains the past; it cannot justify transmitting the same omission to another generation. Once the failure has been exposed, continuing to teach students the legacy framework without providing them with the knowledge required to identify that failure is impossible to defend.

The scale and influence of the California university environment make the opportunity particularly significant. California educates students who subsequently enter universities, pharmaceutical and biotechnology companies, healthcare systems, government, consulting, outcomes research and health-policy organizations throughout the United States and internationally. A transition within major California programs would therefore influence not only current graduate students but future faculty, researchers and practitioners far beyond the state. Conversely, continuing to reproduce a curriculum in which representational measurement remains absent would transmit the same epistemic limitation to another generation.

The 20 topics proposed here consequently represent more than required program content for California. They define a different educational relationship. Faculty are responsible for providing the measurement foundations, subjecting them to critical examination and demonstrating their application; students are responsible for understanding, questioning and applying them. The common objective is a graduate capable of moving beyond inherited numerical procedures to the construction of therapy-impact claims grounded in linear ratio measurement for manifest attributes or Rasch logit ratio measurement for latent attributes, and capable of contributing through those claims to the continuing evolution of objective knowledge.

For California universities, the choice is therefore no longer simply between an existing curriculum and a revised curriculum. It is whether the next generation of students will inherit the measurement failure of the previous generation or be given the scientific knowledge required to move beyond it. Universities cannot continue to teach students measurement failure**.**

TRANSITION TO LAWFUL MEASUREMENT

The transition to lawful measurement requires more than demonstrating the measurement failures of contemporary HTA. It requires a replacement framework grounded in representational measurement. The Maimon Research nine-unit transformation program provides that framework [4]. Beginning with the principle that measurement must precede arithmetic, the program progresses through the definition of attributes, scales of measurement, admissible arithmetic, dimensional homogeneity, manifest and latent attributes, linear ratio measurement, Rasch measurement, attribute possession, and the construction of empirically evaluable therapy-impact claims. The purpose is not to add measurement to the existing HTA paradigm while leaving its analytical structure intact. It is to replace that structure with one in which quantitative claims must first satisfy the requirements of lawful measurement and can then be evaluated, falsified and replicated.

At the same time, the nine units provide the substantive foundation for a graduate course in lawful measurement for HTA**.** Their sequence can be translated directly into a curriculum progressing from measurement theory to the practical construction and application of therapy-impact measures. Faculty can build around the units the lectures, readings, worked examples, exercises and assessments required for graduate instruction, while applying the same principles to research and HTA practice. The resulting course would replace the conventional emphasis on utilities, mapping, QALYs and reference-case modelling with an alternative scientific structure: defining the target attribute, determining whether it is manifest or latent, constructing the appropriate linear or Rasch ratio measure, and using that measure to formulate empirically evaluable claims. The nine-unit program therefore provides not simply a critique of the legacy framework, but the content and organizing structure from which its educational replacement can be built.

Faculty and practitioners who enroll will have access to a 24/7 question-and-answer support service, providing continuing assistance as they work through the implications of representational measurement for teaching, research and HTA practice. This becomes particularly important where faculty are using the program as the foundation for curriculum development. Questions concerning course structure, individual topics, measurement concepts, examples, assignments and their application to existing HTA material can be addressed as they arise. Participants are therefore not expected to complete the nine units and then independently determine how an unfamiliar scientific framework should be translated into teaching or practice. Continuing support is intended to make the movement from understanding to implementation an integral part of the transition.

Additional faculty and institutional support can also be arranged on an agreed basis. This may include Zoom seminars and workshops, assistance with graduate-course and curriculum redesign, development of teaching materials, recommended references and readings, and guest lectures addressing particular aspects of representational measurement and its application to HTA. Support can be tailored to individual faculty members, courses, departments, research centers or professional groups. The nine-unit program should therefore be understood as the starting point for a managed transition to lawful measurement. It provides the replacement scientific framework, the substantive elements required to construct a graduate course around that framework, and continuing access to the expertise and educational resources required for implementation. The objective is not simply to demonstrate why contemporary HTA must change, but to provide faculty and practitioners with the foundations and practical means to build, teach and apply its replacement. There is no going back.

CONCLUSION

The issue facing graduate HTA education in California is no longer whether additional attention might usefully be given to measurement. The accumulated evidence from measurement inversion, curriculum inversion and program-content inversion indicates a more fundamental problem: representational measurement has not provided the scientific foundation for the quantitative methods taught and applied within HTA. The consequence has been the transmission across successive generations of students of an analytical framework in which arithmetic has been allowed to precede measurement.

The 20 topics identified in this paper define what an informed student should now expect from a graduate program concerned with quantitative therapy evaluation. They are not optional additions to an established curriculum. They constitute a coherent body of knowledge beginning with attribute definition and measurement before arithmetic, proceeding through scales of measurement, admissible transformations, ratio measurement and dimensional homogeneity, and culminating in the distinction between manifest and latent attributes. The endpoint is equally clear: quantitative therapy-impact claims require linear ratio measurement for manifest attributes or Rasch logit ratio measurement for latent attributes.

The challenge is therefore one of transition rather than curriculum expansion. Faculty must acquire and integrate a body of measurement knowledge that may have been absent from their own graduate education. Students, in turn, should expect more than technical proficiency in inherited quantitative procedures. They should leave a graduate program capable of identifying an attribute, establishing its measurement requirements, selecting the appropriate measurement pathway and constructing a therapy-impact claim that is empirically evaluable, replicable and capable of falsification.

California universities now have an opportunity to define what graduate education in HTA should mean in a post-legacy environment. Given the exceptional scale and sophistication of the state's academic infrastructure in health economics, pharmacoeconomics, outcomes research, medicine, pharmacy, public health, comparative effectiveness research and health-services research, the opportunity is substantial. California could continue to reproduce an established analytical framework in which the requirements of representational measurement remain largely absent, or its universities could begin the transition toward a curriculum in which measurement provides the organizing scientific foundation for quantitative therapy evaluation.

This responsibility has become more immediate because the measurement failure is no longer hidden within the inherited HTA framework. The accumulated interrogations of HTA knowledge bases, curricula and program content have exposed and documented the recurring absence of representational measurement. Faculty may reasonably argue that they were themselves educated within this framework and were not introduced to the measurement standards now being advanced.

That explains how the legacy was transmitted; it cannot justify transmitting it again. Once the measurement failure has been identified, another generation of California students cannot simply be taught the same framework as though the problem had never been exposed.

The standard should therefore not be whether a program reproduces established professional practice or prepares students to apply methods that have been accepted for decades. Institutional acceptance, methodological sophistication and widespread use do not establish scientific validity. Nor does the reputation of a university transform an inadmissible quantitative operation into an admissible one. The appropriate standard is whether the program equips students to understand measurement, determine what arithmetic is lawful, construct defensible quantitative claims and thereby contribute to normal science and the evolution of objective knowledge.

For the prospective student investing substantial time, money and career opportunity, the question is correspondingly simple: does the California graduate program being considered provide this scientific education? Does it teach why measurement must precede arithmetic? Does it establish the role of ratio measurement? Does it distinguish the measurement requirements of manifest and latent attributes? Does it provide a pathway from attribute definition through lawful measurement to empirically evaluable, replicable and falsifiable therapy-impact claims?

If it cannot demonstrate that pathway, the final question is unavoidable: why enroll?

For California universities, the corresponding question is even more consequential: now that the measurement failure has been exposed, can another generation of students reasonably be taught the same failure?

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