Development of Quantum, an Instructor-Mediated Performance Assessment Test, and Student Measure Validation

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Abstract
This article discusses Quantum, an instructor-mediated performance assessment test, used in simulation to assist nurse educators to objectively measure student performance and document clinical competency. The article describes the process of development, validation, and measurement of student's integrated knowledge, skills, attitudes, and clinical reasoning used in decision-making to improve safe effective nursing practice. The article provides a review of Quantum's evaluation framework including: patient safety, assessment, communication, intervention, and documentation. The sample comprised of pre-licensure student nurses enrolled in core nursing courses from 14 nursing programs. Classical and Rasch data analyses found empirical evidence in support of the reliability of measures and validity of inferences in terms of content validity, optimum scoring structure, unidimensionality, reliability, invariance, responsiveness, consequential validity, and interpretability.

Introduction
Tests of knowledge by ATI, HESI, and Kaplan are important, but they portray an incomplete student appraisal if we really believe there is more to the practice of nursing than knowing. According to research published by Miller in 1990 the cognition zone (‘knows’ or ‘knows how’) correlates poorly with the behavior zone (‘shows how’ or ‘does’) [1]. Benner, Sutphen, Leonard, and Day (2010), in their book Educating nurses: A call for radical transformation, recommended varying the use of assessment of student performance beyond an exclusive focus on multiple-choice exams [2]. In 2014, the National Council of State Boards of Nursing’s National Simulation Study (NCSBN NSS) provided substantial evidence that up to 50% simulation can be effectively substituted for traditional clinical experience in pre-licensure core nursing courses [3]. These recommendations coupled with diminishing clinical sites, high student-faculty ratios, and the need to evaluate multiple learning domains [4], may prompt nursing programs to use a performance assessment test in their simulation laboratory to replace a portion of traditional clinical evaluation. However, validity and reliability evidence has been lacking on instruments to assist nurse educators with being more objective [5]. The subjective nature of clinical evaluation in education and practice stems from the inclusion of instructors in the performance assessment, which complicates the measurement process. Consequently, there are no psychometrically-sound performance assessment tests to objectively measure a student’s performance in simulation [6, 7]. Therefore, documentation was needed on the psychometric qualities of a performance assessment test.

Purpose
An instructor-mediated, performance assessment test designed to objectively measure a student’s clinical competence presents a number of problems, namely, modelling and accounting for sources of error variance that undermine student test score interpretation. There has been little effort in this area to collect and integrated various sources of evidence and theory to support the intended interpretation of test scores derived from an instructor-mediated, performance assessment test. The purpose of this article was to execute an empirical validation investigation of an instructor-mediated, performance assessment test to resolve these problems. To achieve this purpose, this validation study used Quantum as the instructor-mediated, performance assessment test in 14 nursing programs’ simulation laboratories.

Background
Objectively evaluating students’ clinical competency can be the most daunting duty of an educator, whether it is in the clinical setting or the simulation laboratory [8]. As such, the development of an instructor-mediated, performance assessment test to measure a student’s clinical competence plays a large role since it is a time-consuming and difficult process that requires multiple skill sets and conditions [9] including psychometric and subject matter...
Student learning outcomes in simulation is attracting a lot of attention in higher education due to the convergence of several factors including: simulation costs associated with student success, retention rates, and learning gains; accreditation standards; increasing efforts to link higher education funding to student success; and NCSBN NSS’s findings [3]. Outcome assessment should address both the student success and learning gains that result from simulation [15]. “Soft” benefits, such as improved decision-making including the ability to solve clinical problems by setting patient care priorities or responding to a change in the patient’s condition [2], can be further analyzed to trace through to “hard” benefits (e.g., improvements in measures such as student retention). The Joint Commission on Accreditation of Healthcare Organizations (JCAHO) noted that healthcare organizations have historically relied on education and experience to support competence, but an increasing number of healthcare organizations are seeking objective measures of a nurse’s knowledge that is required for safe practice [16]. The anticipated benefits of using an objective performance assessment’s data are one, you tend to improve what you measure; and two, you simply can’t manage what you don’t. Whether it is to drive an educational intervention to improve safe practice or safely decrease the length of orientation for new employees using simulation for teaching and learning reflects a presumption that learning is taking place and the teaching is effective. How do you know if you don’t measure it objectively?

**Method**

Performance assessments offered by the simulation industry or espoused in the literature to measure a student’s clinical competency do not model all variables of the performance assessment and do not account for their effects on students’ test scores. For example, the difficulty of the task performed and characteristics of instructors (e.g., the severity of particular instructor, their consistency, the way they interpret the rating guidelines) are crucial in determining the pattern of scores allocated to students in a performance task, and these sources of variation in a performance assessment must be modelled in order to provide fair and objective student test scores. The aim of this current study was to develop an instructor-mediated, performance assessment test, Quantum, to examine possible sources of error that reduce the validity of students’ test scores.

**Test Development Design**

Quantum was developed by the authors and subject matter experts (SMEs) who understand how important it is to: remove subjectivity from the rating process; have reliable student measures; quantify a student’s performance; and document clinical competency. A psychometrician and SMEs oversaw each clinical scenario’s test blueprint from student preparation, learning objectives, scenario content, simulation set-up document, evaluation criteria, rating guidelines, feedback, and debriefing [17].

Each test blueprint was linked to several educational learning theories: talk aloud protocol [18], the generation effect [19], learning progression [20, 21], and reflective practice [22-24]; applicable standards [15, 25-27]; references [28, 29]; current content [30]; legal aspects of clinical nursing education [31]; and reflects the framework for clinical assessment and the Nursing Skill Development and Clinical Judgment Model [1, 17].

Quantum was first developed for registered nurse (RN) programs and then for license practical (vocational) nurse (LPN/LVN) programs. Quantum-RN evaluated a student nurse’s performance across five subdomains: patient safety, assessment, communication, intervention (including I-SBAR-R (Grbach, n.d.)) [32], and documentation. Quantum-LPN/LV evaluated a student nurse’s performance across the same subdomains, but data collection replaced assessment.

Quantum was comprised of several standardized clinical scenarios that each student must successfully perform in order to demonstrate clinical competence. Each clinical scenario has specific descriptions of activities that demonstrate the performance at basic, intermediate and advanced levels.

**Theoretical Framework for Test Development**

Quantum was developed using Chatterji’s Process Model [33]. The Process Model allowed the researchers to merge the issues of logical analyses of test content and empirical confirmation of the variables in Quantum, both essential to defending the validity of test score interpretations [10]. These iterative procedures employed for validation combined both classical test theory (CTT) and Rasch analyses to document the psychometric qualities of Quantum [34, 35].

**Validation Study Sample**

In 2012, 137 pre-licensure nursing programs throughout the United States were notified of this validation study and its requirements via email. The invitation was open to Board of Nursing approved LPN/LVN, ADN, and BSN nursing programs who use simulation in any one of its core pre-licensure nursing courses. Interested nursing programs had to have access to a simulation laboratory, and a willingness to designate a point of contact of faculty, and support staff. All types of schools and program levels with comparable clinical course curricula, and demographic data that represented a diverse student population were selected. One specific criterion was for students enrolled in, or who just completed a core pre-licensure nursing course. After a field-test participation conference call with interested academic stakeholders, 14 nursing programs participated from geographically diverse areas, namely the South (71%), Northeast (7%), West (14%), and Midwest (7%) as shown in Table 1.

|            | BSN(4) | ADN(5) | LPN/LVN(5) |
|------------|--------|--------|------------|
| Health Assessment | 116    | 126    | 0          |
| Fundamentals   | 109    | 140    | 117        |
| Medical/Surgical | 105    | 111    | 135        |
| Obstetrics     | 102    | 108    | 140        |
| Pediatrics     | 103    | 105    | 131        |
| Mental Health  | 101    | 107    | 116        |
| Leadership     | 93     | 32     | 0          |

Table 1: Frequency Distribution of Sample by Core Pre-Licensure Nursing Course

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Reliability heading, reflecting a high degree of inter-rater agreement as detailed under the became more comfortable with each use. Equivalence estimates scheduled as requested. Faculty found the Tablet intuitive and training were provided with an online tutorial to access before the tutorial to reinforce their training. Instructors not present at rater screen Tablet technology and were given access to the online training set up for their specific use. The tablet technology was designed to ensure standardization. To maximize scoring consistency, all administration of the field test were provided to each school to ensure consistency.

Procedure
Faculty training, simulation set-up, and staff support prior to the administration of the field test were provided to each school to ensure standardization. To maximize scoring consistency, all instructors involved were trained in the use of Quantum’s touch screen Tablet technology and were given access to the online tutorial to reinforce their training. Instructors not present at rater training were provided with an online tutorial to access before the first test administration. Subsequent rater training webinars were scheduled as requested. Faculty found the Tablet intuitive and became more comfortable with each use. Equivalence estimates reflect a high degree of inter-rater agreement as detailed under the heading, Reliability, and shown in Table 3, column labelled ICC.

Student nurses who volunteered were assigned a time and date to perform the associated clinical scenario. Two instructors, serving as raters, used two Android Tablets and logged into their previously created accounts. Their test administration schedules were listed on the Tablet.

At the designated test time, a student arrived and completed the security protocol by verifying his or her identity with a picture, signature, and voice pattern. Each student was given a ten-minute preparation period to read the in-App scenario of the patient’s situation to be managed, and took notes on flow sheets. The preparation period was followed by a 20-minute performance period when both instructors assessed the student’s performance independently using the evaluation criteria on the in-App rating sheet specific to the scenario being tested. At the end of the performance period, the student completed a post-simulation attitudinal survey regarding his or her simulation experience.

Data collection
Data collection strictly followed the ethical standards of the participants’ schools. Data collection combined with field tests is called a validation study [11]. Field test schedules used the laws of parsimony to ensure data connectivity.

Data analysis
CTT approaches [36] and Rasch measurement models [37, 38] were applied to the data using SPSS version 16 [39], Winsteps (version 3.55) and Facets (version 3.47) programs to examine a number of validity aspects of Quantum [40, 41]. These measurement approaches were used to verify that the evaluation criteria making up each subdomain in a clinical scenario were underpinned by a single construct; whether the rating scale functions well; whether there was good targeting between the evaluation criteria and student abilities; whether clinical scenarios were sensitive enough to detect changes in student test scores following intervention; whether major sources of error variance were addressed; whether the evaluation criteria met the measurement criteria of invariance for student test scores; whether the value implications of test score interpretations as a source of action; and to what degree can qualitative meaning be assigned to quantitative measures. Only the core evaluation criteria common to all RN and LPN/LVN participating programs were analyzed in this validation study.

Results
The validity of an intended interpretation of test scores relies on all available evidence [10]. As such, rigorous evaluation statistics regarding evidence relevant to the validity aspects of Quantum follow.

Rating Scale Analysis
Quantum relies on the assumption that instructors will evaluate student performances using the particular criteria on the SME designed 5-point scale ranging (1 = Unacceptable performance to 5 = Superior performance) [10]. Empirical evidence validated a dichotomous scoring structure after subsequent analyses. Consequently, an interval measurement scale and a dependable scoring structure was developed. The interval measurement scale has three distinct features: (1) demonstrates one thing is bigger than the other; (2) determines how much bigger; and (3) lends itself to mathematical computations [42]. These interval measures may then be used in subsequent statistical analyses that assume an interval scale.

In order to address the substantive aspect of validity, empirical evidence shown in Figure 1 and Table 2 relates to the optimal number of rating scale categories for the target construct (i.e., clinical competency).

Figure 1. Probability Curves of 5-Point Rating Scale

Initial scale development assumed that the rating scale was hierarchical, but it failed to produce clear conclusions as depicted in Figure 1, evidence signaling a need to collapse the rating scale structure. In Figure 1, notice at no point was category 2 (Inconsistent) the most likely category to be observed. It can be seen that categories 3 (Effective) and 4 (Highly Effective) represent a narrow range of real performance. Applying Linacre’s (2004) guidelines for interpreting Rasch model indices, in column (2) labelled count on Table 2, there were large frequency counts, indicating stable estimates [43]. The shape of each rating scale distribution signaled aberrant rating category usage.
Table 2: Statistics for the Rating Categories by Clinical Scenario (continued)

| Course               | (1) Rating Category | (2) Count | (3) % | (4) Obs Avg | (5) Exp Avg | (6) Outfit | (7) Step Calib | (8) Monotonically Increase |
|----------------------|---------------------|-----------|-------|-------------|-------------|------------|-----------------|---------------------------|
|                      | Fundamentals        |           |       |             |             |            |                 |                           |
|                      | Unsatisfactory      | 244       | 17%   | -1.28       | -1.37       | 1.00       | None           |                           |
|                      | Inconsistent        | 187       | 13%   | -0.36       | -0.59       | 1.12       | -1.57          |                           |
|                      | Effective           | 230       | 16%   | -0.13       | 0.22        | 0.73       | -0.46          | 1.11                      |
|                      | Highly Effective    | 244       | 17%   | 1.02        | 1.07        | 0.95       | 0.17           | 0.63                      |
|                      | Exceptional         | 532       | 37%   | 3.24        | 2.15        | 1.15       | 1.40           | 1.23                      |
|                      | Medical/Surgical    |           |       |             |             |            |                 |                           |
|                      | Unsatisfactory      | 218       | 14%   | -1.48       | -1.53       | 1.00       | None           |                           |
|                      | Inconsistent        | 172       | 11%   | -0.42       | 0.62        | 1.25       | -2.48          |                           |
|                      | Effective           | 374       | 24%   | -0.18       | 0.37        | 0.95       | -1.05          | 1.43                      |
|                      | Highly Effective    | 343       | 22%   | 1.63        | 1.59        | 0.89       | -0.66          | 0.39                      |
|                      | Exceptional         | 452       | 29%   | 2.77        | 2.78        | 1.00       | 2.72           | 3.38                      |
|                      | Women's Health      |           |       |             |             |            |                 |                           |
|                      | Unsatisfactory      | 1626      | 14%   | -1.21       | -1.26       | 1.01       | None           |                           |
|                      | Inconsistent        | 2787      | 24%   | -0.74       | -0.65       | 1.16       | -1.52          |                           |
|                      | Effective           | 3368      | 29%   | -0.09       | 0.09        | 1.09       | -0.52          | 1.00                      |
|                      | Highly Effective    | 2555      | 22%   | 1.83        | 1.79        | 1.03       | 0.24           | 0.76                      |
|                      | Exceptional         | 1278      | 11%   | 2.32        | 2.34        | 1.00       | 2.05           | 1.81                      |
|                      | Pediatrics          |           |       |             |             |            |                 |                           |
|                      | Unsatisfactory      | 188       | 16%   | -0.95       | -1.10       | 1.01       | None           |                           |
|                      | Inconsistent        | 270       | 23%   | -0.13       | -0.22       | 1.13       | -1.87          |                           |
|                      | Effective           | 211       | 18%   | 0.06        | 0.11        | 0.99       | -1.03          | 0.84                      |
|                      | Highly Effective    | 387       | 33%   | 1.40        | 1.36        | 0.98       | -0.40          | 0.63                      |
|                      | Exceptional         | 117       | 10%   | 2.64        | 2.65        | 1.02       | 1.43           | 1.83                      |
|                      | Mental Health       |           |       |             |             |            |                 |                           |
|                      | Unsatisfactory      | 227       | 18%   | -1.63       | -1.69       | 1.00       | None           |                           |
|                      | Inconsistent        | 290       | 23%   | -0.53       | -0.45       | 1.02       | -1.43          |                           |
|                      | Effective           | 428       | 34%   | 0.02        | 0.07        | 1.00       | -0.61          | 0.82                      |
|                      | Highly Effective    | 214       | 17%   | 1.63        | 1.67        | 1.01       | 0.10           | 0.71                      |
|                      | Exceptional         | 101       | 8%    | 2.71        | 2.68        | 1.00       | 1.92           | 1.82                      |

As seen in column (4) labelled observed average in Table 2, increasing amounts of student clinical competency corresponds to increasing probabilities of the student being observed in higher rating categories of the rating scale [44]. However, the advances across rating categories were uneven, for instance, in Health Assessment-RN: -1.51 to -0.62 logits (a jump of 2.13), and then from -0.07 to 0.68 (a jump of 0.75). This was indicative of problems with instructors applying the appropriate rating category to the student’s performance across evaluation criteria.

A comparison between columns (4) labelled observed average and (5) expected average in Table 2, specifically in the Effective category were contradictory to the intended use of the rating scale in 5 out of 7 RN courses and 3 out of 5 LPN/LVN courses, further evidence signaling a need to collapse this rating category to improve measure stability and accuracy [45].

Column (6) labelled outfit on Table 2 shows all rating categories for each clinical scenario had unweighted mean-squared fit statistics ranging between 0.72 and 1.35 for RN and 0.73 and 1.25 for LPN/LVN. This satisfied Linacre’s guideline as the majority of the rating category fit statistics were around 1.0 and all were less than 2.0.

Column (7) labelled step calibration on Table 2 shows where the probability curves intersect depicted in Figure 1. As shown, advancement from one-step to the next was between 0.26 and 3.50 logits for RN and 0.39 and 3.38 logits for LPN/LVN, further evidence for combining the rating categories to have wider practical meaning since the advancement was smaller than 0.81 logits for 5-point scale [46].
Table 2: Statistics for the Rating Categories by Clinical Scenario

| Course        | (1) Rating Category | (2) Count | (3) %  | (4) Obs Avg | (5) Exp Avg | (6) Outfit | (7) Step Calib | (8) Monotonically Increase |
|---------------|---------------------|-----------|--------|-------------|-------------|------------|----------------|---------------------------|
| Health Assessment | Unsatisfactory   | 959       | 12%    | -1.51       | -1.57       | 1.00       | None           |                           |
|                | Inconsistent       | 799       | 10%    | -0.62       | -0.53       | 1.28       | -2.26          |                           |
|                | Effective          | 1998      | 25%    | -0.07       | 0.04        | 0.92       | -0.19          | 2.07                      |
|                | Highly Effective   | 1279      | 16%    | 0.68        | 0.57        | 0.96       | 0.56           | 0.75                      |
|                | Exceptional        | 2957      | 37%    | 1.67        | 1.73        | 1.01       | 2.49           | 1.93                      |
| Fundamentals   | Unsatisfactory     | 1000      | 13%    | -1.31       | -1.36       | 1.00       | None           |                           |
|                | Inconsistent       | 846       | 11%    | -0.53       | 0.45        | 1.20       | -1.68          |                           |
|                | Effective          | 1846      | 24%    | -0.13       | 0.22        | 1.03       | -0.09          | 1.59                      |
|                | Highly Effective   | 1231      | 16%    | 0.54        | 0.44        | 1.03       | 0.17           | 0.26                      |
|                | Exceptional        | 2769      | 36%    | 1.25        | 1.30        | 1.00       | 1.40           | 1.23                      |
| Medical/Surgical | Unsatisfactory   | 807       | 18%    | -1.83       | -1.59       | 1.00       | None           |                           |
|                | Inconsistent       | 717       | 16%    | -0.60       | -1.29       | 1.20       | -2.50          |                           |
|                | Effective          | 986       | 22%    | -0.09       | 0.09        | 1.35       | -1.03          | 1.47                      |
|                | Highly Effective   | 852       | 19%    | 1.80        | 1.79        | 1.25       | -0.50          | 0.53                      |
|                | Exceptional        | 1121      | 25%    | 3.24        | 3.22        | 1.00       | 3.00           | 3.50                      |
| Women's Health | Unsatisfactory     | 1078      | 19%    | -1.16       | -1.25       | 1.00       | None           |                           |
|                | Inconsistent       | 737       | 13%    | -0.40       | -0.27       | 1.27       | -1.23          |                           |
|                | Effective          | 1305      | 23%    | -0.18       | 0.37        | 0.72       | -0.41          | 0.82                      |
|                | Highly Effective   | 851       | 15%    | 0.72        | 0.67        | 1.04       | 0.19           | 0.60                      |
|                | Exceptional        | 1702      | 30%    | 1.69        | 1.70        | 1.03       | 1.64           | 1.45                      |
| Pediatrics     | Unsatisfactory     | 273       | 18%    | -0.79       | -1.01       | 0.97       | None           |                           |
|                | Inconsistent       | 152       | 10%    | -0.07       | 0.04        | 1.12       | -1.85          |                           |
|                | Effective          | 288       | 19%    | 0.02        | 0.10        | 1.06       | -0.63          | 1.22                      |
|                | Highly Effective   | 258       | 17%    | 0.85        | 0.87        | 1.01       | -0.07          | 0.56                      |
|                | Exceptional        | 546       | 36%    | 1.85        | 1.82        | 1.00       | 2.48           | 2.55                      |
| Mental Health  | Unsatisfactory     | 257       | 18%    | -1.67       | -1.73       | 1.00       | None           |                           |
|                | Inconsistent       | 200       | 14%    | -0.83       | -0.83       | 1.15       | -1.40          |                           |
|                | Effective          | 328       | 23%    | 0.00        | 0.05        | 0.95       | -0.24          | 1.16                      |
|                | Highly Effective   | 242       | 17%    | 1.06        | 1.02        | 0.73       | 0.17           | 0.41                      |
|                | Exceptional        | 399       | 28%    | 1.91        | 1.94        | 1.04       | 1.64           | 1.47                      |
| Leadership     | Unsatisfactory     | 174       | 19%    | -1.21       | -1.26       | 1.00       | None           |                           |
|                | Inconsistent       | 138       | 25%    | -0.53       | -0.68       | 1.20       | -1.85          |                           |
|                | Effective          | 230       | 25%    | -0.02       | 0.10        | 1.18       | 0.66           | 1.19                      |
|                | Highly Effective   | 165       | 18%    | 0.85        | 0.87        | 1.10       | 0.09           | 0.75                      |
|                | Exceptional        | 211       | 23%    | 1.85        | 1.82        | 1.03       | 1.72           | 1.63                      |

Dimensionality Analysis
Researchers investigated whether or not there was more than one variance component explaining the structure of the performance assessment data. Table 3 showed that the eigenvalues of the second component from the SPSS Factor Analysis routines were less than 1.0 for all clinical scenarios [47, 48]; meaning only one component accounted for considerably more variance than the remaining components. The first factor had maximum variance which ranged from 91.67% for the Medical Surgical-RN Advanced scenario to 76.95% for Leadership-RN Basic scenario. The second and all following factors explained smaller and smaller portions of the variance and were all uncorrelated with each other.
This evidence supported that one component or latent factor, "clinical competency," exerts fundamental influence on the observed variables in Quantum. Clinical competency is latent in the sense that it is assumed to actually exist in the student’s integrated KSAs and clinical reasoning ability, but cannot be measured directly. However, it does exert influence on the student’s performance to the evaluation criteria that constituted the scenario’s rating sheet.

These results indicate the sets of evaluation criteria within and between each subdomain can be combined into a single construct – clinical competency – consistent with the scoring structure envisioned by the SMEs. This unidimensionality evidence results in additivity [49]. Additivity refers to the properties of the measurement units. Smith (2002) pointed out these units are called logits (logarithm of odds) and have the desirable property of maintaining the same size (i.e., interval) over the entire continuum [50]. Since the combination of parameters is additive, this implies that Quantum’s parameters (e.g., instructor severity, evaluation criterion difficulty, student ability, and rating scale thresholds) can be expressed as real numbers on a common interval scale.

**Content Validation**

Evidence based on test content featured logical and empirical analyses of the adequacy with which the test content represented the content domain and the relevance of the content domain to the proposed interpretation of test scores [10]. Content relevance, technical quality, and representativeness derived evidence in support of content validity [51].

**Content Relevance**

Content relevance was derived from SME’s logical analysis of current references to support the test development process. The Process Model involved SMEs by core nursing course in all test development phases to ensure that each clinical scenario’s content was relevant with adequate breadth and depth.

**Technical Quality**

Item analyses of the technical quality of the evaluation criteria was addressed via index of difficulty and index of discrimination in CTT or fit statistics in Rasch. Table 3 showed that all Infit mean square (MnSq) statistics were below 1.40 and greater than 0.65. These values of MnSq statistics were reasonably close to the value of 1, the expected value of the MnSq statistics when there is perfect fit between data and model [45], indicating that the data had good fit with the Rasch model for all clinical scenarios.

| Table 3: Goodness of Fit to the Rasch Model, Eigenvalues and Reliability Estimates |
|-----------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Course                                     | RN              | LPN/LVN         |                 |                 |                 |                 |                 |
|                                             | Range of infit MnSq | Eigenvalue of the 2nd principal component | # of items | KR-20 | ICC | Range of infit MnSq | Eigenvalue of the 2nd principal component | # of items | KR-20 | ICC |
| Health Assessment                          |                 |                 |                 |                 |                 |                 |                 |
| Basic                                      | 0.66-1.38       | 0.9615          | 41              | 0.76            | 0.92            | 0.65-1.40       | 0.9131          | 46              | 0.79            | 0.82            |
| Intermediate                               | 0.77-1.37       | 0.9326          | 110             | 0.89            | 0.97            | 0.72-1.38       | 0.9012          | 61              | 0.81            | 0.82            |
| Advanced                                   | 0.81-1.27       | 0.9185          | 119             | 0.90            | 0.99            | 0.74-1.36       | 0.9006          | 95              | 0.83            | 0.87            |
| Fundamentals                               |                 |                 |                 |                 |                 |                 |                 |
| Basic                                      | 0.66-1.40       | 0.9452          | 43              | 0.77            | 0.94            | 0.69-1.40       | 0.8611          | 95              | 0.84            | 0.91            |
| Intermediate                               | 0.72-1.39       | 0.9295          | 56              | 0.80            | 0.95            | 0.72-1.38       | 0.9012          | 61              | 0.81            | 0.82            |
| Advanced                                   | 0.74-1.36       | 0.9011          | 92              | 0.83            | 0.90            | 0.74-1.36       | 0.9006          | 95              | 0.83            | 0.87            |
| Medical/Surgical                           |                 |                 |                 |                 |                 |                 |                 |
| Basic                                      | 0.69-1.40       | 0.8667          | 92              | 0.83            | 0.87            | 0.69-1.40       | 0.8611          | 95              | 0.84            | 0.91            |
| Intermediate                               | 0.72-1.34       | 0.8555          | 110             | 0.87            | 0.94            | 0.72-1.31       | 0.8497          | 113             | 0.87            | 0.94            |
| Advanced                                   | 0.77-1.20       | 0.8263          | 126             | 0.89            | 0.83            | 0.82-1.21       | 0.8281          | 128             | 0.89            | 0.99            |
| Women’s Health                             |                 |                 |                 |                 |                 |                 |                 |
| Basic                                      | 0.63-1.34       | 0.9176          | 66              | 0.75            | 0.82            | 0.65-1.34       | 0.8828          | 69              | 0.76            | 0.84            |
| Intermediate                               | 0.68-1.29       | 0.8936          | 94              | 0.81            | 0.87            | 0.68-1.29       | 0.8601          | 97              | 0.91            | 0.89            |
| Advanced                                   | 0.72-1.27       | 0.8740          | 110             | 0.86            | 0.88            | 0.72-1.27       | 0.8491          | 113             | 0.97            | 0.90            |
| Pediatrics                                 |                 |                 |                 |                 |                 |                 |                 |
| Basic                                      | 0.71-1.36       | 0.9364          | 56              | 0.75            | 0.87            | 0.71-1.36       | 0.9577          | 58              | 0.79            | 0.83            |
| Intermediate                               | 0.72-1.33       | 0.9222          | 71              | 0.77            | 0.88            | 0.72-1.33       | 0.9295          | 73              | 0.82            | 0.87            |
| Advanced                                   | 0.82-1.28       | 0.9037          | 100             | 0.84            | 0.90            | 0.82-1.28       | 0.9144          | 102             | 0.85            | 0.89            |
| Mental Health                              |                 |                 |                 |                 |                 |                 |                 |
| Basic                                      | 0.67-1.40       | 0.9291          | 66              | 0.81            | 0.85            | 0.66-1.40       | 0.9302          | 67              | 0.76            | 0.81            |
| Intermediate                               | 0.70-1.36       | 0.9037          | 89              | 0.86            | 0.84            | 0.70-1.34       | 0.9095          | 89              | 0.82            | 0.82            |
| Advanced                                   | 0.72-1.34       | 0.8906          | 114             | 0.88            | 0.84            | 0.72-1.30       | 0.8926          | 114             | 0.83            | 0.82            |
| Leadership                                 |                 |                 |                 |                 |                 |                 |                 |
| Basic                                      | 0.70-1.36       | 0.9785          | 48              | 0.85            | 0.79            | 0.70-1.36       | 0.9897          | 48              | 0.85            | 0.79            |
| Intermediate                               | 0.79-1.24       | 0.9556          | 65              | 0.89            | 0.91            | 0.79-1.24       | 0.9599          | 65              | 0.89            | 0.91            |
| Advanced                                   | 0.87-1.19       | 0.9321          | 71              | 0.90            | 0.83            | 0.87-1.19       | 0.9321          | 71              | 0.90            | 0.83            |
**Content Representativeness**

Figure 2 showed an example of good content representativeness for clinical scenario – Nurse Leadership and Management of Patient Care: a wide dispersion of evaluation criteria relative to the student measures; and no content gaps. Gaps in content representativeness were examined empirically by using the unique ordering of evaluation criterion difficulties and their individual standard errors as suggested by Smith (2001) [42]. Content representativeness analysis was repeated for each clinical scenario by course to ensure student ability distribution coverage by evaluation criteria.

**Responsiveness**

Figure 2 reflected two features: a floor effect occurring for this sample’s ability distribution and a wide dispersion of evaluation criteria calibrations beyond the highest student measure indicating that this clinical scenario has the capacity to be responsive to an intervention. This illustrated how Quantum is equipped to compare a student’s test score before and after the intervention to support the external aspect of validity [52].

**Reliability**

As recognized by the Standards [10], the level of reliability of test scores has implications for the validity of test score interpretations. Table 3 showed two reliability estimates for equivalence and internal consistency. An appropriate technique to express equivalence (inter-rater agreement) is an intra-class correlation (ICC) based on empirical evidence from the Rating Scale Analysis. Internal consistency refers to measurement error introduced by variations in evaluation criteria content and quality; the validity evidence supports the Kuder–Richardson Formula 20 (KR-20) as a measure for dichotomous items.

For all clinical scenarios, inter-rater agreement estimates were excellent according to research published by Cicchetti in 1994 with ICC estimates ranging from 0.79 to 0.99 [53]. An ICC estimate lower than 0.70 indicates the instructors have a substantial amount of disagreement among them. Continuing, internal consistency estimates using KR-20 ranged from acceptable (0.75) to excellent (0.97) according to research published by Salvucci, Walter, Conley, Fink, and Saba in 1997 [54]. Internal consistency estimates lower than 0.70 are considered questionable. The KR-20 for LPN/LVN Women’s Health – Advanced clinical scenario showed very high reliability (0.95 or higher) indicating that several evaluation criteria were redundant, but deemed necessary by the SMEs.

**Invariance**

Analyses on student measure invariance over evaluation criteria were conducted and presented in Table 3. As the clinical scenario unfolded new evaluation criteria were added. There was improved fit between the data and Rasch model (MnSq values reasonably close to 1), which yielded the same student measures within measurement error. The results indicated that previously obtained student measures are generalizable over the new evaluation criteria.

**Consequential**

The application of cut scores has a direct relationship with the consequential aspect of validity [46]. Quantum features summative feedback that would include a cut score to distinguish between performance levels achieved with a course grade; and formative feedback with the intent to improve learning and future performance [15, 27]. The development of competence depends upon students receiving formal feedback as part of a continuous assessment cycle [55]. Quantum provides definitive feedback and customized remediation linked to the evaluation criteria based on content validity evidence previously described to enable students to identify their strengths and weaknesses, and shows them how to improve where weak or build upon what they do best. Definitive feedback on current student performance is a crucial part of the debriefing process [56].

**Discussion**

Simulation and the diversity of nursing care has created a need for a standardized, performance assessment test to measure a student performance across all three domains of learning, just as standardized tests by ATI, HESI, and Kaplan are needed to measure knowledge at the end of each semester. These results provide important information about the usefulness of information provided by Quantum.

One, many researchers treat assigned ratings as interval measurement scales, but we were able to empirically validate the
Two, Quantum’s capability to estimate and adjust for instructor differences in deriving student test scores is an advantage over other performance assessment tests because the CTT method of basing decisions for rated performances directly on raw scores is unfair to students who encounter severe instructors. Meaning, CTT approaches such as percentage correct, Kappa, and G-theory do not address the issue of construct validity and offer no solution to the problem of obtaining error-adjusted test scores. As Banerji (2000) noted, the lack of agreement on tasks can be identified by CTT analysis but not accounted for in deriving student test scores, a factor that affects test score validity [34]. The capability to estimate and adjust for instructor differences with Quantum is thus an important advantage to objectively measuring a student’s clinical competence.

Three, in order to comply with measurement best practices [10], after each test administration equivalence and internal consistency reliability estimates will be calculated to address the major sources of error variance (e.g., instructors, evaluation criteria) in Quantum that may undermine test score interpretation. Equivalence and internal consistency reliability estimates will be reported on the Administrative Report to provide nurse educators with confidence to interpret students’ test scores knowing the reliability of measures.

Four, Quantum can provide diagnostic statistics to detect a variety of rater effects outlined by Gaberson, Oermann, and Shellenbarger (2015) [59]. For example, a rater bias analysis can be run to detect patterns in data that may be indicative of differential instructor functioning over time. This analysis may appeal to academic stakeholders who need to employ large numbers of clinical adjunct instructors.

Finally, based on relevant validity evidence, researchers were able to demonstrate the suitability of test scores derived from Quantum for a given decision-making context in order to provide nurse educators with a valid option beyond multiple-choice exams [2].

Limitations
Limitations of this study include collecting sufficient statistics prior to shifting from two instructors to one instructor for each student performance. In addition, instructors’ suggested a toggle switch to move easily between subdomains and evaluation criteria on the in-App rating sheet and an application that functions on the latest iPad.

Implications for Nursing Education
Quantum’s outcome assessment data addresses both the student success and learning gains that will result from simulation education. Instructors can observe and evaluate students “soft” benefits, such as their ability to: use nursing process as a means of decision making; and synthesize the information from the scenario with nursing theory in preventive health care.

Student Comments
Regarding learning gains and success, students liked receiving feedback on their performances in simulation. Students reported the value of this learning experience, which spoke to engagement: “…it helped me to think about what I should be looking for ahead of time;” “…it helped me bring it all together;” and “…helped me to think critically.” With definitive feedback, the greater the potential for learning [60], and it is possible to pull apart key pieces during debriefing that can serve as building blocks to teach students how to think like a nurse [56].

Score reports are particularly relevant after passing NCLEX and graduating. Score reports can be used by graduate nurses in their professional portfolio to support any claims made on their resumes or in interviews to prove their past achievements. Overall, definitive feedback helps promote student learning, allows the evaluation of students and course curricula, and permits documentation of clinical competence stages [61].

Conclusion
The discipline of nursing is a hands-on profession requiring an unbiased, instructor-mediated, performance assessment test to measure a student’s performance objectively. Moving beyond multiple-choice tests, Quantum addresses many challenges and issues inherent in a performance assessment measuring student competency. It provides construct validity evidence and offers a solution to obtaining error-adjusted test scores. The introduction of Quantum removes the barriers related to time and workload in an academic environment required to develop psychometrically sound, performance assessment tests. Thereby, alleviating the burden on faculty or facilitators whose responsibility it is to evaluate a student’s performance, differentiate competency, and assign grades. This study supports the use of Quantum as an instructor-mediated, performance assessment test, which consistently measures learner competence and provides a holistic view of the student in either formative or summative experiences. Quantum offers faculty confidence in consistent, objective evaluation ensuring that graduates are safe and competent.

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