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Development of Quantitative Research Skills Competencies to Improve Doctor of Philosophy Nursing Student Training

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ABSTRACT

Background: Competency-based education is essential to prepare future nurse scientists to compete in the world of data-driven science. Yet, few schools of nursing have developed core competencies that guide quantitative research instruction. We described development of new competency-based curriculum in quantitative research for doctor of philosophy (PhD) nursing students. **Method:** We assessed quantitative research methods curricula from among top National Institutes of Health-ranked research-intensive Schools of Nursing. At the University of California, San Francisco School of Nursing, we administered a survey to PhD students and alumni, and interviewed program faculty about current quantitative courses and perceived needs. A committee of PhD faculty framed competencies. **Results:** Core competencies for quantitative methods training were developed. Faculty modified courses to align with core competencies. This allowed an outcome-based approach to design, implement, and evaluate coursework. **Conclusion:** This effort at generating core quantitative research skills competencies could be useful for other nursing schools interested in redesigning PhD training programs. [*J Nurs Educ.* 2018;57(8):483-488.]

Nursing is undergoing a generational transformation. With the constant changes in health care policy, such as the Affordable Care Act, the widespread application of electronic health records and the increase in computational power to analyze large data sets, nurses engaged in research need to be well versed in a comprehensive set of quantitative methods. The evolving health care delivery system has shifted, in part, from focusing on modifying individual behaviors to reducing health disparities and improving population health (Institute of Medicine [IOM], 2010). In this rapidly changing environment, nurses need quantitative research skills to develop new metrics, to navigate and interpret large electronic health record databases, to use data analytics, such as computational biology and machine learning, and to advance clinical and population health (Eckardt et al., 2017). Most importantly, nurses need quantitative skills to advance the unique discipline of nursing. Nurses provide evidence-based, cost-effective, quality care and are expected to generate and test new clinical and population-level interventions that improve health outcomes (American Association of Colleges of Nursing [AACN], 2006a). To be responsive to these changes, Doctor of Philosophy (PhD) nursing programs need curriculum on advanced quantitative methods that will prepare nurse scholars to conduct timely rigorous scientific research (AACN, 2006a,

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2010; Bellack, 2014). Future cohorts of PhD-prepared nursing educators need to work across disciplines (Henly et al., 2015) and to lead scientific discovery for nursing care (Breslin, Sebastian, Trautman, & Rosseter, 2015).

To meet mounting research demands, the field of nursing is called on to increase the number of researchers. *The Future of Nursing*, a seminal report jointly sponsored by the IOM and Robert Wood Johnson Foundation, recommended that nursing programs double the number of nurses with a doctorate by 2020 (IOM, 2010). To increase the number of doctorally prepared nurse faculty and researchers, 10% of all U.S. nursing baccalaureate graduates would need to matriculate into higher education within 5 years of graduation (IOM, 2010).

The nursing doctorate emerged in response to a perceived need for a theoretical and methodological approach that is unique to nursing (Scheckel, 2017). There are several doctoral programs for nurses, including the doctorate in education, the doctorate in nursing science, the PhD and the more recently established the doctorate in nursing practice (DNP). Briefly, nearly a century ago, nursing schools in the United States began offering doctorates in education, but it was not until the second half of the 20th century that doctoral programs (doctorate in nursing science and PhD) were offered in nursing (Ketefian, Neves, & Gutiérrez, 2001). The doctorate in nursing science degree has been essentially replaced by the PhD degree in many institutions; currently most doctoral programs in nursing science award the PhD degree (National Academies of Sciences Engineering and Medicine, 2011). In 2004, a new doctorate, DNP, emerged and programs have multiplied across the United States.

The IOM recommendation to double nurses with doctorate remains agnostic as to whether this doctorate is a DNP or a PhD. The popularity of the DNP has stimulated the need to reexamine the distinct role and the curriculum of the PhD research degree. The PhD program differs fundamentally from the DNP program (Ketefian & Redman, 2015; Melnyk, 2013), which provides advanced preparation in the foundations of leadership, health policy, and advanced nursing practice in specialty areas. The DNP is a practice degree, akin to the doctorate of medicine or the doctorate of pharmacy, and does not focus deeply on research methods, which can be a disadvantage when new graduates compete for academic research positions (AACN, 2006b). New and well-established nursing doctorate programs around the country are undergoing a process of self-assessment and transformation to consider the unique goals of their programs. One of the goals of this process is to be responsive to the needs embedded in health care delivery transformation toward population health (Fawcett & Ellenbecker, 2015) and "big data" (Henly et al., 2015). Another is to provide educators with clear guidelines to advise prospective students about which doctoral degree meets their career goals—the PhD as the research degree, or the DNP, as the clinical or leadership degree (Scheckel, 2017). The differentiation of these degrees means faculty must reimagine PhD training programs, so they will deliver the highest caliber of research training that prepares their students for academic research-track faculty positions (AACN, 2006a; Henly et al., 2015; Melnyk, 2013).

A successful training program hinges on the development of distinct competencies that students are expected to meet at graduation. Frank et al. (2010) defined competency in medical education as "an observable ability of a health professional, integrating multiple components such as knowledge, skills, values, and attitudes" (p. 641). Competencies can narrow the gap between education and practice to improve patient outcomes, clinical judgement, and accountability of learners in nursing (Scott Tilley, 2008). In educational programs, a defined set of core competencies allow educators to develop courses that address these competencies. Competencies should be measurable and facilitate learning progress for individual learners. Hence, course curricula should be able to demonstrate how they address a comprehensive framework of competencies (Frank et al., 2010). This allows an outcome-based approach to design, implement, assess, and evaluate a program, such as a doctoral program in nursing. All doctoral nursing students should demonstrate fundamental competencies in quantitative research methods. We focused on mapping out quantitative skills needed for successful PhD nursing programs. Competencies in other areas, such as qualitative research methods or the ethical conduct of research are equally important but not a focus of our work.

To prepare students for careers as nurse research scientists, University of California, San Francisco (UCSF) School of Nursing (SON) faculty developed a comprehensive plan to evaluate its PhD quantitative methods training program. Starting in 2014, a faculty taskforce of PhD program educators was formed to achieve the following aims:

- To develop core competencies for quantitative research training that expand on the AACN criterion for doctoral programs in nursing (AACN, 2010).
- To identify overlaps and gaps in content of current quantitative methods courses and propose a plan to address these gaps.
- To review and evaluate quantitative methods courses, both intramural and extramural.
- To propose modifications to current quantitative methods courses at UCSF.

The SON Doctoral Program Council then refined the competencies and implemented recommendations. Here we describe the methods we employed to achieve the main aims, the results of our comprehensive self-assessment and the success of implementation of the proposed changes. This process may be useful for other nursing schools interested in redesigning PhD training programs.

Because the recent AACN recommendations do not provide sufficient guidance about advanced research methods training of nurse scholars, we set out to develop comprehensive standards that our students are expected to meet. The single core curriculum element that relates to the focus of our curricular evaluation is the expectation that students have "advanced research design and statistical methods" (AACN, 2010, p. 5). In addition to describing our methods, we also share core competencies and other programmatic documents that we developed during this process. Our experience should serve to provide guidelines to other nursing academicians embarking on the redesign of their doctoral programs, guidelines that move beyond the AACN criterion.

METHOD

For 2 years, UCSF SON faculty underwent an evaluation of the PhD program including input from faculty, students, and alumni, and review of the curriculum at research-intensive SON. For background, the UCSF SON has offered PhD training since 1965. In 2016, UCSF SON had 56 enrolled students in the PhD nursing program (UCSF Office of Institutional Research, 2016). All doctoral students are required to take 2 years of foundational coursework, including theory development, philosophy of nursing science, and qualitative and quantitative research methods. Although UCSF SON offers both quantitative and qualitative research training programs, most students choose to focus on either qualitative or quantitative methods in their second year.

The comprehensive evaluation of the training program started with a creation of the taskforce, which included eight faculty members from UCSF SON who taught core courses in the quantitative research series. One doctoral student, one postdoctoral scholar, and four additional faculty members who taught statistics and research methods also participated in the discussion and reviewed the set of competencies. The committee brought in a consultant on quantitative curriculum methods training from the UCSF Department of Epidemiology and Biostatistics.

We divided the comprehensive self-assessment into four distinct phases. In the first phase, we appraised the status of the current quantitative research methods curriculum of the SON PhD program. We assessed student satisfaction with the quality of training through student course evaluations of the core courses, postqualifying examination surveys, and exit surveys during the prior 5 years. In addition, we reviewed quantitative research methods courses in the UCSF Department of Epidemiology and Biostatistics and the University of California, Berkeley School of Public Health. UCSF has a cooperative agreement with University of California, Berkeley and Stanford University: UCSF SON students can take additional courses at these institutions free of charge.

To supplement our analysis of student surveys from the first phase, in the second phase, we conducted an anonymous, online Qualtrics survey of all PhD students ranging from those who completed 2 years of foundational coursework to students who had graduated in the previous 2 years. This allowed us to see the evolution of needs across the spectrum of learners, including those who were working as postdoctoral scholars and junior faculty. The survey consisted of 22 closed-ended questions with free text boxes for additional comments for each question. We designed the survey to identify growing needs for courses and seminars on quantitative research methods, epidemiology, and advanced statistics. We asked students specifically about each of the 12 research and statistical methods courses offered in SON, additional courses taken in other schools, areas they would have liked to have explored more in-depth, and level of competence within those areas. The majority of UCSF SON faculty use SPSS® program for statistical training. The survey also attempted to capture increasing demands for adding statistical programs such as STATA®, SAS®, and R©, including more hands-on laboratory hours. This allowed us to further capture strengths and weaknesses of quantitative research training beyond that found in the first phase.

During the third phase, we conducted a purposive survey of the top 10 National Institute of Health-funded nursing schools with PhD degree programs across the United States (National Academies of Sciences Engineering and Medicine, 2011) to understand their training in quantitative research. We contacted deans or faculty in these schools and asked:

- If the programs had defined competencies for quantitative research.
- Whether the quantitative methods courses were taught by school of nursing faculty or in other schools such as public health, biostatistics, and psychology.
- PhD student ratios, number of PhD students enrolled each year, student funding, and time to completion.

We collected curricula and syllabi of quantitative research methods courses from course websites and discussed courses with faculty of record for additional information, as needed. Information was collected on both core and elective courses. We reviewed program websites and student handbooks. In addition to the above, we developed criteria to evaluate these programs including review of school-specific competencies and course descriptions and objectives for required biostatistics courses.

In the fourth phase, we reviewed our quantitative research methods course syllabi, compared ours to other schools' program syllabi and course content, and drafted a list of core research methods competencies. We viewed these competencies as the final benchmark of what all successfully matriculated students should know about quantitative research methods. All faculty who teach in the doctoral program vetted the competencies. The taskforce chair (L.M.T.) individually interviewed core biostatistics faculty to gain their feedback. We circulated several revisions of the competencies during the summer. We presented the final set of competencies, along with a final report, at the SON PhD faculty meeting in fall of 2014.

In the fifth phase, modifications to the competencies were completed by SON Doctoral Program Council based on recommendations from the taskforce. The council was charged with assessing whether quantitative research methods courses lined up with the competencies adopted by the school. We used the following steps to review the courses based on the competencies criterion:

- We reviewed all courses using a template.
- We conducted consultation sessions with core course instructors to discuss the results of these reviews.
- We held several Doctoral Program Council meetings to review the results.
- We made a final list of recommendations to realign coverage of main quantitative methods in required courses.

Two faculty members of the council independently evaluated the competencies for each assigned course based on the template criteria and discussed until we reached a consensus.

RESULTS

First Phase: Current Quantitative Research Methods Curricula in UCSF Doctoral Program

All SON PhD students in nursing, including students who pursued qualitative research, are required to take four quantitative research methods courses, equivalent to 15 quarter units

(equivalent to 10 semester units) in their first year. In the second year, nursing students who plan to conduct quantitative research take two additional required courses, equivalent to seven quarter units (equivalent to 4.7 semester units), that combine didactic learning with hands-on training in laboratories to expose students to advanced statistical methods, including nonparametric methods, model specification, handling missing data, and linear and logistic regression. Students can elect to take additional advanced quantitative methods in SON, including longitudinal and repeated measure studies, structural equation modeling or a course on machine learning in their second and third year. In addition to the core courses taught at the SON, students can take methods courses taught in the UCSF Program and at other professional schools at UCSF, University of California, Berkeley or Stanford University. Our analysis of multiple student surveys (course evaluations of the core courses, postqualifying examination surveys, and exit surveys during the past 5 years) showed that course content was variable, with some courses viewed as too "remedial" and others viewed as "lab-driven" and comprehensive. Students stated that survey courses, where experts discuss a statistical approach in one or two sessions "lacked sufficient depth" to allow the student to conduct that analytic approach independently. In course evaluations, students perceived the lack of hands-on laboratory sessions using statistical software programs as main weakness. Overall, students stated that they wanted practice with secondary data analysis using large data sets, biomedical informatics data interpretation and an understanding of applied machine learning algorithms. Finally, students wanted to improve their understanding of complex database management.

Second Phase: Online Survey of UCSF PhD Students

E-mail surveys were sent to 138 current and graduated students, with 127 successfully delivered (11 sent to inactive e-mails) and 78 responses (*response rate* = 61%). Many of the respondents were current doctoral students (n = 62) with the remaining being 16 recent graduates. Quantitative research track students had a higher rate of participation (59%) compared to qualitative students (24%). Of the current students who stated that they planned to use quantitative methods for their dissertation, 35% were collecting primary data, 29% were using secondary data, and 33% were using both. Three-quarters of the students completed or were planning to choose a three-page dissertation option.

Overall, students requested more in-depth statistical courses with hands-on practical training, either through the development of new courses, or the supplementation of existing courses with computer laboratory exercises. Sixty-eight percent of the students stated that they wanted more laboratory courses. Many students requested more laboratory courses and training on other statistical programs, such as Stata (67%), SAS (27%) and R (26%). Students requested new courses covering secondary data and big data (29%), advanced database management (27%), biomedical informatics (15%), digital health (14%), software programming (10%), and machine learning (5%).

Third Phase: Nursing School Doctoral Program Survey

Eight out of 10 schools (two public and six private) responded to the survey. Comparable to UCSF, two schools enrolled the most students, approximately 10 to 15 students per year. Our review of the curricula in other SONs identified that all surveyed peer schools offered a year-long training in epidemiology and quantitative research methods (three quarters or two semesters) in their PhD programs, with some schools requiring 2 years of training. For the most part, SON faculty taught epidemiology and research methods courses, although most biostatistics courses were taught by the faculty from other schools such public health, psychology, or business. Nursing schools located on a university campus with a school of public health had more courses available to nursing students, which allowed students to refine their own training. For example, nursing PhD programs at several schools allowed students to take statistics and advanced research methods courses at other campus schools to meet their dissertation needs. Contents of research methods courses ranged from research design, basic epidemiologic methods, measurement, and survey designs to more advanced methods.

Fourth Phase: Core Competencies in Quantitative Research Methods

Most of the peer schools we approached had not established core competencies for quantitative research methods for PhD training programs. Some schools stated that they relied on AACN doctoral program competencies but given the brevity of these competencies, it is questionable whether they are detailed enough to effectively assess quantitative research methods skills of graduating nursing scholars.

We developed competencies to assess student knowledge of main concepts, skills, and ability to apply them in practice (**Table A**; available in the online version of this article). The core competencies specific to quantitative research methods include eight domains: (a) research question formulation, (b) study design and sampling, (c) quantitative measurement, (d) bias and confounding, (e) data science in health, (f) statistical analysis, (g) synthesis, and (h) implementation science. We expect that all doctoral students in the quantitative research track will meet these core competencies by graduation. We will add advanced competencies as students choose to specialize research areas.

Fifth Phase: Mapping Competencies and Implementation of Change

The Doctoral Program Council conducted a review of the quantitative research method courses-based taskforce findings and mapped learning activities in each of the quantitative research methods courses with the competencies. Informed by course mapping, the council recognized that many of the competencies were met in multiple courses, but also identified needs for linkages between some courses to enhance student learning and for training in use of advanced statistical packages for big data. We made several recommendations to modify the curriculum. The recommendations included:

- Develop a course to link research methodology and biostatistics content for first year students.
- Modify advanced quantitative research methods courses.
- Develop laboratories that use other statistical packages, such as Stata, SAS, and R.
- Develop electives using big data sets and machine learning.

The SON Doctoral Program Council reviewed the list of

competencies, approved them and set expectations for students to achieve these competencies.

DISCUSSION

To our knowledge, this is the first report on a process of a comprehensive evaluation to develop core competencies for quantitative research methods, map these competencies to existing courses, and leverage competencies to develop a new curricular roadmap for nursing PhD students. Our process may assist other schools in evaluating and developing rigorous quantitative research methods courses. Through this rigorous 2-year process, we identified several successes and gaps; these lessons could benefit other schools endeavoring to develop robust quantitative research training programs. This evaluation led us to two main conclusions. First, there is an urgent need to develop sufficiently detailed competencies in quantitative methods training to assess the contribution of each course to the overall program. Second, nursing programs should create a PhD roadmap specific to quantitative research to prepare scholars to advance the field of nursing research.

Competencies

The benchmarks of this comprehensive evaluation were based on a set of competencies that were specifically developed for the nursing PhD program. Doctoral research programs are expected to train students to become experts in a specific area of research, and often develop individualized programs of learning to meet these expectations (AACN, 2010). However, this may lead to variability in the quality of the training experience, depending on academic mentorship (Potempa, Redman, & Anderson, 2008) and program capacity (Minnick, Norman, Donaghey, Fisher, & McKirgan, 2010). To avoid this potential unevenness in the training experience, we developed a core set of competencies that all doctoral students on the quantitative research track must meet by graduation. We based the competencies on student and faculty input and through a series of faculty meetings to create consensus for the future research methods training courses. Although the AACN provides a broad set of expected outcomes and elements that should be included in the curriculum of nursing PhD programs (AACN, 2010), we developed an in-depth set of competencies that are specific for the development of courses for doctoral quantitative research methods courses. The AACN states that core curricular elements include "advanced research design and statistical methods", "data, information and knowledge management, processing and analysis" and "scientific methods, including team science" (AACN, 2010, p. 5). Wyman & Henly, 2015) conducted a comprehensive web scraping study, which analyzed the content of 120 PhD nursing programs in the United States. They reviewed website-based course content and concluded that changes must be made to meet the AACN core elements (AACN, 2010) and to improve the education of future nursing scholars (Wyman & Henly, 2015). We have expanded on the AACN core elements and developed detailed quantitative research competencies that could be used effectively to assess graduating students. This will ensure that students have achieved a level of competency that will align with their future nursing research careers (Anema & McCoy, 2010).

Realigning PhD Courses: The Roadmap

During the early years of nursing PhD programs, curricula focused on the development of nursing science, carving out a niche in early scientific discovery. Currently, there are more than 130 schools of nursing offering research-focused doctorates in the Unites States and nursing PhD students must be exposed to leading-edge research training (Breslin et al., 2015). As nurses engage with other health science professionals, nursing PhD students will benefit from extensive training in quantitative research methods covering epidemiology and advanced biostatistics to be conversant in the science of related fields of research. Our survey of the literature and of quantitative methods training programs at other nursing PhD programs in the United States led us to believe that successful learning and retention of quantitative methods skills using a competency-based approach could be achieved through spiraling of content, (i.e., when the core concepts are reviewed and referred to in several courses at successively higher levels). At the core of quantitative research methods, training is the need for training in both theoretical concepts and in the practical application of new concepts.

We also compared our quantitative methods curricula with curricula in eight peer institutions. Our evaluation indicated that some schools have moved to 2-year training in quantitative methods and supplemented SON course offerings with more advanced courses from other professional schools. The UCSF SON PhD roadmap, specific to quantitative research track, includes plans for more hands-on laboratory hours and access to more advanced courses in their second year. Similarly, to other top-tier SONs around the country, we instituted a sequence of quantitative methods courses that laid out parallel courses in epidemiology and research methods and biostatistics for 2 years, with more advanced concepts covered in the second year. This model fits the reality of nursing researchers who work in interprofessional research groups where demands are placed on them to accelerate and excel in their analytic approaches. We need to intensify our training efforts so nursing scholars can keep pace with the rapidly evolving field of science (IOM, 2010).

We acknowledge several limitations. First, our purposive sample of nursing schools was small, limited to data from eight schools, and does not represent quantitative research methods curricula at other schools. We did not perform a comprehensive survey all nursing schools offering PhD training but selected schools of nursing that ranked similarly to UCSF. Second, we chose to focus narrowly on coursework and competencies in quantitative research methods and did not expand this assessment to other curricula (e.g., qualitative research methods) as that would have been beyond the scope of this taskforce. Third, we may not have captured a full range of PhD student experiences, especially for those still in the program. Alumni provided a long-distance view of the limitations and strengths of their academic preparation in the PhD program at UCSF. Fourth, our curriculum was based on competencies that may not include content areas others may deem important to a nursing PhD education. Future discussions should expand on our insights to develop further the competencies that are fundamental to the nursing discipline. A final limitation of this study is that it focuses on doctoral education in the United States. Therefore, it may not represent programs that do not rely on required coursework as

part of the PhD program in nursing. However, although coursework for quantitative research methods can vary across settings, the key competencies required for research training should be the same, and our process for developing these competencies could serve as an example for other schools.

CONCLUSION

The AACN guidelines do not provide sufficient guidance for developing quantitative research skills in doctoral research programs (AACN, 2006b, 2010). Our comprehensive self-assessment of training in research methods for doctoral nursing students showed the need for synergistic learning opportunities with a greater focus on practical, computer laboratory application and expanded research methods training in the first 2 years of doctoral training. The UCSF quantitative research skills competencies could be used by nursing training programs to assess the quality of individual courses and entire curricula, as well as offer opportunities to expand instruction to meet students' needs. As DNP programs grow across the United States, the UCSF quantitative research skills competencies could help prioritize the rigorous research training for PhD nursing students that is necessary for future academic roles and research careers in nursing. The list will require ongoing assessment and revision to address changing competencies related to scientific inquiry. A solid foundation in quantitative research skills will enhance PhD-prepared nurses' ability to contribute new theoretical frameworks and conceptual models to our innovative, interdisciplinary approaches to care.

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Table A

Core Competencies in Quantitative Research Methods for University of California, San Francisco School of Nursing Doctor of Philosophy Program Graduates

a) Research Question Formation

1. Develop a scientific research question, specific aims, and null hypotheses supported by current knowledge and significance of the problem.
2. Evaluate the quality of available evidence relevant to a given research question.
3. Identify the different components of a research question and hypothesis (population of interest, setting, variables of interest).
4. Explain potential effect of the results of the research question(s) on future clinical, public health, or nursing practice.
5. Identify a theory or conceptual framework underlying the research question that includes theory-based processes influencing the outcomes(s).

b) Study Design and Sampling

Study Design

1. Select an appropriate study design to answer a stated research question.
2. Identify and differentiate the components of different study designs, including time frame, sampling, and types of variables, research questions, and potential biases associated with them.
3. State advantages and disadvantages of different study designs.
4. Describe how population-based findings relate to clinical settings and patients.
5. Explain the concepts of internal validity and external validity and generalizability with regards to study design.
6. Articulate methods for making a sound causal inference about research findings.

Sampling

7. State difference between population and sample and how to achieve a representative sample.
8. Discuss selection of a study sample with appropriate characteristics to test a stated hypothesis (e.g., sample frame and size)
9. Identify and differentiate the characteristics of probability sampling (e.g., simple random sampling, systematic sampling, cluster sampling) and nonprobability sampling (e.g., consecutive sampling, convenience sampling, judgmental sampling) and describe their advantages and disadvantages.
10. Explain the benefits and risks of selection criteria for inclusion and exclusion in study and identify the sample characteristics.

Sample Size and Power

11. Explain, calculate and interpret statistical concepts: Type I, II, III errors, sample size, power, effect size, and statistical versus clinical significance.

c) Quantitative Measurement

1. Explain the rationale for decisions to use different types of variables (e.g., categorical and continuous).
2. Define measurement precision and accuracy and methods to enhance them.
3. Describe types of validity and their relevance to data and conclusions: statistical conclusion, face, content, criterion-related, construct, internal and external, predictive and consequential validity.
4. Describe types of reliability and relevance to data and conclusions: Test–retest, intra-observer, inter-observer, internal consistency and parallel-alternate forms.
5. Discuss methods of assessing reliability (various types of coefficient of variation, intraclass correlation coefficient, Kappa statistic, various types of analysis of variance (ANOVA) models and Bland-Altman plots) and validity (validity index, multi-trait-multi-method matrix (MTMM), and index of item-objective congruence).
6. Identify key principles of instrument development.

d) Bias and Confounding

1. Identify different types of bias and describe its relevance to drawing a correct causal inference.
2. State the difference between systematic and random error and give an example of each.
3. Describe ways that bias can be reduced in the planning an analysis phase of a study.
4. Describe threats to the validity of an observation from confounding and methods to minimize potential effects of confounding.
5. Discuss the different statistical approaches to account for confounding.

e) Data Science in Health

Data Management

1. Describe major types of data used in health science (e.g., questionnaires, discrete observations, medical images, continuous sensor signals, laboratory data).
2. Demonstrate how to clean and merge data sets.
3. Be able to conduct basic analyses using a statistical program, whether by using prespecified commands or writing programming syntax.
4. Be able to interpret findings as reported in the output files from statistical programs.

Secondary Data

5. Describe advantages and disadvantages of using secondary data (access, linkage, quality, validation, missing data).
6. Describe data sets using complex sampling designs (e.g., probability weighted observations).

Missing Data

7. State assumptions underlying missing data.
8. Describe various problems presented by missing data.
9. Identify methods for handling missing data.

f) Statistical Analysis

1. Explain the difference between a population parameter and a sample statistic.
2. Identify types of variables (ordinal, nominal, continuous, categorical, etc.).
3. Identify, conduct, and interpret the statistical significance of a test, using probability and *p*-values.
4. Differentiate parametric and nonparametric tests.
5. Identify conduct and interpret group comparisons for continuous and categorical data using correlation, *t* tests, ANOVA, Mann-Whitney, Kruskal-Wallis, Sign.
6. Determine the appropriate statistical tests to use (including comparisons, correlation, regression model, mixed model, logistic regression, multi-level modeling, and hierarchical linear modeling).
7. Explain the numerator and denominator of estimates of probability, odds and rates.
8. Explain rationale for using intention-to-treat or per-protocol analysis or subgroup analysis in an experimental study.

g) Synthesis

1. Systematically critique and synthesize scientific literature.
2. Identify process for conducting a systematic review or meta-analysis.

h) Implementation Science

1. Describe translational research science.
2. Define dissemination, implementation and knowledge exchange in the context of clinical, nursing, and public health research studies.