TEACHING INTRODUCTORY STATISTICS FOR EVIDENCE-BASED PRACTICE: INTEGRATION OF CONTEXT

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ABSTRACT
The ability to critically evaluate quantitative research outcomes is an essential skill for effective decision-making, particularly in the health and behavioral sciences, where the focus is on evidence-based practice and clinical judgment. Introductory college-level statistics courses can serve as a vehicle for engendering these competencies. In this regard, the first course in statistics has been targeted for reform, aimed at building a meaningful foundation for statistical thinking. There is a consensus among educators that the goal of the introductory statistics course should be to foster statistical literacy by emphasizing concepts and applications rather than mathematical procedures and computations; an instructional method that embodies active-learning. Underpinning this pedagogical approach is the constructivist philosophy which regards context knowledge as central to meaningful and appropriate analysis, interpretation and use of data. This paper presents a model for conceptualizing an introductory statistics course to foster evidence-based practice (EBP). It depicts a unifying and holistic view of statistics, and posits that meaningful evidence results from the interaction of statistical methods with the data context, which refers to the research design, the underlying theory, and the practice domain.

INTRODUCTION

According to Cobb and Moore (1997, p.801): "Statistics is a methodological discipline. It exists not for itself but rather to offer to other fields of study a coherent set of ideas and tools for dealing with data." The ability to critically evaluate quantitative research outcomes is an essential skill for informed decision-making, and this is particularly relevant to the health and behavioral sciences, where the focus is on evidence-based practice and clinical judgment (Hassad, 2011; Jones, 2010). Evidence-based practice (EBP) is typically defined as "the conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients" (Sackett et al., 1996, p.71). EBP emphasizes attention to the interpretation, reliability, validity, and applicability of data, toward optimum patient care; and such appraisal and use of data necessitate statistical competence (Cox, 1997). Underpinning the growing importance of EBP, is the change in the nature, availability and accessibility of evidence, in an era of data explosion (Karthikeyan & Pais, 2010), and increased accountability for patient care. This represents a paradigmatic shift in health care practice, and a need for training programs that foster statistical and data literacy (Monahan, 2008; Carlson et al., 2011).

In this regard, the first course in statistics has been targeted for reform, aimed at building a meaningful foundation for statistical thinking (Garfield et al., 2002), and as Hogg (1991) observed, "good statistics is not equated with mathematical rigor or purity, but is more closely associated with careful thinking". The rationale for curricular and pedagogical reform of introductory statistics is further supported by the recognition that for most students, this course may be their only formal exposure to statistics, (Garfield et al., 2002; Moore, 1988). Toward this end, there is a consensus among educators that the goal of the introductory statistics course should be to foster statistical thinking and literacy by emphasizing concepts and applications rather than mathematical procedures, formulas and calculations (Franklin & Garfield, 2006); an instructional approach that embodies active learning. Statistics is fast becoming a core course for most college majors (Doehler, Taylor, & Smith, 2013), and it has been described as "the single most preferred course in terms of admittance into graduate school" (Alder & Vollick, 2000, p.1).

The goal of statistics education reform is to present statistics in an applied and practical manner, using real-world, interesting and relevant data, so as to engage and motivate students to construct meaning, as well as acquire conceptual understanding and transferrable knowledge and skills. Reform is also intended to facilitate students to develop positive attitudes toward statistics (Olani et al., 2011). Underpinning this pedagogical approach is the constructivist philosophy which regards context knowledge as central to meaningful and appropriate analysis, interpretation and use of data. However, with regard to the teaching of introductory statistics, the data context is generally either disregarded (Gal & Ograjensek, 2011), or misunderstood as being limited to the sample and setting, rather than the holistic perspective which integrates knowledge of the research design, the underlying theory, and the practice domain. This broader context provides a framework which can foster a richer meaning-making experience; a necessary foundation for statistical thinking and literacy. Meaningful evidence results from the interaction of statistical methods with the data context.

OBJECTIVE

The objective of this paper is to present a model for conceptualizing an introductory statistics course, aimed at fostering evidence-based practice (EBP) in the health and behavioral sciences. The course concept depicts a unifying and holistic view of statistics, and posits that knowledge of the data context is central to meaningful and appropriate statistical analysis. This paper adopts a broader perspective of the data context, with the following components, each of which is explained below, under "COURSE MODEL".

1. Knowledge of the research design
2. Knowledge of the underlying theory
3. Knowledge of the practice domain

THEORETICAL FRAMEWORK

The conceptual underpinning of this course model is constructivism, which is considered a family of concepts and principles about the construction of knowledge and meaning (von Glasersfeld, 1987; Cobb, 1994; delMas et al., 1999; Trigwell & Prosser, 2004; Fosnot, 2005). In the constructivist context, the instructor utilizes active learning strategies to scaffold activities and tasks (so that students can progress from the simple to the complex), explore information, discover concepts, and construct knowledge and meaning. According to Fosnot (2005), in this context, instructors become "facilitators, provocateurs and questioners" (p.13). This allows for the development of deep and conceptual understanding, that is, the ability to know "what to do and why" (Skemp, 1987, p. 9) rather than surface knowledge (from rote learning associated with behaviorist pedagogy). A key goal in selecting active learning strategies is to facilitate cognitive apprenticeship (Dennen, 2004) through authentic activities (Leont'ev, 1972), encompassing projects, group work (including discussions), problem-solving situations, oral and written presentations, as well as other tasks which model discipline-specific real-world activities, through expert demonstration and guidance (coaching). These activities should be structured and administered so as to provide stimuli for cognitive dissonance or conflict (Liu & Matthews, 2005) which serves to promote inquiry, and challenges the individual to think critically and reason, resulting in learning that is deep and conceptual, and hence a meaning-making experience (Dennen, 2004). The Consortium for the Advancement of Undergraduate Statistics Education (CAUSE) maintains a digital library of resources to support the use of active learning strategies (see https://www.causeweb.org).

COURSE MODEL

The course model (Figure 1) depicts a holistic view of statistics by way of the interaction of statistical methods with the data context (that is, knowledge of the research design, the underlying theory, and the practice domain), from which meaning and interpretation of data are derived. Statistical methods (in particular, inferential) can be viewed as unifying, in this regard, given that the information from these context domains is necessary to address the underlying assumptions and logic of statistical models, toward conducting appropriate analysis. Knowledge of the broader context can facilitate students to clarify and make coherent connections between concepts, as well as relate information to the real world, which can promote critical and statistical thinking. The role of each context domain in informing statistical methods is explained below.

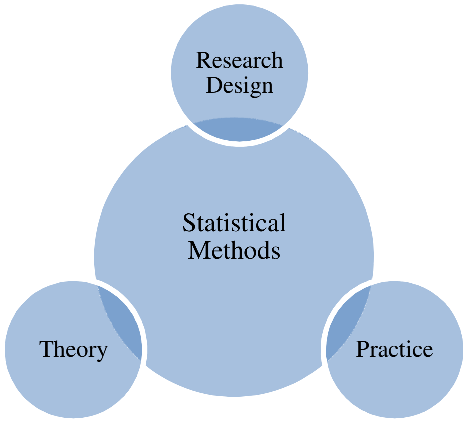

Figure 1: A Holistic Perspective of Statistics:
Interaction of Statistical Methods with the Broader Data Context

THE ROLE OF THE RESEARCH DESIGN IN INFORMING STATISTICAL METHODS

The end goal of statistical analysis is to make sense of numerical data, a process that is context-dependent (Moore, 1990; Pfannkuch & Wild, 2004; Langrall, Mooney, & Williams, 2005). This implies that knowledge and understanding of the research design (that produced the data) is necessary for meaningful interpretation. The input for statistical analysis is quantitative data, which can be generated by a broad spectrum of quantitative research designs that typically address the research problem, the hypothesis or objective, variables measured, treatment or intervention, the sample, the setting, instruments, methods of data collection, and statistical analysis. Quantitative research encompasses experimental and non-experimental designs, as well as meta-analysis (a systematic synthesis of quantitative research studies), and the data produced by the various research designs can differ by structure and complexity (e.g., cross-sectional, repeated measures, and multi-level), requiring different approaches to statistical modeling and analysis. Indeed, quantitative research may be basic or descriptive rather than analytical, which is aimed at testing hypotheses to identify possible explanations for observed outcomes.

Additionally, an understanding of the research design should guide how the results are reported and applied (Gal & Ograjensek, 2011), especially regarding observed relationships between variables, and whether these represent mere associations, or support causal inferences. In this regard, the knowledge of the research design also allows for the recognition of possible confounding factors, which could be a consideration for data analysis or future research. Also, information about some elements of the research design (such as sample type and size, instruments, methods of data collection, and setting) is necessary for assessing data quality, as well as internal and external validity. Such information addresses the strengths, limitations, and applicability of the results to a particular setting, which is the focus of evidence-based practice. Notably, the literature on evidence-based practice (especially in the health and behavioral sciences) reflects a bias toward the use of quantitative data and experimental designs (Smith, Tong, & Smith, 2006), with the rationale that these represent the "gold standard" of evidence by allowing for objectivity, replicability, and generalizability (Barbour, 2001). Nonetheless, this remains controversial, as indeed, qualitative data and non-experimental research designs may be optimal in particular contexts, rendering useful and the "best available" evidence.

A comprehensive understanding of the research design ("the big picture") can foster statistical literacy, which refers to the ability to understand, critically evaluate, and use statistical information and data-based arguments (Gal 2000; Garfield et al., 2002). It makes for a more meaningful experience when students can situate and contextualize the data; they are better able to tell the story of the data, and appreciate how the selection and use of statistical methods are determined. Moreover, knowledge of the research design facilitates the construction of meaning by serving as a map to promote and guide critical thinking about the data, and this can lead to conceptual understanding and transferrable knowledge and skills. Above all, attention to the research design (the "big picture") leads to a more holistic view of statistics rather than the perspective that statistics is abstract, mechanical, and merely numerical analysis. The holistic approach addresses the relevance and utility of data, and this can enable the development of favorable attitudes toward the discipline of statistics, including the production and use of data for decision-making.

THE ROLE OF THEORY IN INFORMING STATISTICAL METHODS

A theory is a conceptual framework or model that explains and/or predicts phenomena, and organizes variables in a plausible and parsimonious manner (Green, 2000). More specifically, this conceptual framework supports the research hypothesis or objective, and informs the specification and definition of variables of interest (including independent and dependent, if applicable). Thus, this model guides measurement, as well as the identification of confounding factors; fundamental considerations for statistical analysis. Accordingly, the theory informs the development and testing of statistical and substantive models (with attention to mediator and moderator variables, if relevant). The selection of statistical methods, whether univariate, bivariate or multivariate, will be based on the complexity of the models being tested, which is linked to the underlying theory.

The theoretical framework constitutes the empirical and scientific basis of the research, and hence the model for assessing construct validity (a necessary consideration for evidence-based practice). While construct validity has multiple components, its core dimension is criterion validity, which is conventionally determined by statistical measures, primarily correlation coefficients. Such measures indicate the extent to which an observed correlation or relationship is in a theoretically predictable direction. Meaningful interpretation of these coefficients requires attention to both statistical significance (from hypothesis testing) and substantive significance (from knowledge of theory and practice). Indeed, theory-based research (theory testing) implies the use of inferential statistics and deductive reasoning, which can promote critical thinking about data, especially regarding deterministic and probabilistic modeling (Lopez et al., 2004), and the role of uncertainty in decision-making; critical underpinnings of evidence-based practice.

THE ROLE OF PRACTICE CONSIDERATIONS IN INFORMING STATISTICAL METHODS

Meaningful statistical analysis is context or discipline-specific, for example, psychology, medicine, business, and education. In other words, disciplinary content knowledge is necessary for obtaining reliable and valid results (Lopez et al., 2004). Each discipline (or practice domain) has specific problems, priorities, needs, theories, methods, conventions, and indeed nuances, which will determine the optimal research design. Accordingly, key elements of statistical analysis, such as variables, constructs, models, and measurement approaches may vary by discipline. Additionally, the intended application of the results with reference to particular subgroups and settings, is a key consideration for appropriate statistical analysis, and indeed, evidence-based practice, which emphasizes data quality. Toward this end, measures of reliability and validity are relevant, and these are largely statistically determined. Knowledge of the practice domain will guide not only what variables are selected, measured, modeled and analyzed, but also, how the results are presented, and situated within the wider disciplinary context regarding utility and applicability. Most importantly, disciplinary content knowledge will allow for the evaluation of statistical significance in relation to practical (substantive or clinical) significance. While quantitative measures such as effect size, confidence interval, and level of significance, are the outcomes of inferential statistical analyses, their interpretation and utility depend on the area of practice and application (McMillan & Foley, 2011).

SUMMARY AND IMPLICATIONS FOR TEACHING

Instructors and students of introductory statistics, at the college level, tend to focus on mathematizing data, an exercise in abstraction; void of context and meaning. As noted by Gal & Ograjensek (2011) "statistics are often taught in a vacuum in which no relation is established between substantive, methodological and technical issues" (p.2). While the data context is gaining attention and importance from the statistics education community, as necessary for promoting statistical literacy, its definition and integration in this regard, are lacking. In particular, educators need to recognize that the data context extends beyond the sample and setting, and that this broader context can facilitate students to better clarify and make coherent connections between concepts, as well as relate information to the real world; the foundation of critical and statistical thinking, which underpins evidence-based practice. This paper presents a course concept that depicts a unifying and holistic view of statistics, by adopting a broader perspective of the data context (that is, knowledge of the research design, the underlying theory, and the practice domain), and argues that meaningful evidence results from the interaction of statistical methods with the data context. Moreover, this holistic approach addresses the relevance and utility of data, and this can enable students to develop favorable attitudes toward the discipline of statistics, including the production and use of data for decision-making. The introductory statistics course is opportune for fostering such habits and dispositions.

Designing and teaching an introductory statistics course that underscores integration of the broader data context can be challenging, as a range of interdisciplinary knowledge and skills is required. In addition to knowledge of statistical methods, research design, theory, and the particular discipline (or practice domain), relevant pedagogical content knowledge (PCK) is required. PCK "represents the blending of content and pedagogy into an understanding of how particular topics, problems or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (Shulman, 1987, p. 4). In other words, the emphasis is on the pedagogy of integrative learning. A relevant instructional model is problem-based learning (Nowacki, 2011), a pedagogical approach that is centered around students working in small groups to explore and solve real-world problems within their discipline.

Focusing on the broader context represents a new way of thinking about data for both instructors and students, a shift that may be met with some resistance, particularly given the diversity of learning styles in any classroom. Statistical thinking is primarily a mindset, which can be facilitated and nurtured through active learning, including the use of appropriate assessment strategies. Statistics educators have recognized this challenge, which has implications for faculty preparation, reform of the graduate curriculum (Hassad, 2010), professional development, textbook content and design, the availability of resources, as well as empirical research regarding the impact of this curricular model on statistical literacy and evidence-based practice. At the minimum, knowledge, understanding, and effective integration of the data context, require that instructors be engaged in research and statistical analysis within the discipline, and toward this end, the scholar-practitioner model seems relevant. Team-teaching may also be helpful, in this regard.

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