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Validation: A Burgeoning Methodology for Mathematics Education Scholarship

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RCML History

The Research Council on Mathematics Learning, formerly The Research Council for Diagnostic and Prescriptive Mathematics, grew from a seed planted at a 1974 national conference held at Kent State University. A need for an informational sharing structure in diagnostic, prescriptive, and remedial mathematics was identified by James W. Heddens. A group of invited professional educators convened to explore, discuss, and exchange ideas especially in regard to pupils having difficulty in learning mathematics. It was noted that there was considerable fragmentation and repetition of effort in research on learning deficiencies at all levels of student mathematical development. The discussions centered on how individuals could pool their talents, resources, and research efforts to help develop a body of knowledge. The intent was for teams of researchers to work together in collaborative research focused on solving student difficulties encountered in learning mathematics.

Specific areas identified were:

1. Synthesize innovative approaches.
2. Create insightful diagnostic instruments.
3. Create diagnostic techniques.
4. Develop new and interesting materials.
5. Examine research reporting strategies.

As a professional organization, the **Research Council on Mathematics Learning (RCML)** may be thought of as a vehicle to be used by its membership to accomplish specific goals. There is opportunity for everyone to actively participate in **RCML**. Indeed, such participation is mandatory if **RCML** is to continue to provide a forum for exploration, examination, and professional growth for mathematics educators at all levels.

The Founding Members of the Council are those individuals that presented papers at one of the first three National Remedial Mathematics Conferences held at Kent State University in 1974, 1975, and 1976.

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Leading and Learning for Measurement and Assessment Practices

VALIDATION: A BURGEONING METHODOLOGY FOR MATHEMATICS EDUCATION SCHOLARSHIP

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Validity-related issues are a growing topic within the mathematics education community. Until recently, validation has been treated as something to gather when convenient or is rarely reported in ways that conform to current standards for assessment development. This theoretically-focused proceeding adds to a burgeoning theoretical argument that validation should be considered a methodology within mathematics education scholarship. We connect to design-science research, which is a well-established framework within mathematics education. The goal for this proceeding is to foster the conversation about validation using examples and to communicate information about validation in ways that are broadly accessible.

Introduction

In the last four years, validity issues are taking a greater focus within assessment and measurement using quantitative instruments. This is evidenced through a special issue of *Investigations in Mathematics Learning*, National Science Foundation-funded conferences on validity issues within mathematics education contexts, and peer-reviewed manuscripts and books addressing validity and validation issues within the scope of mathematics education scholarship. These works are springing from mathematics education researchers working collaboratively with others from different disciplines such as learning scientists, psychometricians, research methodologists, and special educators. Grounding ideas in theoretical and methodological frameworks is central to generalizable research that has broader impacts (Confrey, 2018). While there are procedures for validation (e.g., Kane, 2012; Schilling & Hill, 2007), there are few that frame validation as a methodology with its own nuances (e.g., Jacobsen & Borowski, in press). There may be many reasons for why validation has not been treated as a methodology and some of those include but are not limited to (a) pressures not to conduct validation studies, (b) challenges in publishing validation arguments (Bostic, Krupa, Carney, & Shih, in press), and (c) decreased emphasis in methodological training of doctoral students in the disciplines (Shih, Reys, Reys, & Engledowl, in press). To that end, this paper aims to augment recent work by

Jacobsen and Borowski (in press) to ground validation work in mathematics education as a methodology akin to design science.

Relevant Literature

What is a Methodological Framework?

For this proceeding, we characterize a methodological framework as one that allows a researcher to apply analytical tools to respond to a research question (Creswell, 2012). For our purposes here, methodology implies ways to conduct research in a manner that synergizes with a chosen theoretical, philosophical, or epistemological framework.

One Approach to Design-science as a Methodology

Design science research was developed to address central questions about learning (Collins, Joseph, & Bielaczyc, 2004). A central component of design research is a "temporal process flowing roughly from conceptualization to realization" (Middleton, Gorard, Taylor, & Bannan-Ritland, 2003, p. 63). Design research can: (a) address theoretical questions about the nature of learning in context, (b) provide a methodological approach for studying learning phenomena in an authentic setting as opposed to laboratory settings, (c) go beyond a singular measure of learning, and (d) derive justifiable findings from formative evaluation (Collins et al., 2004). Design research thus serves scholars as a methodological tool. There are multiple ways to frame design-science methodologies. In sum, a design-science based methodology (e.g., Middleton et al., 2003; Schwartz, Change, & Martin, 2003) fosters "a focus on instruments that both precipitate and measure effects has historically been effective at supporting innovation" (Schwartz et al., 2003, p. 63); in our own research, a test in diverse classroom settings.

One design-science methodological approach has seven phases within its design cycle: (1) grounded models, (2) artifact development, (3) feasibility study, (4) prototyping and trials, (5) field study, (6) testing, and (7) dissemination and impact (Middleton et al., 2003). For phase 1, reviews of literature and interfacing with experts helps to ground work on assessment development. It begins to answer questions such as: What will this instrument do? What has already been done in this area of assessment development? How will the interpretations/outcomes from the assessment be used? In phase 2, a rough draft assessment is produced based upon responses to these questions and others. For phase 3, data are gathered to evaluate the quality of the initial draft and make revisions. Cognitive interviews with a measure or real-time observations with an assessment might be used to explore response processes evidence. In phase 4, revisions are made, and a new artifact is produced. A content review committee (i.e., expert panel) or potential typical respondents might then examine the instrument for content, response processes, and/or internal structure validity evidence. In phase 5, implementation studies with a larger sample are conducted to examine the assessment for facets related to internal structure and usability. This sets up for phase 6, when psychometric studies are conducted because there are sufficient (i.e., size and type) data. Finally, at phase 7, the developed assessment is disseminated for broad use. This is also the stage where effectiveness studies are conducted to engage questions such as: How sensitive is the assessment to the desired phenomena? Are there quantitative similarities between the assessment and similar instruments? What are the contexts for which might the instrument not be appropriate? Through these seven steps, researchers are able to reify an idea into an actionable product, like an assessment.

Validity and Validation: Definitions and practice

Validity is "the degree to which evidence and theory support the interpretations of test scores for proposed uses of tests" (AERA, APA, & NCME, 2014, p. 11). Because peer-reviewed manuscripts have historically tied validity to an instrument (see Bostic et al., in press), it must re-state that validity is linked to the interpretations and outcomes - not the assessment. Validity gives scholars confidence that the interpretations from quantitative scores derived from an assessment are the intended ones and not associated with a different construct. The *Standards for Educational and Psychological Testing* (AERA et al., 2014) frame five validity sources for assessment developers and users: test content, response processes, relations to other variables, internal structure, and consequences from testing.

The validation process is cyclical (see Figure 1) in nature and requires iterative loops before an assessment is ready for broad-scale use. The first step is to determine what an assessment will do and what it will measure.

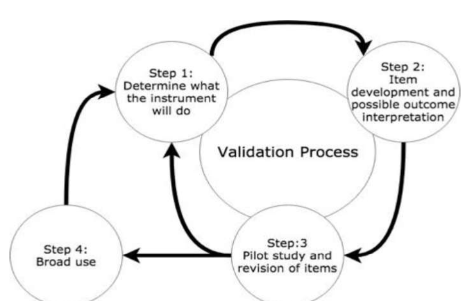

Figure 1. Validation process. See Gerber, Bostic, & Lavery (2018) for further information.

This typically requires determining a construct, defined here as “the concept or characteristic that a test is designed to measure” (AERA et al., 2014, p. 11). The second step is developing items and reflecting on ways of interpreting results. During this step, assessment developers think deeply about validity evidence. Drawing across validation frameworks (e.g., Kane, 2012; Schilling & Hill, 2007), this step is likely the most arduous but also the most important. In step three, an assessment is piloted to gather data, inform revisions, and a return to examining the construct that was selected. The reason for returning to step one is that it is possible to move away from the intended construct; therefore, a formative check is warranted. If there is sufficient evidence for the assessment developers suggesting it is functioning adequately, then broader use is acceptable (step 4). Previously, presentations at RCML focused on assessment development address this validation process (e.g., Bostic & Matney, 2018) but didn’t connect them to validation as a methodology within mathematics education scholarship. Digging into previous work by this team, Bostic and Matney (2018) present and foster discussions at RCML annual meetings around the *Standards* (AERA et al., 2014) and how they enact across three assessments ready for broad use in scholarship. This paper picks up where that one ended and extends work to be more educative and approachable to scholars with a wide range of experience in measurement. In what follows, we connect the validation process, one design-science framework (Middleton et al., 2003), with one problem-solving measure (e.g., PSM6; see Bostic & Sondergeld, 2015) that is a component of a series of measures available for grades 3-8 in Table 1.

Table 1

Connecting validation and design-science stages with PSMs

Validation	Actions completed in PSM development	Design-science
(1) Determine what the instrument will do	Examine relevant lit, review assessments, conduct interviews with expert panel	(1) Grounded models
(2) Item development and possible outcome interpretation	Conduct expert panel review, cognitive interviews, small-scale pilot with one class of students	(2) Artifact development
(3) Pilot study and revision of items	Perform small-scale study (~ 100 respondents), analyze with Rasch modeling, revise items appropriately.	(3) Feasibility study, (4) Prototyping, trials, (5) Field study
(4) Broad use	Perform large-scale study with 300+ respondents.	(6) Testing, (7) Dissemination

It is evident that there are clear connections between validation stages and one design-science framework. Where validation may be a broader term and include many aspects, the design-science framework breaks it down into subcomponents in much the same way sources of validity are categorized in the *Standards* (AERA et al., 2014).

A central piece of the validation process is a methodological (i.e., procedural) aim - that is, how to accomplish specific goals. There are specific decisions to be made, which are tied to a desired outcome and chosen theoretical framework (e.g., AERA et al., 2014; Kane, 2012; Schilling & Hill, 2007). These decisions involve when, how, and from whom to collect data - and what manner to analyze those data and for what purpose. Ways to communicate choices for those decisions to potential users is not as simple as a manuscript section labelled participants, instrumentation, data collection, and data analysis. Because the involvement of participants varies at different stages in both design science and validation, it becomes complicated to convey this information. Moreover, the ways information is gathered during those stages are analyzed can vary. For instance, assessment developers might choose to analyze a few samples of assessment data at first using one approach and digging deeply into it (e.g., grounded theory; see Charmaz, 2006). Later (i.e., broad use) they might require a different analytical approach in which they look to confirm broad themes through inductive analysis (Hatch, 2002) earlier in the validation process. Another challenge is that the goal (i.e., assessment being developed) is not validated but its outcomes are. Thus, a central focus on conveying information must be a clear, convincing argument that the outcomes from using an assessment are logically drawn and not that it is merely sound psychometrically.

Current Discussions of Validation as a Methodology

Jacobsen and Borowski (in press) argue that validation acts as a methodological tool that has been underutilized. They and others (e.g., Bostic, 2017, Bostic et al., in press) note the lack of validation work within mathematics education scholarship. Albeit, gathering validity evidence and constructing a validity argument during the design and use phases for an assessment are central to generating generalizable research (AERA et al., 2014; Kane, 2012). Without a validation argument for the interpretations of scores from an assessment, it is uncertain how the scores on that assessment are accurate reflections of an individual or group's attributes (Bostic et al., in press; Kane, 2012). Thus, validation ought to have a central place in mathematics education research that uses quantitative assessments if an aim is to understand factors related to teaching and learning in their authentic settings. Design research draws upon authentic (real world) settings of research and not lab settings. Therefore, validation and design research share a mutual interest in understanding "what is" rather than "what might be".

Implications for Current Assessment Development: A Brief Example

A current National Science Foundation-funded project titled Developing and Evaluating Assessments of Problem Solving (DEAP; NSF #1720646, 1720661) is using the validation stages and a design-science framework (see Middleton et al., 2003) simultaneously to develop a series of measures that assess elementary (i.e., grades 3, 4, and 5) students' problem-solving ability within the context of math content and practices addressed in the Common Core State Standards for Mathematics (2010). This series connects to previously developed measures for grades 6-8. The development team is currently in stage 3 of the validation cycle and is preparing to re-enter the cycle after conducting the initial product and pilot testing. Concomitantly, the team's work might be classified at stage 5 of the design-science framework. More information about current assessment development activities are available (see Bostic, Matney, Sondergeld, & Stone, 2018).

Conclusions and Next Steps

As a result of using validation as a methodology within mathematics education scholarship, assessment developers are better equipped to converse with potential users (e.g., teachers, district representatives, scholars) and those closely associated with test-takers (e.g., students, parents/guardians, school personnel). Data gathering takes a practical approach to inform product development and validate outcomes/interpretations of the assessments. Assessment is central to sound research and without valid outcomes from assessment – the field cannot truly trust their implications. An issue coming from the fervor among mathematics education scholars is that validity must become part of the critical conversation about scholarship that aims to have high impact (Williams & Latham, 2017). As a result of a growing focus on validity issues, methodological framing of such scholarship becomes a bigger issue. Applying traditional quantitative or qualitative methodologies to communicate scholarship on validity issues and validation arguments presents unnecessary challenges to both authors and readers. Hence, validation should be considered as a viable methodological tool in empirical mathematics education research. We argue that validation as a methodology in mathematics education scholarship has utility. Validation bears striking similarities to design science, which is an established methodology. We recognize that this work and Jacobsen and Borowski (in press) are at the leading edge and more scholarship is needed to better ground validation as a methodology within mathematics education scholarship. Continued validation projects within mathematics education and discussions with diverse scholars will ultimately derive a powerful means for scholars to have broad impact and substantiate intellectual merit for work examining assessment and measurement within mathematics education contexts.

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