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Book Review

The Learning Sciences in Educational Assessment: The Role of Cognitive Models

Jacqueline P. Leighton and Mark J. Gierl
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In *The Learning Sciences in Educational Assessment: The Role of Cognitive Models*, overviews of diagrammatic cognitive models in reading, science, and mathematics are presented with the intent to inform research on the design and development of large-scale educational assessments (LSAs).

In the introduction, the authors argue that LSAs should be designed and developed based on an up-to-date understanding of learning theory in order to capture information about the degree to which students are acquiring innovative and higher order thinking skills for the 21st century. They contend that LSAs are often designed based on cognitive models of test specifications that have not been empirically corroborated or evaluated as tools leading to the development of items that elicit required thinking skills. They further hypothesize that LSAs with designs based on cognitive models from the learning sciences will provide richer information about student problem-solving and thinking. However, to date there are no published studies that investigate whether such designs lead to tests that are better at measuring the desired knowledge and skills than current LSAs. The challenge, therefore, is to develop and empirically test cognitive models in the domains of reading, mathematics, and science that illustrate the knowledge and skills to be measured with LSAs. Systematic records of learning science cognitive models and research in each academic domain are needed, as are convenient ways to diagrammatically represent cognitive models to make them more relevant for assessment specialists. Last, the authors claim that learning should be evaluated systematically and scientifically, and that LSAs should be redesigned based on learning sciences to produce better measures of achievement. Thus, the purpose of the book is to present promising relevant diagrammatic cognitive models that might inform future research in the design and development of LSAs of reading, science, and mathematics.

In Chapter 2, the authors effectively explain cognitive models, describe their past and present use, and describe how they can be used to inform educational assessment. The authors are clear in explaining cognitive models and in leading the reader to understand the pressing need for cognitive models in educational assessment planning. They also describe five features of cognitive models identified by the National Research Council (NRC) that should be used for test design. The authors describe these features as being "broad and inclusive" (p. 61) and note that they are not often used to inform the design of LSAs, perhaps because they are too restrictive. The authors then introduce three proposed characteristics of cognitive models that would be necessary to link learning with assessment, and assert that their proposed features are preferable to those of the NRC because they are less restrictive and more general. It would have been helpful if the authors had discussed how their three features are not overly broad.

The characteristics proposed by the authors for evaluating cognitive models are grain size (the depth and breadth of knowledge and skills measured), measurability (the ability to describe the knowledge and skills intended to be measured well enough that test developers can create test items to measure them), and instructional relevance of the knowledge and skills to be measured to a broad group of educational stakeholders. The authors provide appropriate examples as well as guiding questions that serve to clarify their proposed characteristics of cognitive models. This section prepares the reader well for upcoming chapters on cognitive models for specific content area assessments.

Chapter 3 focuses on cognitive models of task performance for reading comprehension. Reading comprehension skills are critical to advancement in academic studies and it is unsettling to have national test results which place only a third of American students in fourth and eighth grades at or above a proficient reading level (National Center for Education Statistics, 2009). This chapter focuses on the bottom-up and top-down reading comprehension processes required for understanding written text and, specifically, how these processes interact, as described in the construction-integration (Kintsch, 1988; Kintsch & Rawson, 2005; see also Just & Carpenter, 1987) and the constructionist models (Graesser, 2007; Graesser, Singer, & Trabasso, 1994). The explanation of each of these models in relation to the cognitive processes enabling reading comprehension is important because these models are complementary. For example, the former model is focused on making associative inferences. The latter emphasizes the role of reader goal direction in inferences. Therefore, providing this expanded view is helpful because neither one is universally applicable for assessment development. However, further research is needed because neither takes into account the applied approach of educational assessment in its description of mental processes in reading comprehension (Leighton & Gierl, 2007).

Chapter 4 introduces cognitive models for scientific reasoning and discovery which are key elements for economic productiveness and essential skills for the twenty-first century. They point out the uniqueness of science compared to other content domains. Science is a highly complex domain, and its instruction must target aspects of process skills in addition to content knowledge. The authors describe and evaluate in detail the scientific discovery as a dual search (SDDS) model (Klahr & Dunbar, 1988; see also Dunbar & Fugelsang, 2005; Klahr, 2000) and Kuhn's (2001; 2005) knowing/phases of inquiry (KPI) model. Both models are useful in understanding the role cognitive models can play in science assessment design. Differences between the two models are pointed out, and the way in which they measure up to the authors' three specified features is generally very similar. Our only critique is that both examples may focus too narrowly on process skills. It may have been useful to include other factors, such as content-based knowledge, given the importance of content knowledge.

Chapter 5 introduces cognitive models for mathematical reasoning. The chapter begins by emphasizing the significance of mathematics ability for maximizing students' prospects of obtaining desirable employment. Yet a high proportion of American students are below proficient standards in mathematics (National Mathematics Advisory Panel, 2008). In addition, students' interest and motivation for math are low, which the authors speculate may be improved through the use of theoretically-derived LSAs. Although there is considerable research on mathematical reasoning and cognition, most is of limited use for the design and development of LSAs because its focus is too specific and narrow. Test developers require research about basic mathematics processes and their interactions in higher level reasoning skills. The authors present two diagrammatic cognitive models for mathematical reasoning: Anderson's adaptive control of thought-rational (ACT-R) (Anderson, 1996; Ritter, Anderson, Koedinger, & Corbett, 2007) and the five strands (5-S) model (Kilpatrick, Swafford, & Findell, 2001). The ACT-R is specified with enough detail to direct the generation of algorithms for implementing computer-based testing and has been applied broadly to mathematical reasoning. However, ACT-R lacks one component that the 5-S model includes: disposition for mathematical thinking.

Throughout Chapters 3, 4, and 5 the authors consistently use helpful examples that guide the reader in understanding the intricacies and issues relevant to the cognitive models introduced. For example, in discussing the SDDS model, the authors provide a straightforward and brief metaphor to explain the process of generating frames and assigning slot values. In addition to providing examples, the authors provide clear, step-by-step descriptions of the diagrammatic overviews of the cognitive models that may otherwise be confusing.

In Chapter 6, the authors effectively combine what has been presented in previous chapters by comparing the various domain models on granularity, measurability, and instructional relevance. They again argue that cognitive models should be used to inform assessment design in order to make test-based inferences about what students are able to do. However, the authors note that currently there are no cognitive models that relate *directly* to large-scale educational assessments, and rather, cognitive models need to be adapted for large-scale assessment design. In the discussion on future directions, the authors briefly mention Bennett and Gitomer's (2008) research on Cognitively Based Assessments of, for, and as Learning (CBAL™). This research appears to be fully in line with what the authors are advocating. We would have liked a more thorough description of Bennett and Gitomer's work or similar research and explanation of how the proposed cognitive models could be used in designing assessments.

Chapter 7 presents and reviews twelve cognitively-based statistical methods that have been used in research of cognition and assessment. This chapter also highlights three particularly helpful examples of practically applied cognitive/statistical methods. This chapter is intended as a guide for researchers and practitioners in identifying and differentiating between potentially useful methods and choosing appropriate software for analyses. The authors are, however, quick to point out the flaws which consistently appear relative to the generalizability of each example. In addition, it would be useful to have a more thorough description of the 12 methods listed, though one can assume this was not done for the sake of chapter length.

This book is clearly relevant and of interest to large-scale assessment designers and developers, cognitive or measurement researchers, and educational policy makers. It is less relevant for classroom teachers because its main focus is on using cognitive models for designing LSAs. Nonetheless, the book provides opportunities for classroom teachers interested in cognition and assessment to reflect on models of cognition and how they might inform classroom instruction and assessment. For example, the authors show that the 5-S model for mathematical reasoning has components that can be modeled in the classroom and targeted as mathematics learning outcomes. However, given the limited amount of content directed specifically at classroom assessment, the title of this book should have made its focus on LSAs more apparent.

This book has few shortcomings and many strong points. Undoubtedly, it is beyond the scope of one text to provide complete reviews of all of the theories, models, and processes of cognition involved in reading comprehension, mathematics, and science performance. A reader looking for complete reviews of any one of the subject areas would need to consult several reference materials. A major strength of this book is that it points interested readers in the right direction by providing thoughtful overviews together with thorough references to more detailed information.

Overall, the authors provide a thorough summary of the research that incorporates cognition with models of task performance and statistical methodologies. As the cognitive field is so vast, it is very useful to have an in-depth review of this important area of specialization. As such, this book certainly makes a useful contribution to the fields of cognition and assessment alike. A further highlight of this book is the authors' fresh take on the interaction between cognition and assessment. As they point out, test developers do not often refer to cognitive models in item designs. Although this is likely due to the inherent disconnect between cognitive models and their practicality in the applied field of educational assessment, one must not assume they are irreconcilable. To this end, the book does not offer any new conversion catalysts to begin the paradigmatic shift that must take place in order to bridge this gap. Nevertheless, an important conversation has been set forth to narrow the distance between the fields.

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