The ACT Master(y) model for Measurement, Learning and Navigation

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ABSTRACT: Historically, measurement and learning have evolved independently. More recently (e.g., Deonovic, et al., 2018) efforts have been made to close the gap and connect the two bodies of research together. Network models are at the center of this integration. To support an integrative real world data driven approach to integrated measurement, learning, and navigation of learners, models are needed that encode prior knowledge from both fields of research. The ACT master(y) model introduced here is such a model.

Keywords: network psychometrics, learning, measurement.

1   INTRODUCTION

The ACT Master(y) model has been developed at ACTNext to support **large scale** systems for personalized **learning**, **measurement** and **navigation**. Many models exist that support some of these, but no single model currently supports all of them. The Master(y) model builds on these partial solutions but is the only model that bridges the gap between assessment on the one hand and learning and navigation on the other hand. We introduce the key components below and explain briefly how they fit together.

2   KEY INGREDIENTS

Before introducing the ACT master(y) model proper, we lay out the key ingredients that together allow for baking the master(y) model.

2.1   Measurement

From over a Century of large scale assessment we've learned that assessment material (e.g., ACT test items) has a hierarchical structure. Mathematics items correlate more with other mathematics items than with reading items. Within mathematics, algebra items correlate more with other algebra items than with geometry items. This hierarchical structure is encoded in the **ACT Holistic Framework** (Camara et al., 2015), which is a key ingredient to the Master(y) model.

Every skill in the holistic (or any other) framework is conceptualized as being either mastered or not mastered. Every assessment item is tagged to a skill in the framework, with a different probability of a correct response for masters (a) and non-masters (b). With a mastery probability of p we obtain the following measurement model (where a>b) in Table 1.

Table 1: Basic measurement model

	Master	Non-Master
Correct	ap	b(1-p)
Wrong	(1-a)p	(1-b)(1-p)
Margin	p	1-p

However useful a framework with its associated measurement model is for assessment purposes; it does not quite help with deciding what a learner should do next.

2.2   Learning and Navigation

Building on foundational work by Jean-Claude Falmagne (implemented in his Aleks learning system), **knowledge graphs** have become one of the dominant models for learning and navigation. A knowledge graph encodes prerequisite relations between (fine grained) skills. It's no use teaching quadratic equations to learners that haven't mastered linear equations. These relations help in deciding whether a student is ready to learn a new skill, needs to study more on the skill she currently is working on, or revisit an earlier acquired skill which is preventing her from moving on.

2.3   Validity

Learners don't learn because they want to become skilled test takers, but to become skilled professionals (in their profession of choice). Almost any non-trivial activity in almost any profession requires using a (large) number of skills to get something done. The Master(y) model borrows ideas from **Cognitive Diagnosis Models** to link real life problems to skills, to help build the validity argument of a learning, assessment and navigation system to prepare learners for their profession of choice. Some skills, such as the cross cutting capabilities (aka, 21th century skills) in the holistic framework, are not easily assessed in isolation and out of context. The same structure allows for making inferences on (say) critical thinking, from items related to various cognitive skills.

3   THE ACT MASTER(Y) MODEL

The ACT Master(y) model combines these three ingredients in a single statistical model, which can support a scalable learning, measurement and navigation solution. Figure 1 below gives a graphical representation of the ACT Master(y) model. Squares denote observable variables (either item responses, or educational resources a learner has consumed), circles denote skills. Undirected edges encode the hierarchical structure of the Holistic Framework, and directed edges encode the prerequisite structure of a knowledge graph. The Q layer in the network serves to encode the dependence on multiple skills for observable variables.

4   THE ACT MASTER(Y) MODEL AT SCALE

A learning, measurement and navigation solution needs to support real-time skill tracking at scale. The ACTNext Recommendation and Diagnostics (RAD) Engine is an API that combines the power of an intelligent educational-content delivery platform with state of the art, real-time skill estimate tracking. Currently, the RAD API powers recommendations in **ACT Academy**, but fully extends and integrates into any Learning and Assessment System (LAS), that aligns to any subject or set of

standards (i.e. Common Core, **ACT Holistic Framework**, etc.) and *adaptively delivers relevant, free, and personalized content* to meet the needs of learners everywhere.

The combination of the ACT Master(y) model on the one hand and the RAD API on the other hand offers a flexible and scalable solution to support learning, measurement and navigation at scale.
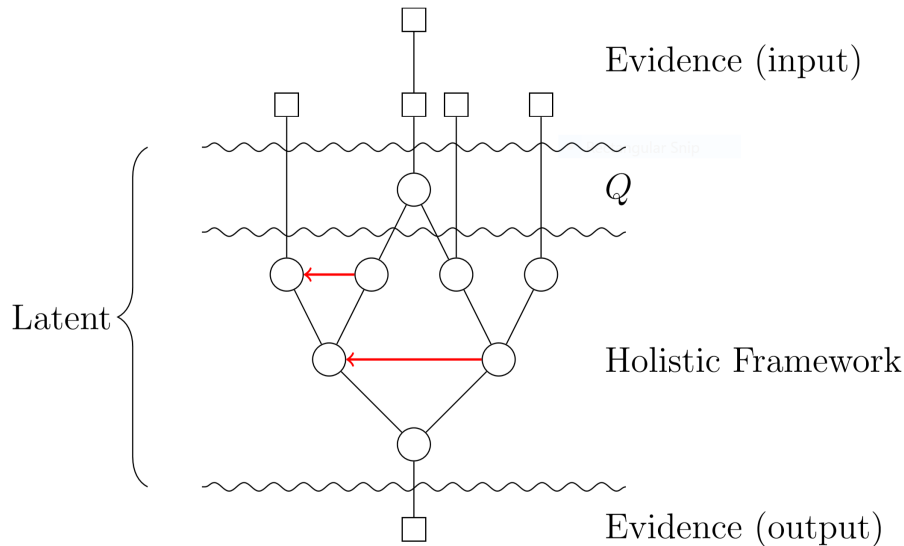

Figure 1: Graphical representation of the ACT Master Model

5   DISCUSSION

Over the last decade network models have gained wide popularity in psychology, and psychometrics in particular. A good overview of network psychometrics is found in Marsman, et al. (2018) and the book chapter by Epskamp, et al. (2018). Its impact goes from psychopathology, spear headed by Denny Borsboom (e.g., Borsboom & Cramer, 2013), to attitudes, spear headed by Han van der Maas (e.g., Dalege et al, 2016), and education(al measurement), spear headed by Gunter Maris (e.g., Savi et al., 2019).

The ACT master(y) model grew out of network psychometrics. It was developed to deal with Learning, Measurement and Navigation in an integrated fashion, but with interpretability, scalability, and applicability in real world learning systems in mind. To achieve these goals, we integrated as much prior (substantive) knowledge as we could into the modeling itself, thereby constraining it, but at the same time making it extremely tractable from a statistical point of view.

As always, when substantive knowledge meets data you can find out that the substantive knowledge was wrong or incomplete. Hence the ACT master(y) model is not an end point, but the start of a data driven iterative process of improvement to support the ultimate goals of Learning, Measurement and Navigation.

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