Ability beliefs in engineering: Developing a measure for younger students

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BACKGROUND

- Increasing concern for low percentage of adults earning degrees and pursuing careers in engineering and Science Technology Engineering Math (STEM)-related fields (NAE, 2011; NSB, 2012; NSF, 2015)
- Increasing positions but shortage of skilled workers (My College Options & STEMconnector, 2012)
- Particular **lack** of **females** and **ethnic minorities** (NSF, 2010; PCAST, 2010)
- Early experiences affect later skill development and motivation to learn (Heckman, 2006)
- Children's **ability beliefs**—perceptions of their current competence in a given domain—affect performance in the future (Eccles & Wigfield, 2002; Wigfield & Eccles, 2000), and understanding effects of early beliefs and experiences can aid in decreasing disparities (Heckman, 2006).
- Gap in literature on age-appropriate and gender-invariant measures for young children in assessing **ability beliefs** related to engineering.

Research Goal

Develop a measure to examine the development of children's ability beliefs in the engineering domain using an iterative process, considering differences in age and gender.

METHODS

Participants

- Two Southwestern U.S. schools - 399 students (46% girls)
  - 51% in Grades K-2 (younger)
  - 49% in Grades 3-5 (older)

Measures

2 Domains: Competence (COM) and Growth Mindset (GM)

- 15 Items each
  - 4 STEM/STEAM: e.g., "How good are you at science?"
  - 10 Activity/Skill: e.g., "How good are you at trying out your ideas?"
  - 1 Engineering: e.g., "How good are you at engineering?"
- Likert-scale 0 - 3 ("Not at all good," "A little good," "Sort of good," and "Very good")

Step 1: Factor Structure

- Initial theory: **activity** and **skill** items would load onto separate factors by domain (Figure 1).
  - Problem: Activity and skill correlation > 1, which resulted in a non-positive definite covariance matrix
- Solution: after revisiting theory, we decided to
  1. Combine items across activity and skill for each domain
  2. Use a higher-order factor called "Ability Beliefs" (Figure 2)

Step 2: Invariance Testing

- Our interest is in **subpopulations with occupational disparities** along with **developmental appropriateness**.
- Broad—do not drop an item that measures **systematic group differences**
- Wide—capture range of activity/skills for **both genders** and **age groups**
- Configural invariance—number of factors and general pattern of high and low loadings same for each group

Table 1. *Model fit indices for invariance testing by grade and gender.*

	Subdomain	χ^2	df	p-value	RMSEA	RMSEA 90% CI	CFI	SRMR
Grade	COMP	147.522	71	< .001	0.074	0.057, 0.090	0.864	0.059
	GRO	242.083	71	< .001	0.11	0.095, 0.125	0.841	0.063
Gender	COMP	152.458	71	< .001	0.081	0.063, 0.098	0.822	0.065
	GRO	271.002	71	< .001	0.126	0.111, 0.142	0.792	0.072

Cutoff values: *χ^2 > .05; RMSEA < .08; CFI > .90; SRMR < .08*

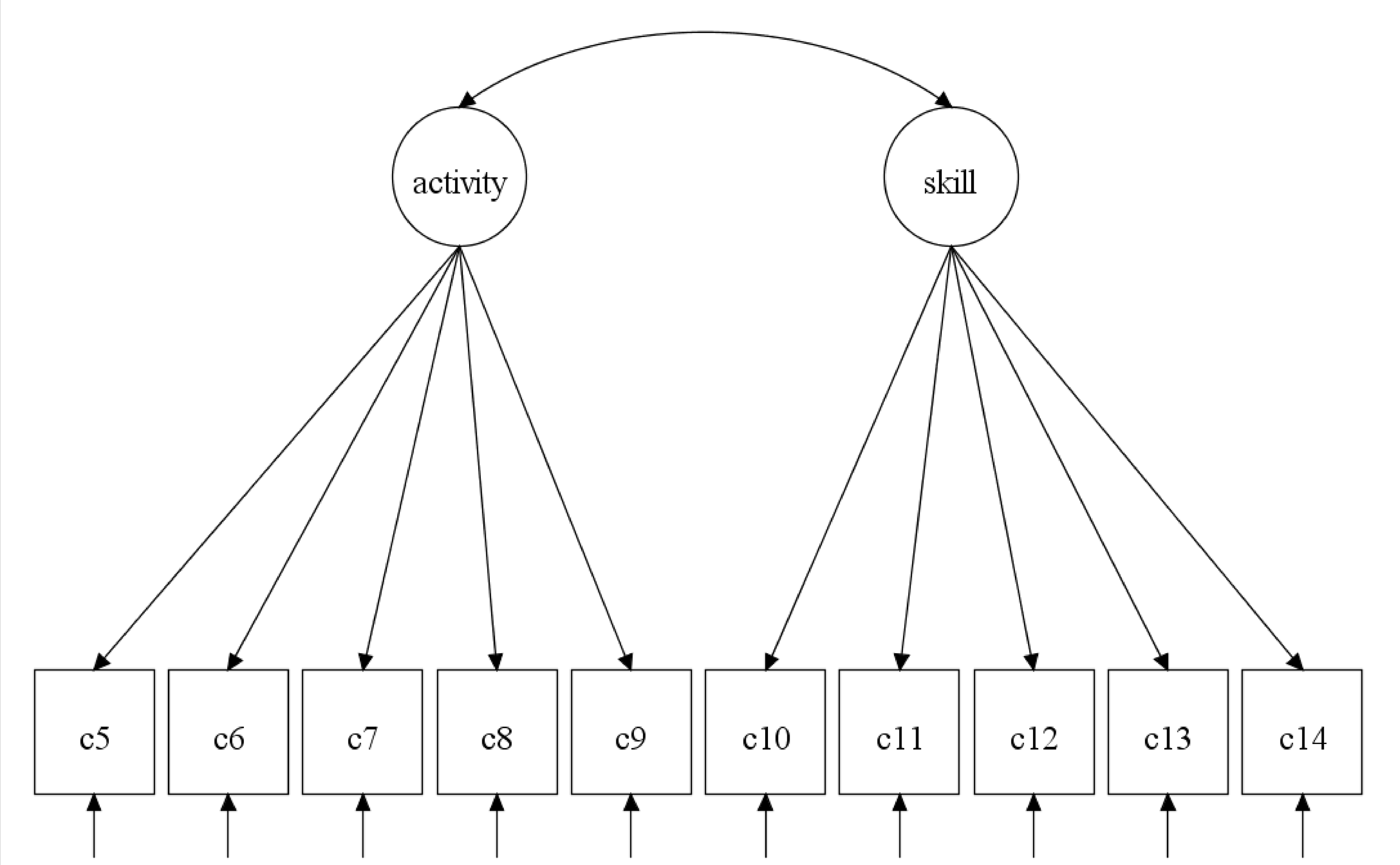

Figure 1. Hypothesized skill versus activity factor structure.

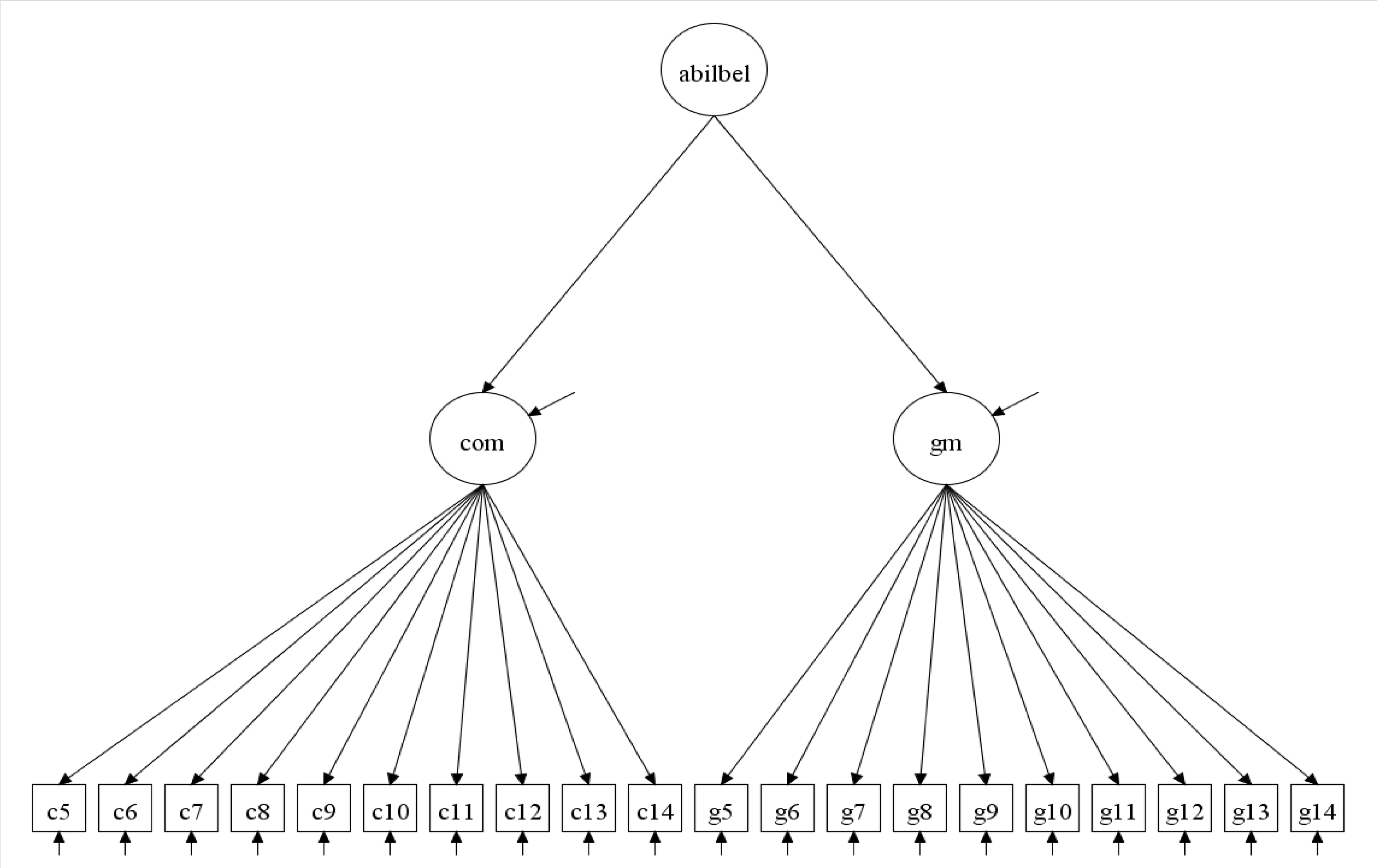

Figure 2. Ability beliefs higher-order factor structure.

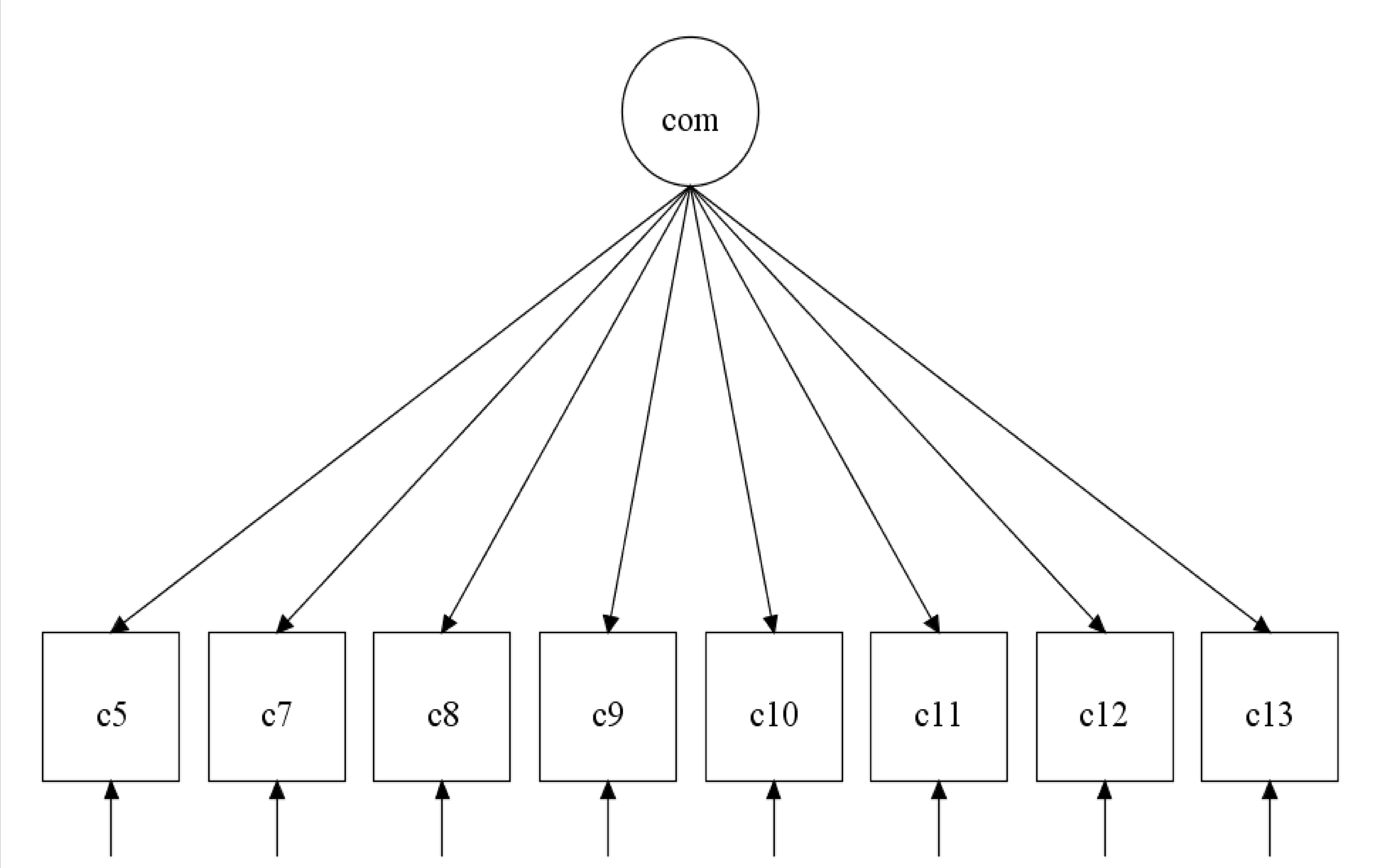

Figure 3. Final model to be used.

Step 3: Reliability

- Reliability analyses (Cronbach's alpha) were conducted as a measure of **internal consistency** for the items
- Range of the subscale Cronbach's alpha: 0.696—0.867
- Examined 'Cronbach's alpha when item is deleted' for each item
- Considered corrected item-total correlation (CITC)—correlation between an item with the scale computed from only the other items

Step 4a: Compiling Evidence

- Some items had recurring patterns (e.g., low loadings, high 'Cronbach's alpha when item is deleted', low CITC, etc.)
- Based on the patterns, we formed 3 criteria for "problem" items (Table 2) to recommend for elimination:
  1. Factor loadings below 0.4
  2. R^2 less than 0.2
  3. Correlation with another item greater than 0.4

Table 2. *List of "problem items".*

Problem Items	Compare
6. How good are you at building with things like legos, blocks, and k'nex (K-2); How good are you at building things using different materials (3-5)?	8. How good are you at taking things apart and putting them back together?
10. How good are you at trying when things are hard and not giving up?	10. (Growth Mindset) If you worked really hard, how good could you be at trying when things are hard and not giving up?
12. How good are you at thinking of many different ways to solve a problem (K-2); How good are you at looking at problems in different ways to find solutions (3-5)?	5. How good are you at solving problems?

Step 4b: Theoretical Considerations

- The analyses were presented to the team and theoretical considerations were raised, including gender differences and definitions of construct.

Final Decision

- Drop items 6 and 14
- Drop GM factor—GM highly correlated with COM and was not providing unique information

DISCUSSION

- Replicate factor structures with Pilot 2 data (new sample)
- Test invariance by ethnic group with larger sample
- Analyze parent and teacher-report measures
- Test theories for relations between constructs

Limitations

- Validity issues of lengthy measure (e.g., fatigue, skipping questions)
- Small sample sizes—combine Pilot 1 and 2 data

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