Conclusions From the Validation of a Vignette-Based Instrument to Measure Maker Mindsets

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Abstract: This manuscript describes the initial validation of an instrument to help measure maker mindset. Following initial item development and content validity testing, researchers assessed construct validity of the 24 items—15 vignette-based and 9 self-report—with exploratory factor analysis and 243 participants. Results supported validity for the resilience/growth mindset and willingness to tinker constructs, but not for collaboration orientation. However, further analysis suggested social desirability bias may have affected the results. In addition, vignettes did not load as predicted with their corresponding self-report items, nor did the self-report items demonstrate a coherent factor structure. Therefore, we suggest self-report data may inappropriate for measuring these constructs.

Introduction

To better understand the effect of maker-based educational environments on learners, we developed the Maker Mindset Instrument (MMI), a scale-based questionnaire to measure constructs often aggregated into the concept of *maker mindsets* (defined below). Our goal is to develop a measure that could be used in middle, secondary, and even postsecondary environments. We envision researchers using the MMI to help understand the impact of maker-based instructional designs and experiences on learners, and practitioners using the MMI as a formative assessment to inform curricular choices and to help predict student successes and/or frustrations. This paper summarizes the first two phases of the validation of the MMI before focusing on the third phase of validation.

Method

Instrument development proceeded in two stages: development and validation. We developed an initial set of constructs related to maker mindset based on a literature review. These included: self-efficacy (Chu, Quek, Bhangaonkar, Ging, & Sridharamurthy, 2015), motivation (Chu et al., 2015), interest (Chu et al., 2015), a sense of curiosity (Regalla, 2016), an interdisciplinary approach to challenges (Regalla, 2016), a disposition to share and collaborate (Dougherty, 2012; Martin, 2015; Regalla, 2016), a growth mindset (Martin, 2015; Regalla, 2016), playfulness (Honey & Kanter, 2013; Martin, 2015), resilience in the face of frustration (Martin, 2015; Regalla, 2016), can-do attitude (Dougherty, 2012), iterative approach to problem solving (Calabrese Barton, Tan, & Greenberg, 2017; Dougherty, 2012), do-it-yourself orientation (Peppler & Bender, 2013), and creativity (Calabrese Barton et al., 2017; Dougherty, 2012; Peppler & Bender, 2013). From this list of 13, we grouped together theoretically overlapping constructs (e.g., disposition to collaborate and interdisciplinary approach to challenges). We eliminated constructs if they were related to mindset, but not essential to our aim to measure features closely aligned with and specific to making (e.g., interest). We also excluded large constructs, such as motivation and self-efficacy, which are affected by too many factors (e.g., temporal factors such as fatigue and time of day), to be accurately measured in a multi-construct scale. Finally, we excluded constructs that would be measured better with a performance metric, such as problem-solving. The result was a group of 5 constructs: resilience, growth mindset, creativity, willingness to tinker, and collaboration orientation.

The validation process had three phases. The first phase (Cohen, Margulieux, Renken, Jones, & Smith, 2018) employed a card sorting procedure (Blanchard & Banerji, 2016) to establish content validity. To try to address the unreliability of self-report measures, we wrote 5 items per construct in the form of short vignettes (approximately 50-70 words). We hypothesized that vignettes would allow respondents to reveal their own mindset by answering a question about a fictitious character without requiring potentially biased self-reporting (Evans et al., 2015). The vignettes were constructed so that within a construct half of the vignettes were positively framed and half were negatively framed. The content focused on school-related situations, and ethnically diversity character names were used.

A group of professionals who work in the field of maker education (n=17) completed the card sorting task. Qualitative analysis of the group names assigned by the participants as well as multidimensional scaling analysis revealed 3 sub-scales that matched researchers' intended constructs, providing face validity: one for collaboration-related items, one for resilience and growth mindset items, and one for items related to tinkering

and creative thinking. Based on this analysis, we eliminated nine items that were not central in the constructs, leaving a total of 16 items.

The second phase of the validation process employed exploratory factor analysis (EFA). Preliminary investigation of the data collected from undergraduate students in a learning science participant pool (n=103) completed the 16-item MMI. Though the sample size was too small for a valid factor analysis, examination of the results indicated that a ceiling effect was present for some items which were worded in such a way to encourage more extreme responses. Therefore, we closed data collection for the second phase prior to collecting sufficient data for the EFA, reworked the language of some of the items, and eliminated one item entirely.

The third phase of the process, results of which are reported below, was an EFA using the revised items. In addition to the 15 vignettes, we added 9 self-report questions, 3 related to each construct, to provide more information about the vignette format (e.g., "I feel comfortable starting a project even if I don't already know how to finish it" for the willingness to tinker construct). Two hundred forty-three undergraduate students recruited from a learning sciences participant pool completed the revised 24-item MMI.

Results

The 24 items of the MMI were analyzed with EFA to examine the latent factor structure and to help identify any further problematic items. The number of factors was determined through examination of scree plots and through examination of the component matrix, rotated with varimax rotation and Kaiser normalization. Only items with loading coefficients higher than .40 were used, which is consistent with this type of exploratory work.

We calculated Kaiser-Meyer-Olkin Measure of Sampling Adequacy (*KMO*=.78) and Bartlett's Test of Sphericity (BTS=1107.62, $p < .001$), both of which confirmed the appropriateness of EFA for this data set. The initial EFA in this phase resulted in 6 factors, with 7 items cross-loading on 2 factors. The resilience/growth mindset vignettes loaded together, however, no pattern emerged for the other factors. To explore further the nature of these results, we ran EFAs separately for the vignettes and for the self-report items. The EFA on only the vignettes returned 3 factors. Again, the first factor included most of the resilience/growth mindset items, but the other 2 constructs were distributed among the other 2 factors. Three items cross-loaded on 2 factors, so we omitted these items from future analysis. In addition, we hypothesized that the multifaceted nature of collaboration orientation caused those items to be conflated with other constructs, so we eliminated those items from subsequent analysis, leaving 8 vignettes. The EFA on these 8 items yielded 2 factors, with resilience/growth mindset items loading on one factor and tinkering items loading on the other (Table 1). The EFA on the self-report items returned 3 factors, however the items did not load onto any of the factors with any discernable pattern (Table 2). A final EFA on the 8 vignette items and the 6 self-report items did not result in a coherent factor structure (Table 3). Internal reliability estimates were moderate for the vignettes, Cronbach's *alpha* = 0.68.

Table 1: Item factors, loadings, and reliability coefficients for the vignette-based MMI items

Items	Factor 1	Factor 2
RGM_V8	.712	
RGM_V4	.706	
RGM_V9	.634	
RGM_V6	.553	
T_V15		.746
T_V16		.611
T_V14		.610
T_V12		.599

Table 2: Item factors, loadings, and reliability coefficients for the self-report-based MMI items

Items	Factor 1	Factor 2	Factor 3	Factor 4
C_SR2	.764			
T_SR2	.761			
RGM_SR3	.625			
C_SR1		.807		
C_SR3		.716		
RGM_SR2		.465		
RGM_SR1			.780	

T_ SR1			.704	
T_ SR3				.931

Table 3: Item factors, loadings, and reliability coefficients for the vignette- and self-report-based MMI items

Items	Factor 1	Factor 2	Factor 3	Factor 4
RGM_V8	.728			
RGM_V4	.701			
RGM_SR2	.522			
T_SR2	.491			
T_V14	.446	.402		.445
RGM_V6	.435			
T_SR3	.402			
T_V16		.728		
T_V15		.727		
T_V12		.485		
T_SR1			.693	
RGM_SR1			.679	
RGM_SR3				.747
RGM_V9				.492

Alternative analysis: Item orientation

Though the EFA indicated a two-factor structure for the vignettes based on two constructs, an alternative analysis is that the factor structure could be responding to the orientation of the items. The four resilience/growth mindset items in the final EFA are all negatively oriented. For example, a resilience/growth mindset item reads:

> Chadna's first history test is coming up. She spends extra time studying for it until she feels well prepared. When she gets her grade back, it's lower than she expected based on how much she studied.
> *How much do you agree with the following statement: Chadna will probably score similarly on the next test, even if she spends extra time studying again.*

Contrast the negative orientation of this item with one of the tinkering items, all of which were oriented positively:

> Akio needs to make a presentation for the science fair. He was going to make part of it with popsicle sticks, but no one can take him to the store to get some. He decided to find a new material to make that part of the presentation.
> *How much do you agree with the following statement? Akio will likely be able to find a new material that will work without having to go to the store.*

The resilience/growth mindset item presents a scenario in which a student fails at a task, and the prompt which follows it asks respondents to agree or disagree with the idea that the student is simply bad at the task and always will be. In contrast, the student in the willingness to tinker item is creatively solving a problem, and the prompt asks respondents to agree or disagree with the idea that the student will be resourceful enough to succeed.

We suspect that some responses might be influenced by social desirability bias, which "reflects the tendency on behalf of the subjects to deny socially undesirable traits and to claim socially desirable ones, and the tendency to say things which place the speaker in a favourable light" (Nederhof, 1985, p. 264). Though presenting third-person vignettes can mitigate social desirability bias (Evans et al., 2015), the associated prompt (e.g., "How much do you agree with the following statement? Based on this first experience, Samuel will always struggle with programming") could be a source of social desirability bias in this study (Wason, Polonsky, & Hyman, 2002).

Discussion

The results of the validation process to this point do not allow us to make any conclusive decisions about the validity of the MMI. An EFA that included both the vignettes and self-report items did not yield any discernable factor structure. Further, separate EFAs on the vignettes alone and on the self-report questions alone also did not yield a factor structure. However, further research could resolve outstanding questions about the validity of the

vignette-based questions (see Future research, below). Additionally, our analysis suggests that future research into measuring maker mindset should consider other methods for measuring collaboration orientation. Given the multifaceted nature of collaboration, qualitative data collection and analysis may be most appropriate.

This analysis contributes to broader issues related to measuring a multifaceted domain like maker mindset. As is the case in other analyses of this kind, our analysis showed that self-report data may lack sufficient validity to understand latent constructs. That the self-report items did not load with their corresponding factors in the vignettes unsurprising; as we describe above, we cannot conclude definitively that the vignettes were measuring the constructs they were designed to measure. However, when examined on their own, the self-report items still did not evince a coherent factor structure. This finding aligns with what the field knows about the accuracies (or more often, inaccuracies) of students' metacognition. Further, these findings highlight the importance of considering social desirability bias as a threat to the validity of vignette-based measurements.

Future research

To test the effect of social desirability bias on the vignette factor structure, we will restate the negatively framed items to be positively oriented and repeat the EFA with another sample of students. If the results of that analysis indicate that further validation is warranted, we will try to establish convergent and divergent validity. That process will include administering the MMI along with other instruments, such as Need for Cognition (NFC; Cacioppo & Petty, 1982), and Dweck's (2006) mindset questionnaire. Scores on these measures will provide convergent validity for our constructs, meaning they will confirm whether people score similarly on existing scales that should measure similar constructs. For example, we expect NFC scores, which measures one's preference for complex problems and thinking will be related to MMI's willingness to tinker scores. We expect these scales also will provide divergent validity. For example, NFC scores should not be related to resilience.

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