Perceptions of Mathematics Relevance

EDRS 797: Introduction to Measurement and Survey Development
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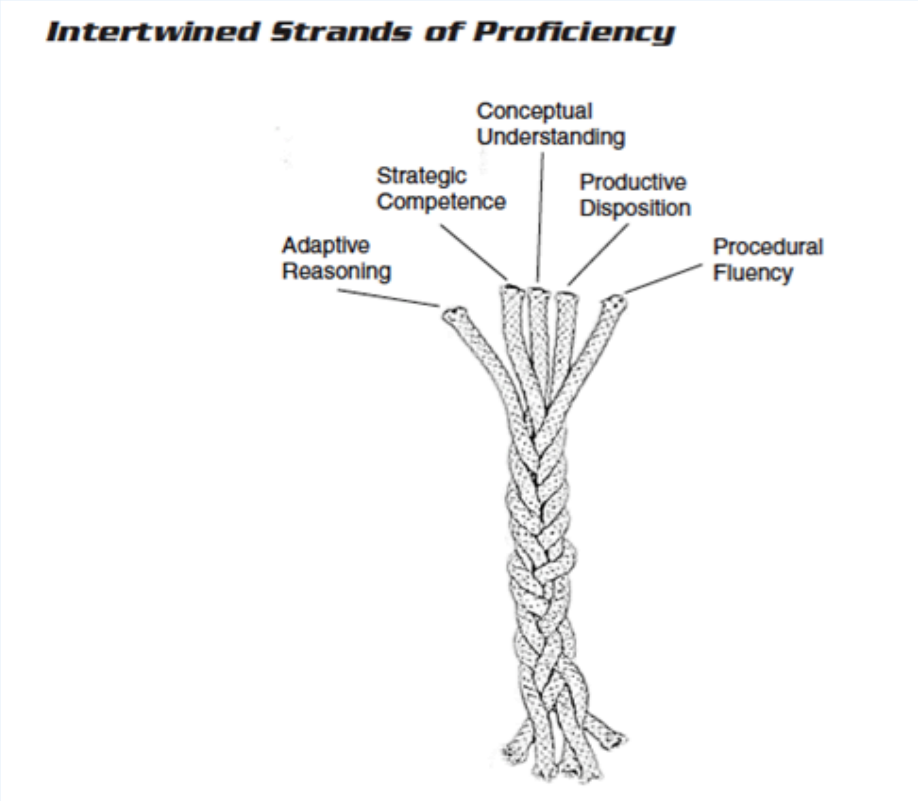
Problem Statement

The National Research Council (2001) described the conditions and structures that must exist for all students to learn and be proficient in mathematics.



Problem Statement

Future Directions for Research in Mathematics Education (NCTM, 2015)

- Changing perceptions about what it means to do mathematics
- **Changing the public's perception about the role of mathematics in society**
- Achieving equity in mathematics education

Impact of Perceptions

Students' attitudes and beliefs towards mathematics can influence:

- Mathematical thinking, performance, future opportunities, and decisions (Beyers, 2001; Kilpatrick, Swafford, & Findell, 2001; NCTM, 1989).
- Engagement on academic tasks such as time spent on working on problems, exploring solutions, gathering data, listening to explanations, reading texts, and justifying (Kilpatrick et. al., 2001; NCTM 1989).

Literature Review: Student Perceptions

- Mathematics is boring and impractical
  (Murray, 2011)

- Mathematics learned in the classroom cannot be applied to everyday life
  (Boaler, 2000)

- Mathematics is only useful in mathematics lessons and for exams
  (Onion, 2004)

Gaps in Literature

- Prior research is primarily qualitative
- Lack of quantitative measures about the relevance of mathematics content
  - 2009 High School Longitudinal Survey by U.S. Department of Education National Center for Education Statistics
  - TIMSS 2011 Students Value Mathematics Scale
  - Attitudes in Mathematics Inventory (ATMI) (Tapia & Marsh, 2004)

Need for quantitative measure of students' perceptions on a continuum

Research Purpose

Develop and validate an instrument to measure secondary students' perceptions of the relevance of mathematics content

Methods

Methods: Literature Search for Item Development

Databases searched: Social Sciences Citation Index, APA Psycnet, Education Full Text, Education Research Complete, Science Direct, and ERIC databases.

Key words: relevance, meaningfulness, usefulness, utility value, and task value

Methods: Content Validity

Expert Interviews (Gehlbach & Brinkworth, 2011)

Reviews with experts in mathematics education, educational psychology, and/or applied educational measurement

- A professor in mathematics education
  Expertise in equity frameworks
- A Ph.D. candidate in educational psychology
  Expertise measurement of attitudes and beliefs in mathematics education

Methods: Content Validity

Expert Interviews

- Interview protocol
  - Before the interview each expert received the definition of the construct, purpose of the instrument, and the list of items.
  - During the interviews the experts were asked:
    - How understandable and clear was each item?
    - Did the item represent each construct dimension?
  - A think-aloud protocol was used during the interviews.
  - Extensive field notes and digital recording equipment were used to capture responses.
- The results of the expert interviews were discussed within the research team, and the items were revised accordingly.

Methods: Face Validity

Cognitive Interview Participants

Gender	Grade	Math Course	Career Interest
Female	9	Geometry HN	Veterinarian
Female	9	Geometry HN	Physicist
Female	9	Algebra 2HN	Forensic Science
Male	9	Geometry Advanced	Zoologist
Male	10	Precalculus	Scientist
Female	11	Precalculus HN	Business
Male	11	Algebra 2	US Navy pilot
Male	11	IB SL1	Engineering
Male	11	College Math Concepts	US Air Force combat rescue
Female	12	IB Math Studies	Business

Methods: Face Validity

Cognitive Pretesting prior to pilot testing (Gehlbach & Brinkworth, 2011)

- Researchers read question aloud
- Students rephrase questions in their own words
- Students engage in "think aloud" as they answer questions
- Audio recordings and student database of student responses and field notes
- Open coding for significant themes

Qualitative confirmatory analysis after pilot testing (Karabenick et al., 2007)

Methods: Pilot Study Administration

Participants: 74 high school students; mean age of 16.2 (SD = 1.29)

Gender	Male 51.4%	Female 48.6%		
Ethnicity	White 75.7%	African-American 8.1%	Other 16.2%	
Grade Level	Freshman 18.9%	Sophomore 21.6%	Junior 12.2%	Senior 47.3%
Career Interest	STEM 40.5%	Non-STEM 37.9%	Undecided 21.7%	
Mathematics Achievement	Mostly A's 45.9%	A's and B's 36.5%	Other 17.6%	

Methods: Pilot Study Administration

Convenience sampling and snowball sampling

- Parental consent in the form of emailed survey link to students
- Student assent at the beginning of the survey
- Incentive for survey completion (Raffle for $10 Starbucks giftcard)

Google Forms

- 22 relevance items followed by demographic survey

Methods: Construct Validity

To identify the underlying factor structure of mathematics relevance, we conducted an exploratory factor analysis with

- the principal axis factoring extraction method
- the Oblimin rotation method

The number of factors to retain was determined based on

- the Eigenvalue > 1 rule, scree plot, map, and parallel analysis
- interpretability of the factors being extracted

Methods: Predictive Validity

Predictive validity of the scale was examined through

- regressing the dimensions on the grades the participants typically receive in their mathematics classes (multiple regression)
- regressing the dimensions on the career choice: STEM vs. non-STEM (logistic regression)

Results

Results: Items Writing (Original Scale)

Compilation and composition of 47 items with citations

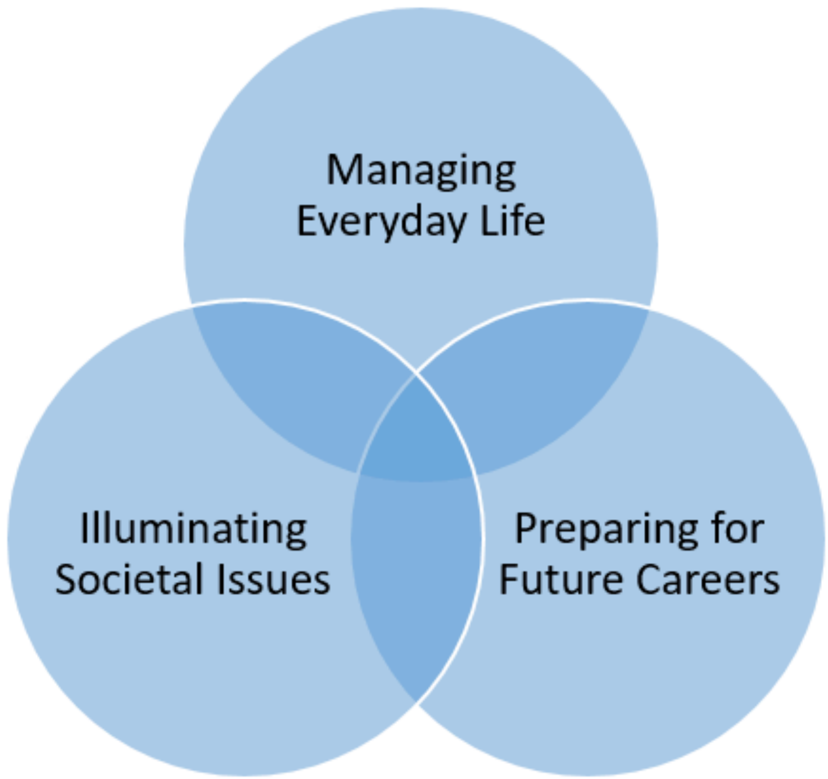
Existing Instrumentation

- Perceived Relevance of Science Scale (Adapted from Siegel & Ranney,2003)
- Student Attitudes Survey (Brookstein, Hegedus, Dalton, Tapper, & Moniz, 2011)
- Short Form Attitudes Toward Mathematics Inventory (Lin & Chapman, 2013)

Researcher-Created Items (informed by literature)

- Darby-Hobbs (2013) – presence of expectation, need, aspiration
- Woolley et al. (2013) – career relevant instruction
- Gutstein & Peterson (2006) – teaching math for social justice

Results: Operationalization of Relevance



Our operationalization of relevance does NOT include:

- Mathematics as a gateway to college admissions
- Mathematics as culturally responsive/relevant
- Like or dislike of mathematics as a subject
- Student ability and achievement
- Specific examples of usefulness

Results: Content Validity

Experts' Recommendations

Item: **My math knowledge makes me a more valuable member of society.**

- Experts:
  - H: Think they will know what they need. Responsible would be different. There's a lot of issues with valuable. Guess you could say 'contribute' Having learned math do you see yourself as more value than if you had not learned math. Maybe rephrase as, studying math makes me more of an informed citizen. It may be a little hard for them to understand but I think most secondary have defined that for themselves.
  - F: I'm not liking the word 'more'. Are we implying math makes someone a more valuable member of society compared to someone in the humanities? Maybe rephrase as my math skills makes me a valuable contributor to society.
- Team response:
  - K: agree
  - Monique: **Studying math makes me a valuable contributor to society OR Studying math makes me more of an informed citizen.**
  - T: or Studying math makes me a more informed citizen.
  - I: Agree Informed citizen, because valuable contributor requires students more and high.
  - D: I agree with Dr. F's questions -- sounds exactly like that. People who don't study math are not valuable contributors or informed citizens? That's simply offensive to people in humanities. Knowing math would be somewhat better, still bad though...

Results: Content Validity

Experts' Recommendations

- Language
  - Revise to middle-school level
  - Math skills vs. math knowledge

- Societal Issues dimension
  - Students difficulty interpreting "societal issues"
  - More accessible construct is "helping my community"
  - Big ideas may prove complex for students
  - Use specific examples such as "income inequality"

Results: Face Validity

Cognitive Pretesting

1st Subscale (Managing everyday life)

Narrow interpretation of "high school mathematics"

2nd Subscale (Illuminating societal issues)

Challenging Vocabulary **"***inequity, advocate, information, community"*

3rd Subscale (Preparing for future careers)

Broad Interpretation of *"professional life"* and *"earn a living"*

General Item Redundancy

"use" vs *"apply"*

"problem solving skills" vs *"knowledge"*

Results: Face Validity

Cognitive Pretesting

Item wording in response to expert interview

I can use my math skills to help others.

14. I can use my math skills to help others in my community. OMIT - ambiguity

*A - Agree (less broad than society, more broad than self, **statistics for sports team**)*

*B - Disagree (community service, babysitting, **helping neighbors** - in a social sympathetic way)*

*C - Strongly Agree (Is that other students in my community? A lot of people ask for help - not tutoring - but **helping on math during lunch**)*

D - I really don't know (Is others in my community friends or everyone that lives in Vienna?) I really don't know what the issues are in Vienna)

E - Somewhat Agree (I can apply what I've earned - struggled to think of an example)

K1: Does my understanding of math help problems or tasks of the community. I don't understand

*K2: I can use geometry to **help others in my community build houses and gardens**, unless I'm **helping others with their math homework.***

K3: Math skills helping friends, buying food. I also think of Clifton/Centreville as my community. When do I use math to help someone.

*K4: I can use math to solve community problems like **my friend can't do math** and he wants to know one plus one. Agree*

*K5: **Helping tutor in math.***

Revised item presented to students

Differing **interpretations** of community (green)

Results: Descriptive Statistics

The means of the hypothesized career and everyday relevance items were comparable.

The means of the hypothesized societal relevance items were lower than the means of the other two dimensions.

Also, the mean for E7r ("I already know more math than I need in my daily life") was out of pattern.

All items had similar variance.

Item Label	Mean	*SD*
C1	4.54	1.581
C2	4.32	1.589
C3r	4.14	1.608
C4	4.41	1.516
C5	4.95	1.084
C6r	4.39	1.603
C7	5.08	1.070
C8	4.26	1.588
E1	4.14	1.573
E2	4.31	1.281
E3	4.39	1.451
E4	5.14	1.275
E5r	4.68	1.386
E6	4.31	1.442
E7r	2.92	1.524
E8	4.97	1.146
S1	4.55	1.305
S2	3.41	1.404
S3	3.39	1.560
S4	4.03	1.526
S5	3.73	1.474
S6	3.28	1.609

Results: Construct Validity

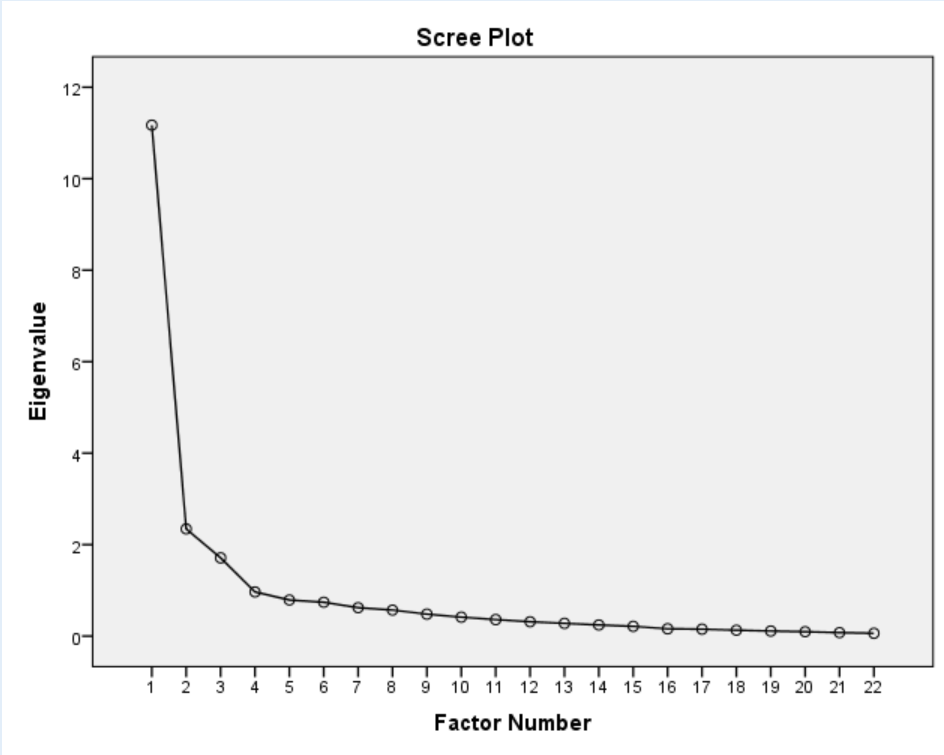
EFA assumptions:

- Most items were positively skewed (as revealed by histograms)
- The assumption of linearity was met through examination of bivariate scatterplots
- Sufficient variance was present in the matrix as indicated by the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (meritorious)
- Invertibility of the matrix was supported by its determinant (less than 0.00000001)
- Necessary strength of correlations among variables was checked through the significant result of the Barlett's test of Spherisity
- Correlational analysis revealed low correlations ($r < 0.30$) for items E4, E7r, and C3r

Results: Number of Factors to Retain

22 items:

- Map: 4 factors
- Parallel Analysis: 3 factors
- Eigenvalue > 1: 3 factors
- Scree Plot: 2-3 factors



Results: Construct Validity

Our theoretical 3 factor solution was not supported by EFA
(64.27% of total variance explained)

Only a few items loading on the third factor suggested considering a 2-factor model

Items were not loading on the theoretically identified factors; some were also cross-loading

Low communalities (less than 0.5) were also problematic

Item Label	Factor Loadings			Communalities
	Factor 1	Factor 2	Factor 3	
C1	.046	**.773**	.174	.738
C2	.130	**.817**	.078	.839
C3r	-.010	**.689**	-.205	.441
C4	.177	**.685**	.209	.766
C5	.034	.395	**.514**	.548
C6r	.039	**.795**	-.120	.628
C7	.026	.273	**.608**	.546
C8	-.113	1.002	.035	.916
E1	.335	.345	.264	.528
E2	**.562**	.021	.256	.500
E3	**.534**	.220	.347	.746
E4	.094	-.138	**.688**	.488
E5r	.456	.323	.192	.595
E6	**.529**	.130	.384	.685
E7r	**.605**	.136	-.376	.421
E8	.422	-.014	.517	.593
S1	**.478**	.204	.222	.518
S2	**.745**	.127	.114	.750
S3	**.838**	.047	-.030	.727
S4	**.585**	.310	.191	.771
S5	**.815**	-.084	.156	.710
S6	**.921**	-.123	-.134	.685

Results: Construct Validity

Two-factor model provided interpretable solution with 62.44% of variance explained (a total of 6 items were deleted from the original scale: E1, E5r, E7r, C4, C5, and C7).

Factor 1 - everyday and societal relevance (mean = 4.33; SD = 1.36), Factor 2 - career relevance (mean = 4.14; SD = 1.10).

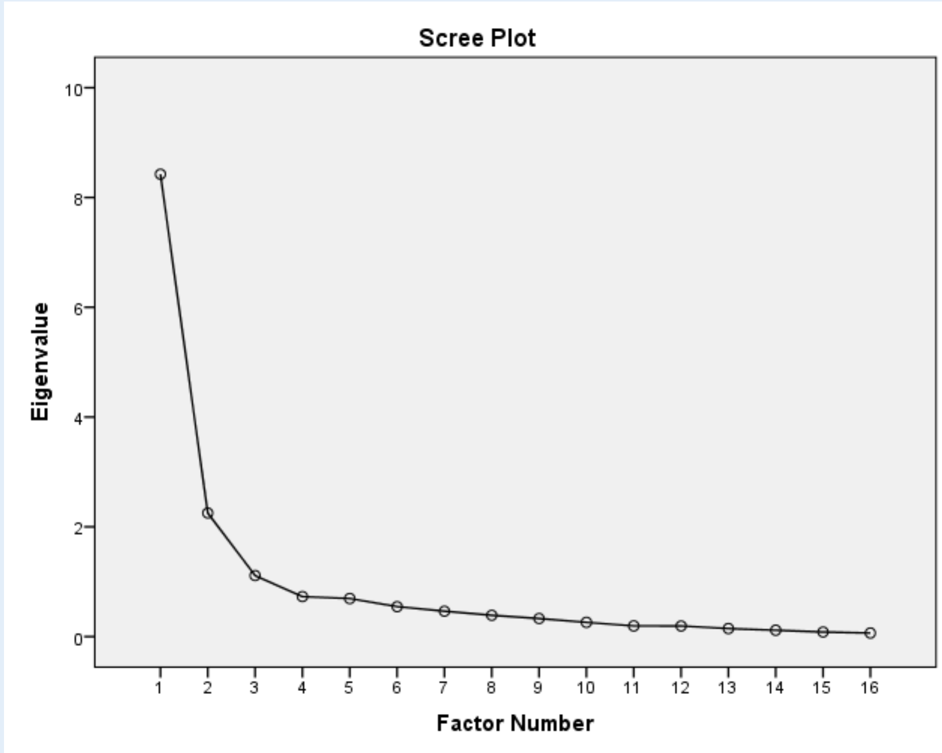
Total scale mean = 4.20; SD = 1.05. The two factors were moderately correlated (r = .424).

Item Label	Factor Loadings		Communalities
	Factor 1	Factor 2	
C1	.246	**.713**	.718
C2	.264	**.776**	.845
C3r	-.098	**.682**	.419
C6r	.020	**.773**	.611
C8	.019	**.947**	.913
E2	**.698**	.019	.499
E3	**.746**	.192	.715
E4	**.498**	-.163	.206
E6	**.759**	.107	.656
E8	**.737**	-.053	.513
S1	**.623**	.187	.522
S2	**.793**	.147	.749
S3	**.751**	.106	.643
S4	**.711**	.306	.784
S5	**.862**	-.063	.701
S6	**.716**	-.032	.494

Results: Number of Factors to Retain

16 items:

- Map: 3 factors
- Parallel Analysis: 2 factors
- Eigenvalue > 1: 3 (2) factors
- Scree Plot: 2 factors



Results: Predictive Validity with Math Grades

A regression analysis was conducted to determine whether Career Relevance, and Everyday Life and Societal Relevance predict students' math grades

The results indicated that 21% of variance in math grades was explained by the model

Only Everyday Life and Societal Relevance appeared to be a significant predictor of math grades

The correlation between the overall relevance scale and math grades was moderate (r = .458)

Model	*B*	*β*	Correlation		
			Zero-order	Partial	Part
(Constant)	6.064				
Career Relevance	.125	.157	.349	.147	.132
Everyday Life and Societal Relevance	.350*	.354*	.439	.318	.298

* Significant at $p < .05$

Note: math grades variable is heavily positively skewed.

Results: Predictive Validity with Career Choice

A logistic regression was conducted to determine whether relevance dimensions predict students' career choice.

The results showed that only career relevance is a significant predictor of career choice.

Every one point change in career relevance increases the odds of being a STEM major by 3.337.

Career Aspirations	Sample size (N)	Career Relevance *M (SD)*	Everyday Life and Societal Relevance *M (SD)*
Non-STEM	30	3.61 (1.50)	3.76 (1.21)
STEM	28	5.23 (.73)	4.49 (.93)

Observed	Predicted		% Correct
	Non-STEM	STEM	
Model 1			
Non-STEM	22	8	73.3
STEM	6	22	78.6
Overall % Correct			75.9

Predictor	B	Wald	df	p	Exp(B)
Model 0					
(Constant)	-.069	.069	1	.793	.993
Model 1					
(Constant)	-6.050	10.173	1	.001	.002
Career Relevance	1.205	10.855	1	.001	3.337
Everyday Life and Societal Relevance	.112	.129	1	.720	1.118

Qualitative Confirmatory Analysis
Cognitive Pretesting

Name	Omitted Items
E1	I use math to make decisions outside of school.
E5r	I don't need math in my daily life.
E7r	I already know more math than I need in my daily life.
C4	I need math knowledge to be successful in my career.
C5	Knowing math will make me more competitive in the job market.
C7	Studying math gives me more career choices.

Omitted Items - Confirmation from Cognitive Interviews

Item E7r: "That seems like more of an opinionated question because I like math and I would love to learn more math."

Item C7: Strongly agree (Describes math as both gateway and career choices, restricted access)

Discussion: EFA with Small Sample Size

Thresholds depend upon: (Winter, Dodou, & Wieringa, 2009)

Communalities: Strengthens as level of communalities increases. Recommended >.8	Range: .419 - .913 One out of pattern: .206
Loadings, Factors, Respondents: Simulations results for .6 loading with 2 factors indicated that a sufficient number for satisfactory factor recovery for 12-24 items is 34-39 respondents.	Loadings range: .6 - .9 Factors: 2 Items: 16 Respondents: 74
Sample insufficiently representative of the population will distort the factor structure	Sample has high level of homogeneity: Math grades positively skewed Race/Ethnicity

Limitations

Time Constraints

- Insufficient sample size (n < 220) for EFA
  Need both parents' consent and students' assent within short data collection time
- Follow-up expert and cognitive pretest interviews not conducted

Sampling

- Snowball Sampling & Convenience Sampling
  Not representative of high school student population

Implications

Developing and validating the scale addressed a gap in the field of math education

- Lack of scales or measurements about relevance of math

Preliminary results support continued development of the scale

Well-developed & validated scale will be used by

- High school students: Metacognitive reflection as high school comprehend and interpret the meaning of mathematics
- Educators: Understanding students' perceptions of mathematics usefulness
- Policy makers and curriculum designers: Understanding perceived relevance of math in classrooms and school divisions

Next Steps for Research

- Continue collecting data to enlarge and diversify the sample
  - Socioeconomic Status
  - Ethnicity
  - Achievement

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