NEEDED MATH

FUNDED BY THE NATIONAL SCIENCE FOUNDATION, GRANT # 2100062

Identifying Needed Math Competencies:

Where We are Now and Finding a Pathway Forward

Introductions

- PI: Michael Hacker michael.hacker@hofstra.edu
- Marilyn Barger marilyn.barger@flate.org
- Lisa Seidman Lseidman@madisoncollege.edu

Hi-Tec 2023

- Hi-Tec 2023 falls at pivot point in life of Needed Math project
- Draft results are available and we are looking for input to guide final phase of project

Overview of This Talk

- Part I: Introduction to Needed Math project
- Part II: Provide draft results from project's national survey of educators and technicians
- Part III: Where to now? Discussion

We Think There is a Problem Relating to Math

-Hence our grant project

Quote from Educator Who Completed Survey

"K-12 (and college) math is taught as a purely theoretical construct, to prepare students for more advanced math classes, as if everyone is going to be a math major in college. This is completely wrong-headed and results in people fearing and hating math. Historically, most mathematics was developed to do things in the real world such as counting sheep, calculating the area of a house, determining the pitch of a roof, or calculating energy needed to heat a house. Math should be taught that way up until college… we need to stop avoiding teaching math as a practical tool for the vast majority of people, just so that we can prepare a small minority of people to love the beauty of theoretical math so that they can be good math majors in college. And then go on to be math teachers, thereby propagating the cycle."

Quote from a Completed Survey

"I am very passionate about this topic because although my students have all had 12+ years of math classes, most do not feel they are good at it, do not like it, and do not know how to use math as a tool. Their math classes were not application-based but instead were all theory. The few applications they were taught, such as the famous "A train leave Chicago at 2PM travelling east at 45 miles per hour…" are so contrived that they give students no idea what math is useful for in their real lives."

The Needed Math Project

NEEDED MATH is a three-year Targeted Research Project in Technician Education to improve alignment of the mathematics taught in two-year technical college programs with the math manufacturing technicians use in the workplace.

This project followed an ATE conference grant to explore the topic with educators and industry representatives.

The Needed Math Project

- **Initial research included:**
  - industry site visits
  - reviewing manufacturing skill sets, competency models, etc.
  - various common core math standards
  - certification exams relating to manufacturing
  - interviews/meetings with various math education groups
  - reviewing technical mathematics textbooks
  - surveys of manufacturing technicians, technical subject, and mathematics instructors

Survey: Based on Initial Research Findings

- Purpose of Survey:
  - Determine where there is consensus and where significant differences between math educators, technical educators, and technicians in:
    - Frequency of use of specific math tools
    - Preparation of technicians to use those math tools

Survey Development

- Complex and difficult
- Occurred over 2.5 years
  - Based on research, as noted above

Resulting Survey

- 40 items identified and compiled into survey format
- Draft survey was tested with small group
- “Talk-alouds”
- Final survey was sent to more than 10,000 people and to colleagues
- ≈ 560 people completed entire survey

MEASUREMENT

1. Make conversions between units of measurement (for example, inches to centimeters)
2. Work with ratios or rates (for example, percentages, concentrations, speed)
3. Take measurements using physical tools (for example, calipers, micrometers, scales) or instruments (for example, voltmeters, oscilloscopes, pressure gauges).
4. Make estimates (for example, of measurements, quantities, production runs)
5. Do work that requires accuracy to a specified tolerance (for example, +/- 5%, +/- 0.003 inches)

STATISTICS

6. Read, document, and/or interpret sensor data (for example from temperature, pressure, or flow sensors)?
7. Use sampling to collect data (for example sampling a production run)
8. Read and interpret tables, graphs, or plots of data
9. Make tables, graphs, or plots of data
10. Use, interpret, or calculate statistical measures (for example, average, standard deviation, range)
11. Read and analyze control charts
12. Use data to optimize a production process (for example, minimize waste and costs, or maximize production and quality)

Etc.

Three Groups Surveyed

- Math educators in two-year college settings
- Technical educators in two-year college settings
- Technicians in manufacturing workplaces

For Each Math Tool on Survey,Two Ratings

1. On scale of 1-5, how often do you, as part of your job in manufacturing, need to…

2. On scale of 1-5 how well do you believe courses required in school prepare manufacturing technicians to do this task on the job?

Results: Frequency

Item #	Item Wording	Math Educators MEd)		Tech Educators (TEd)		Technicians		Whole Group (WG) Ranking		
		MEd Rank	MEd Mean	TE Rank	TEd Mean	Tech Rank	Mean	By Rank	WG Mean	By Item
Q3	Take measurements using physical tools or instruments (Freq)	1	4.80	1	4.80	1	4.71	1	4.77	Q3
Q26	Use blueprints, diagrams, drawings, flow charts, or schematics (Freq)	7	4.56	2	4.61	5	4.36	2	4.51	Q26
Q28	Use metric (or SI) prefixes (Freq)	3	4.68	7	4.35	2	4.56	3	4.48	Q28
Q4	Make estimates (Freq)	2	4.72	4	4.48	6	4.35	4	4.48	Q4
Q2	Work with ratios or rates (Freq)	6	4.60	6	4.36	3	4.42	5	4.42	Q2
Q6	Read, document, and/or interpret sensor data (Freq)	5	4.65	5	4.43	10	4.12	6	4.36	Q6
Q5	Do work that requires accuracy to a specified tolerance (Freq)	4	4.68	3	4.50	11	3.98	7	4.35	Q5
Q39	Use data to troubleshoot problems (Freq)	10	4.19	8	4.25	4	4.38	8	4.28	Q39
Q1	Make conversions (Freq)	12.5	4.08	9	4.16	7	4.24	9	4.18	Q1
Q31	Make conversions between different ways of expressing numbers (Freq)	8	4.37	10	4.04	8	4.21	10	4.15	Q31
Q8	Read and interpret tables, graphs, or plots of data (Freq)	15	4.06	11	4.00	9	4.18	11	4.07	Q8
Q32	Work with prepared spreadsheets (Freq)	14	4.07	12	3.79	12	3.83	12	3.85	Q32
Q21	Use spatial reasoning (Freq)	9	4.30	13	3.78	19	3.35	13	3.72	Q21
Q7	Use sampling to collect data (Freq)	21	3.73	14	3.66	17	3.39	14	3.58	Q7
Q22	Use angle measurements (Freq)	11	4.09	15	3.62	23	3.23	15	3.57	Q22
Q34	Use a scientific or graphing calculator (Freq)	19	3.85	18	3.57	20	3.34	16	3.54	Q34
Q11	Read and analyze control charts (Freq)	12.5	4.08	17	3.58	27	3.17	17	3.53	Q11
Q37	Use math to prepare reports (Freq)	24	3.66	20	3.49	21	3.32	18	3.46	Q37
Q13	Substitute numbers into formulas and evaluate (Freq)	16	3.92	25	3.25	14	3.48	19	3.44	Q13
Q20	Use geometric topics (Freq)	25	3.65	19	3.54	26	3.20	20	3.44	Q20
Q36	Collect, analyze, and use information from a system (Freq)	18	3.87	16	3.60	31.5	2.93	21	3.42	Q36
Q18	Find perimeters, areas, or volumes (Freq)	17	3.92	22	3.38	25	3.21	22	3.41	Q18
Q10	Use, interpret, or calculate statistical measures (Freq)	27	3.45	24	3.28	13	3.53	23	3.40	Q10
Q27	Use scientific or engineering notations (Freq)	20	3.82	28	3.12	15	3.45	24	3.35	Q27
Q16	Use direct or inverse variation (Freq)	22	3.72	23	3.36	29	3.11	25	3.33	Q16
Q12	Use data to optimize a production process (Freq)	30	3.39	21	3.40	28	3.12	26	3.30	Q12
Q25	Work with amplitude, frequency, or period (Freq)	31	3.31	27	3.17	16	3.44	27	3.29	Q25
Q30	Use inequalities (Freq)	26	3.65	29	3.09	22	3.30	28	3.25	Q30
Q9	Make tables, graphs, or plots of data (Freq)	34	3.19	30	3.08	18	3.38	29	3.15	Q9
Q33	Use spreadsheets for tasks beyond working with prepared spreadsheets (Freq)	32	3.27	32	2.95	24	3.21	30	3.10	Q33
Q24	Use right triangle trigonometry (Freq)	29	3.39	33	2.94	34	2.81	31	2.98	Q24
Q23	Use Geometric Dimensioning and Tolerance (Freq)	23	3.69	31	3.08	36	2.46	32	2.96	Q23
Q38	Use graphs, tables, data, formulas or simulations (Freq)	33	3.23	34	2.75	31.5	2.93	33	2.90	Q38
Q17	Work with exponential functions (Freq)	37	2.72	35	2.71	30	3.06	34	2.83	Q17
Q35	Use math when using a CNC system (Freq)	28	3.41	26	3.19	40	1.94	35	2.79	Q35
Q15	Fit a curve to data (Freq)	36	2.78	37	2.49	35	2.76	36	2.63	Q15
Q19	Work with logarithms (Freq)	38	2.68	39	2.47	33	2.83	37	2.63	Q19
Q40	Use math to forecast performance measures or future outcomes (Freq)	35	2.95	38	2.47	37	2.31	38	2.50	Q40
Q14	Manipulate a formula to get a new formula (Freq)	39	2.57	36	2.55	39	1.98	39	2.47	Q14
Q29	Use complex numbers (Freq)	40	1.87	40	1.83	38	2.17	40	1.95	Q29
			149.59		139.17		135.73			
	items highlighted in yellow indicate a significant ANOVA result with a p-value less than 0.05.									

Results: Preparation

Item #	Item Wording	Math Educators MEd)		Tech Educators (TEd)		Technicians		Whole Group (WG) Ranking		
		MEd Rank	MEd Mean	TE Rank	TEd Mean	Tech Rank	Mean	By Rank	WG Mean	By Item
Q31A	Make conversions between different ways of expressing numbers (Prep)	2	3.48	4.5	3.26	2	3.03	1	3.22	Q31A
Q28A	Use metric (or SI) prefixes (Prep)	7	3.16	1	3.32	3	3.02	2	3.19	Q28A
Q2A	Work with ratios or rates (Prep)	5	3.26	4.5	3.26	7.5	2.90	3	3.13	Q2A
Q18A	Find perimeters, areas, or volumes (Prep)	3	3.40	9	3.13	6	2.94	4	3.11	Q18A
Q13A	Substitute numbers into formulas and evaluate (Prep)	1	3.63	13	3.08	9	2.88	5	3.11	Q13A
Q1A	Make conversions (Prep)	8	3.16	6	3.19	7.5	2.90	6	3.08	Q1A
Q34A	Use a scientific or graphing calculator (Prep)	4	3.33	8	3.14	15	2.71	7	3.03	Q34A
Q8A	Read and interpret tables, graphs, or plots of data (Prep)	9	3.13	10	3.11	11	2.83	8	3.02	Q8A
Q22A	Use angle measurements (Prep)	6	3.22	11	3.11	14	2.74	9	3.00	Q22A
Q3A	Take measurements using physical tools or instruments (Prep)	20	2.66	2	3.32	18.5	2.64	10	2.97	Q3A
Q30A	Use inequalities (Prep)	10	3.12	18	2.93	5	2.94	11	2.97	Q30A
Q20A	Use geometric topics (Prep)	13	2.98	14	3.06	13	2.77	12	2.95	Q20A
Q27A	Use scientific or engineering notations (Prep)	12	3.02	17	2.95	10	2.85	13	2.93	Q27A
Q9A	Make tables, graphs, or plots of data (Prep)	15	2.86	20	2.88	1	3.27	14	2.93	Q9A
Q5A	Do work that requires accuracy to a specified tolerance (Prep)	21	2.63	7	3.16	17	2.65	15	2.89	Q5A
Q4A	Make estimates (Prep)	16	2.84	15	3.06	18.5	2.64	16	2.88	Q4A
Q24A	Use right triangle trigonometry (Prep)	11	3.03	21	2.86	12	2.79	17.5	2.87	Q24A
Q6A	Read, document, and/or interpret sensor data (Prep)	22	2.59	12	3.09	16	2.69	17.5	2.87	Q6A
Q14A	Manipulate a formula to get a new formula (Prep)	14	2.88	23	2.81	4	3.02	19	2.86	Q14A
Q26A	Use blueprints, diagrams, drawings, flow charts, or schematics (Prep)	27	2.34	3	3.27	26	2.50	20	2.85	Q26A
Q39A	Use data to troubleshoot problems (Prep)	30.5	2.31	16	2.95	25	2.55	21	2.71	Q39A
Q32A	Work with prepared spreadsheets (Prep)	32	2.27	19	2.90	20	2.64	22	2.70	Q32A
Q17A	Work with exponential functions (Prep)	17	2.82	28	2.61	23	2.59	23	2.64	Q17A
Q10A	Use, interpret, or calculate statistical measures (Prep)	19	2.74	29	2.60	21	2.63	24.5	2.64	Q10A
Q7A	Use sampling to collect data (Prep)	23	2.43	22	2.85	29	2.43	24.5	2.64	Q7A
Q16A	Use direct or inverse variation (Prep)	18	2.76	25	2.67	28	2.44	26	2.61	Q16A
Q37A	Use math to prepare reports (Prep)	29	2.32	27	2.64	22	2.60	27	2.57	Q37A
Q25A	Work with amplitude, frequency, or period (Prep)	24	2.41	26	2.67	30	2.42	28	2.54	Q25A
Q21A	Use spatial reasoning (Prep)	30.5	2.31	24	2.73	36	2.16	29	2.46	Q21A
Q15A	Fit a curve to data (Prep)	26	2.37	35	2.39	24	2.59	30	2.46	Q15A
Q19A	Work with logarithms (Prep)	25	2.38	36	2.38	27	2.47	31	2.41	Q19A
Q11A	Read and analyze control charts (Prep)	34	2.19	31	2.57	33	2.18	32	2.37	Q11A
Q12A	Use data to optimize a production process (Prep)	28	2.33	33	2.50	35	2.17	33	2.36	Q12A
Q36A	Collect, analyze, and use information from a system (Prep)	35	2.18	30	2.57	37	2.10	34	2.35	Q36A
Q38A	Use graphs, tables, data, formulas or simulations (Prep)	36	2.17	37	2.32	31	2.34	35	2.30	Q38A
Q33A	Use spreadsheets for tasks beyond working with prepared spreadsheets (Prep)	38	1.96	34	2.44	32	2.28	36	2.30	Q33A
Q35A	Use math when using a CNC system (Prep)	37	2.13	32	2.53	39	1.97	37	2.27	Q35A
Q29A	Use complex numbers (Prep)	33	2.20	39	2.12	34	2.17	38	2.15	Q29A
Q23A	Use Geometric Dimensioning and Tolerance (Prep)	39	1.96	38	2.31	40	1.93	39	2.12	Q23A
Q40A	Use math to forecast performance measures or future outcomes (Prep)	40	1.91	40	2.07	38	2.03	40	2.03	Q40A
			106.85		112.78		103.41			
	items highlighted in yellow indicate a significant ANOVA result with a p-value less than 0.05.									

This is a spreadsheet showing the ratings by subgroup of the survey

Interpretation

- There are statistically significant differences between groups in items highlighted in yellow
- Project statisticians are still working on interpreting all these results
- So, today, will provide only our own broad takeaways from the results

Takeaway 1

- Survey successfully identified almost 40 items that all three surveyed groups agree are frequently used in the workplace, and, we would therefore say are of high importance
- A few items are specific to particular workplaces (e.g., CNC) and therefore scored lower in frequency of use

Takeaway 2

- *Items relating to **measurements** ranked most highly.* This includes:
  - Q3. Take measurements using physical tools (for example, calipers, micrometers, scales) or instruments (for example, voltmeters, oscilloscopes, pressure gauges).
  - Q2 Work with ratios or rates (for example, percentages, concentrations, speed)
  - Q4. Make estimates (for example, of measurements, quantities, production runs)
  - Q5. Do work that requires accuracy to a specified tolerance (for example, +/- 5%, +/- 0.003 inches)
  - Q28. Use metric (or SI) prefixes (for example, micro, kilo)
  - Q6. Read, document, and/or interpret sensor data (for example from temperature, pressure, or flow sensors)

- The only task in the top 7 (for frequency) that is perhaps less related to measurement topics is Q26. “Use blueprints, diagrams, drawings, flow charts, or schematics.” However, measurements might still be important in interpreting such things as blueprints.

Takeaway 3

- *Scores for preparation across the board are lower than for frequency of use*. Overall, averaging the results of all 40 survey items:
    - Technicians' average was **2.58** for preparation and **3.48** for frequency.
    - Tech educators' average was **2.80** for preparation and **3.54** for frequency.
    - Math educators' average was **2.67** for preparation and **3.83** for frequency.

Takeaway 4

- *An essential question asked in the grant proposal is whether there are differences in perception among the three groups in the importance of various math skills and the preparation of technicians entering their jobs*.
- We think that overall, the three groups agree – even though there are some statistically significant differences in certain items
- Overall, math educators think items are used somewhat more frequently than the other two groups and technicians had overall lowest scores for frequency – but this is not surprising
  - Educators prepare students for an array of jobs and know that individuals will use a subset of what is taught

- Some items might be interesting to pursue with interviews
- On specific questions, for example, technicians differ from educators in question 36, “Collect, analyze, and use information from a system that provides overall operational performance data in real time (for example, to act on production performance).”
  - Perhaps technicians often assist in trouble-shooting but do not interpret their efforts to involve working with data

A Comment about Measurements

We think measurements are vital, but that is not necessarily reflected in math education. Has a fifth grader really mastered measurements?

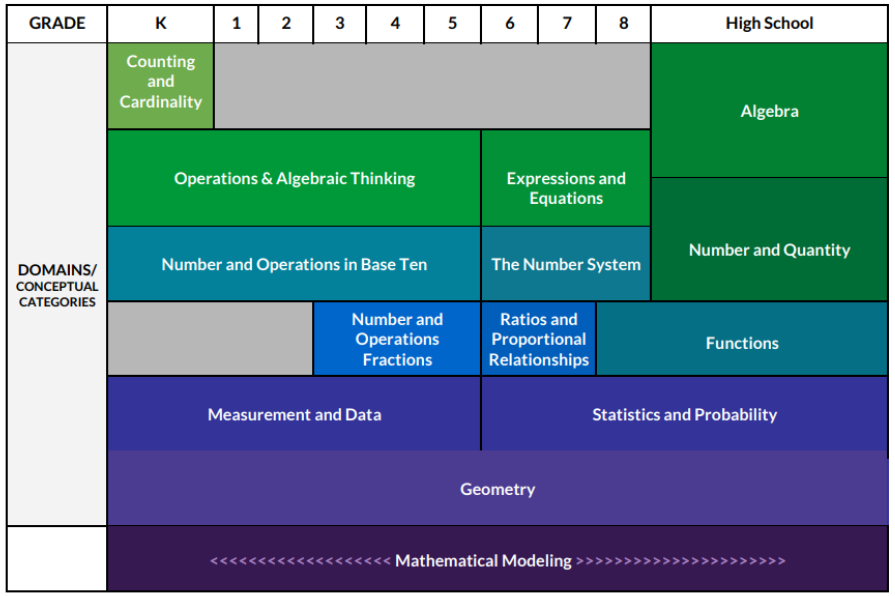
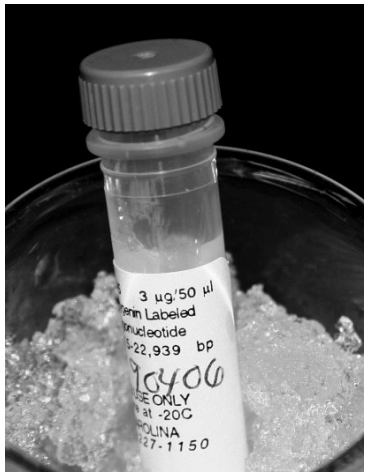


Figure from Wisconsin State Math Common Core Skill Standards

Scenarios

- Next stage of project is to provide scenarios
- It seemed obvious to me initially how this might be done, but it is not actually all that obvious
- So, we want input from you
- Want to avoid “reinventing the wheel”

For example, an Excerpt From My Idea



Suppose that, in our scenario, the PCR procedure specifies that the analyst must add **400 ng** of oligonucleotides to the PCR tube. In this case, the analyst removes a vial containing oligonucleotides from the freezer, see Figure 2. How much should the analyst pipette from this vial into the PCR tube to obtain 400 ng?

(More information is provided, but this is the idea. This scenario addresses measurements, ratios and proportions, metric system, and unit conversions.)

Another Example From the Team

Produce 50 12-foot lengths of pipe from 6-inch-long sections of 2-inch NPT 316 SS schedule 40 pipe, threaded on both ends. The 6-inch sections must be joined by flanges which will be fastened by nuts and bolts. Using 6-inch Dia. 316 SS round bar stock, produce enough flanges with bored and threaded holes and gaskets to join the pipe sections. Machine to 5.750 OD, bore 2.188, and part off the blank. Consider the waste generated by the parting off tool. Leave provision for finishing to a final thickness of 0.625. Thread the 2.188 bore to 2-inch in the flange for a tight fit, with the 6-foot pipe not to extend beyond the end of flange face. Machine four through holes for 5/8-inch-18 UNF bolts on 4.750 PCD (pitch circle diameter). Deburr the parts, pass for inspection. The tolerance on all operations is +/-0.010 inches.

Needed math includes arithmetic, 2D and 3D geometry, measurement, number sense, percentages, polar coordinates, and fraction-to-decimal conversion.

Leads to Questions We Want to Ask

- Do you share the concerns about your students and their ability to use math tools? If so, how can the Needed Math Project help you and your students?
- Do we need new scenarios?
- How should scenarios be constructed, with how much complexity?
- Should we venture into more conceptual realms, such as positive and negative controls or interpretation of trouble-shooting data?
- Do you want to participate as part of a collaborative working group?

Needed Math Next Steps

- Scenarios
- Establish collaborative working groups for project sustainability
- Disseminate results
- Finalize data analysis, report outcomes

Lisa Seidman: LSeidman@madisoncollege.edu)
Marilyn Barger: marilyn.barger@flate.org

Thank you all!

FOR FURTHER INFORMATION
visit WWW.NEEDEDMATH.ORG
Or contact us: NEEDEDMATH@gmail.com or
Michael Hacker: michael.hacker@hofstra.edu

NEEDED MATH

FUNDED BY THE NATIONAL SCIENCE FOUNDATION, GRANT # 2100062