NSF

HOFSTRA UNIVERSITY

CSR CENTER FOR STEM RESEARCH

NEEDED MATH

FUNDED BY THE NATIONAL SCIENCE FOUNDATION, GRANT # 2100062

Project Intent

- To improve alignment of the mathematics taught in two-year technical college programs with the mathematics manufacturing technicians need and use in the workplace.

- To develop a list of mathematical skills and competencies that technicians need in the manufacturing workplace.

- To set in motion a mechanism for the development of authentic scenarios illustrating what technicians do in industry. These can be useful in discussions between industrialists and technical educators.

Pre-Conference Workshop Agenda

12 pm to 12:55 p.m. (BOXED LUNCH TIME)

- Welcome and Introductions, Workshop Agenda (Michael)
- Research Results (Bernie)
- Introduction to Scenarios and Overviews (Paul, Jay, Rod, Lisa)

1 p.m. to 1:45 p.m. Small Group Work (Organized by Scenario)

- Participants choose a scenario to work on.
- Break up into six subgroups of about five persons each (two Circuit Breaker, two Preparing RNA Samples, two Clean-in-Place)
- Read, review, and better understand the scenario.
- Work in sub-groups to discuss the chosen scenario.
    - What would work and what is likely not to work with students.
    - How does this methodology differ from typical instructional activities?
    - What do students learn? What is likely to engage them?

Pre-Conference Workshop Agenda

1:45 p.m. to 2:25 p.m. Whole Group Debriefing (Paul)

- How is this approach different from end-of-text book problems.
- Why is this hard?

Introduce and Demonstrate AI tool using one example in detail (Rita, David)

2:15 p.m. to 2:45 p.m. Small Group Work (Organized by Domain)

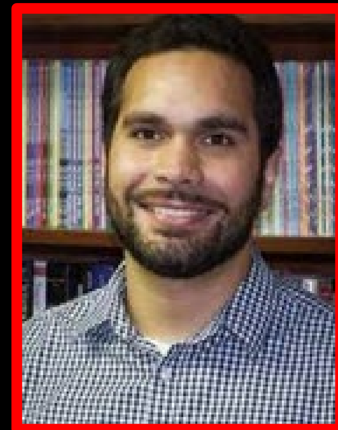
- Breakout Groups according to Domain (Bio, electronics, machining, semiconductors, misc.)
- Within each group, individuals craft a prompt.
  (Tell GPT one thing graduates of your program need to do on the job.)
- Email attempts you made to use the tool to generate scenarios to: Neededmath@gmail.com

2:45 p.m. to 3:00 p.m. Large Group Discussion and Conclusions

- 5 minutes: SURVEY (Rita)
- Invitation to follow up presentation at 3:10 pm (Thursday, 10/24) in the Blue Room


Marilyn Barger
Director, FLATE


Rosemary Brester, CEO, Hobart Machined Products, Inc.


David Cassell, Deloitte
Research Associate


Sol Garfunkel,
Exec. Dir. *COMAP*


Bernard Gorman,
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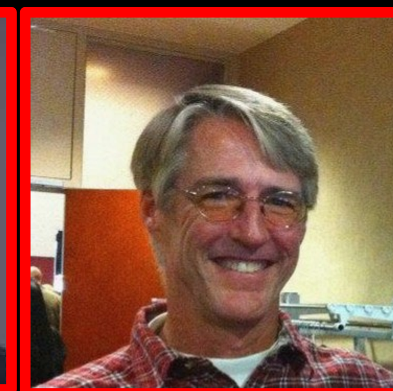
Hofstra Univ.

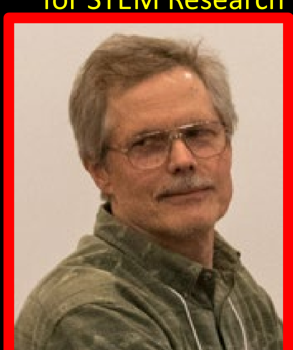
Needed Math Project Team


Michael Hacker, PI
Hofstra University Center for STEM Research


Deborah Hecht, CUNY
External Evaluator


Paul Horwitz, Co-PI,
Concord Consortium


Jay Martin, Wake Tech


Rod Null, Co-PI,
Rhodes CC


Gerhard Salinger, Co-PI
Former NSF Program Officer


Lisa Seidman, Madison
Area Technical College


Gordon Snyder,
Holyoke CC


Xi (Rita) Wang
Research Associate

NEEDED MATH
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The Needed Math Survey 2023

Bernard S. Gorman, PhD

David Cassell, PhD

Purpose

We developed, conducted, and analyzed a survey to assess the use of math skills and the perceived amounts of preparation needed to perform these skills by three groups: Manufacturing Technicians (n=107), Applied Mathematics Instructors (n=56), and Technical Subject Educators (n=150). In all, the usable sample size was 313.

Forty items were generated by the NM team.

Grouping Items into Facets

- On the basis of judgments by the research team, the items were then grouped into seven facets: *Algebra, Arithmetic, Geometry, Measurement, Modeling, Use of Technology, and Statistics.*

40 Survey Items

Copies are available at the ATE Connects session or email us at neededmath@gmail.com

NEEDED MATH

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LIST OF NEEDED MATH SURVEY ITEMS

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)?

ALGEBRA

13. Substitute numbers into formulas and evaluate (for example, given F=1.8C+32, find F when C= 37).
14. Manipulate a formula to get a new formula (for example, $c^2 = a^2+b^2$ can be changed to $b = \sqrt{c^2 - a^2}$)
15. Fit a curve to data (for example, construct a graph from a series of standards or data points)?
16. Use direct or inverse variation (for example, increase temperature to increase pressure, or increase speed to decrease time)?
17. Work with exponential functions (for example, cell growth, charging a capacitor, compound interest for money)?

GEOMETRY/TRIGONOMETRY

18. Find perimeters, areas, or volumes?
19. Work with logarithms (for example, working with pH, decibels)?
20. Use geometric topics such as parallel, perpendicular, angles, symmetry, etc.?
21. Use spatial reasoning (for example, think about and manipulate objects in three dimensions)?
22. Use angle measurements?
23. Use Geometric Dimensioning and Tolerance (GD&T)?
24. Use right triangle trigonometry (for example, sines, cosines)?
25. Work with amplitude, frequency, or period (for example, wave forms)?
26. Use blueprints, diagrams, drawings, flow charts, or schematics?

ARITHMETIC

27. Use scientific or engineering notations (for example, 5.4×10^{-2} or 54×10^{-3})?
28. Use metric (or SI) prefixes (for example, micro, kilo)?
29. Use complex numbers (such as 3+5i, 7+j4)?
30. Use inequalities to show that something is bigger ($a > b$) or smaller ($a < b$) than something else, or within a range ($a \geq b \geq c$)?
31. Make conversions between different ways of expressing numbers (for example, changing fractions to decimals, changing decimals to percents)?

USE OF TECHNOLOGY

32. Work with prepared spreadsheets (for example, read information from or input information into spreadsheets)?
33. Use spreadsheets for tasks beyond working with prepared spreadsheets (for example, interpreting data, changing formulas, producing pivot tables or graphs/charts)?
34. Use a scientific or graphing calculator?
35. Use math when using a computer numerical control (CNC) system (for example, use trigonometry to determine tool location relative to part geometry)?
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)?

MODELING

37. Use math to prepare reports (for example, quotes, invoices, standard operating procedures, manufacturing batch records, inventory reports, and/or productivity reports)?
38. Use graphs, tables, data, formulas or simulations to develop a model of procedures or processes to inform current decisions and/or future work?
39. Use data to troubleshoot problems?.
40. Use math to forecast performance measures or future outcomes (for example, use predictive analysis to find the probability of a tool failing, or using a curve of best fit to find unknown values)?

Developing Survey Items

A validation panel of people from technical education and industry reviewed the items.

Our evaluator requested that we ask to do “thinkalouds” with a few of those to be surveyed.

We pilot-tested survey items.

We sent the final survey to about 9000 technicians and faculty from D&B lists. We received 313 “clean” responses.

Usage Items

For example, for an item referring to assessing measurement tolerance (Q5) , the *Usage* item had this format:

Q5: *How often do you do work that requires accuracy to a specified tolerance?*

It had these choices:

- 1= Never/hardly ever
- 2 = One or twice yearly
- 3 =Monthly
- 4 = Once a week
- 5 = Almost Every Day

Preparation Items

The corresponding *Preparation* item had this format:

Q5A. How well-prepared were you to do work that requires accuracy to a specified tolerance?

It had these choices:

- 1= Not at all
- 2 = Slightly
- 3 = Moderately well
- 4 = Very Well
- 5 = Extremely Well

Examples Using the Statistics Factor

Q6	Statistics	Read, document, and/or interpret sensor data (Freq)
Q6A	Statistics	Read, document, and/or interpret sensor data (Prep)
Q7	Statistics	Use sampling to collect data (Freq)
Q7A	Statistics	Use sampling to collect data (Prep)
Q8	Statistics	Read and interpret tables, graphs, or plots of data (Freq)
Q8A	Statistics	Read and interpret tables, graphs, or plots of data (Prep)

Differences

- There are some significant differences between the means of the three roles on usage and preparation.
- For half of the factors, technicians differ from one or both of the educator groups.

Factors and Mean Ratings of Needed Math Subgroups					
Factor	**Item**	**Technical Educator (1)**	**Math Educator (2)**	**Technician (3)**	**Post-Hoc Tests**
Algebra	Use	2.96	3.22	3.04	*ns*
	Prep	2.67	2.93	2.72	*ns*
Arithmetic	Use	3.26	3.81	3.55	(2>1), (2>3)
	Prep	2.89	3.05	2.85	*ns*
Geometry	Use	3.43	3.87	3.35	(2>1), (2>3)
	Prep	2.82	2.75	2.63	*ns*
Measurement	Use	4.49	4.55	4.31	(3<2), (3<1)
	Prep	3.13	2.92	2.79	(3<1)
Modeling	Use	3.26	3.63	3.23	*ns*
	Prep	2.46	2.30	2.42	*ns*
Statistics	Use	3.69	3.89	3.49	(3<2)
	Prep	2.75	2.61	2.55	*ns*
Technology	Use	3.40	3.86	3.05	(2>1), (2>3), (1>3)
	Prep	2.69	2.45	2.41	(3<1)

Means, ANOVA, and Post-hoc Tests for the Top 10 Usage Items

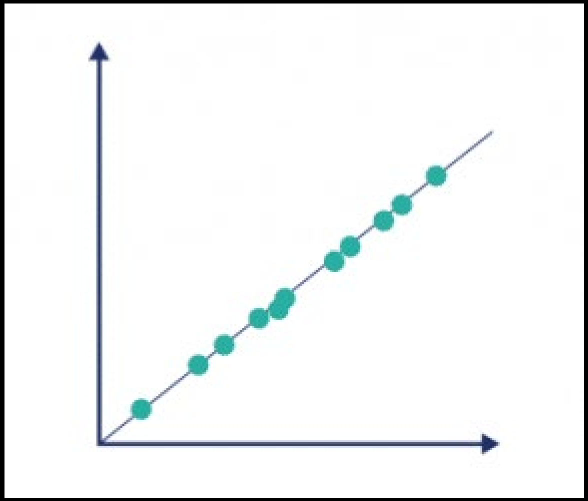
A	B	C	D	E	F	G	H	I
Means, ANOVA, and Post-hoc Tests for the Top 10 Usage Items								
			Groups					
Item	Rank	Overall	1_ Math Ed	2._Tech Ed	3_Technician	F	sig	Post-Hoc
Q3 Take measurements using physical tools or instruments	1.00	4.77	4.80	4.79	4.73	0.40	ns	
Q26 Use blueprints, diagrams, drawings, flow charts, or schematics	2.00	4.56	4.71	4.54	4.50	0.98	ns	
Q4 Make estimates	3.00	4.48	4.76	4.27	4.60	6.26	*	(3 2)(2 1)
Q28 Use metric (or SI) prefixes	4.00	4.47	4.76	4.27	4.60	2.49	ns	
Q2 Work with ratios or rates	5.00	4.40	4.60	4.37	4.33	1.70	ns	
Q6 Read, document, and/or interpret sensor data	6.00	4.34	4.73	4.41	4.03	7.58	***	(3 2)(2 1)
Q5 Do work that requires accuracy to a specified tolerance	7.00	4.32	4.73	4.51	3.86	16.75	***	(3) (2 1)
Q39 Use data to troubleshoot problems	8.00	4.31	4.31	4.27	4.35	0.16	ns	
Q1 Make conversions	9.00	4.21	3.98	4.26	4.27	1.72	ns	
Q31 Make conversions between different ways of expressing numbers	10.00	4.18	4.49	4.07	4.17	2.92	ns	

*Note: ns = non-significant, * p<.05, ** p<.01, *** p <.001*

For Post-hoc Tests: Means are in ascening order. Any two means surrounded by the same parenheses are not significantly different

Correlations of Usage and Preparation Factors

- We investigated whether there were relationships among ratings of the use of mathematics tasks and the amount of perceived preparation rated by members of the three roles.



About the Correlations

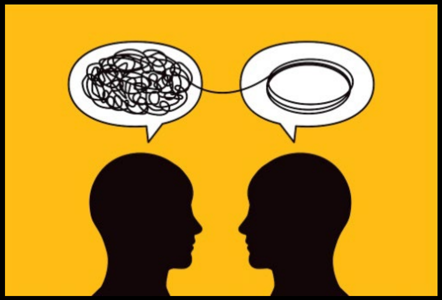
Although there were statistically significantly correlations, the correlations among use and preparation were generally low to moderate for all three roles.

This was especially so among the Technicians.

Therefore, frequent use of mathematics skills is not a guarantee of preparation for these skills.

Survey Findings

- It is clear that technicians, mathematics educators, and technical educators differ on their judgments of the usage and preparations needed for mathematics skills.



Further Survey Analyses

- What are the demographic differences among the three roles?
- What are the differences among subgroups of technicians? For example, in Biotech and Manufacturing?

Onward to Scenarios !!

Purpose of the Scenarios

- To provide realistic, contextualized examples of the use of math in the manufacturing workplace.
  - Answering the question: *"When am I ever going to use this?"*
- To illustrate why the math encountered in the workplace is difficult even though the manipulations themselves are mostly learned in middle school.
- Math ≠ arithmetic!

Paul Horwitz, The Concord Consortium

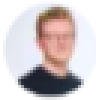
Clean In Place Systems

Food and Beverage Industry

NCSU Howling Cow and Diversey

Jay Martin Wake Technical Community College

Man died ‘after cleaning fluid was left in beer lines at his local pub’



Jasper King

Published Dec 5, 2023, 9:20am | **Updated** Dec 5, 2023, 3:50pm

A man died when he drank beer that is believed to have contained toxic cleaning chemicals.

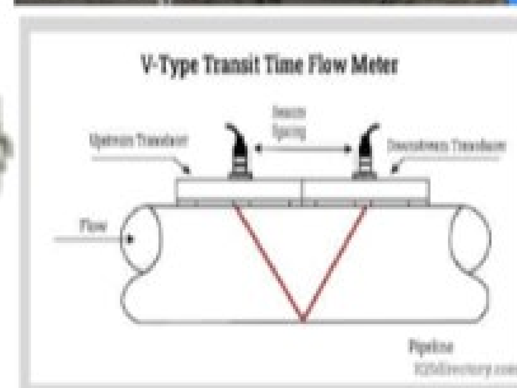
Connor Sebastian, 31, and two others started vomiting violently very soon after swallowing their drinks at the Burke Street Pub in Winston Salem, North Carolina.

A bartender called emergency services at around 8.20pm on November 9.

> ‘On Tuesdays, people come in here. A contracted company comes in here to clean our beer lines out, and I think that they left the cleaner in one of the beer lines.’

Connor was taken to hospital with the other two people but later died.

CIP and Data Collection



[NCSU Howling Cow CIP]

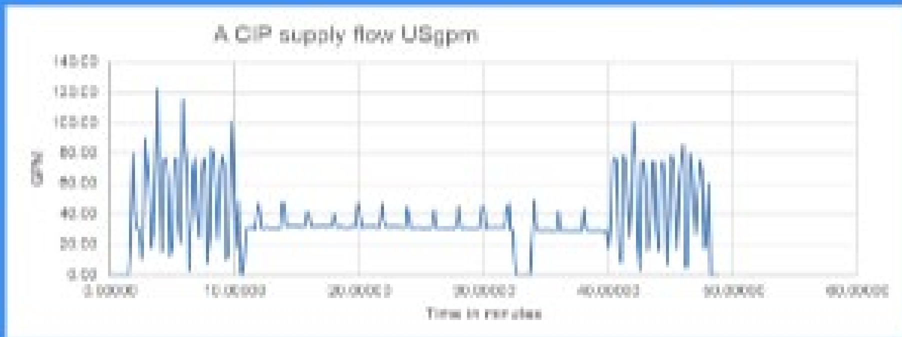
What is the right amount of water to use?

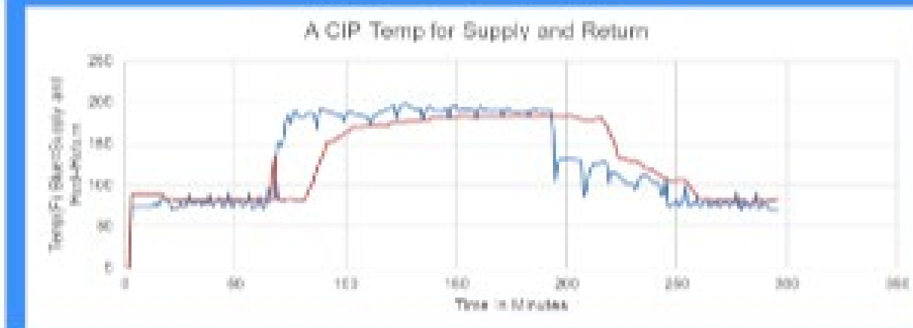
Industry Standard is to send to drain 3 times the amount in one circuit volume!

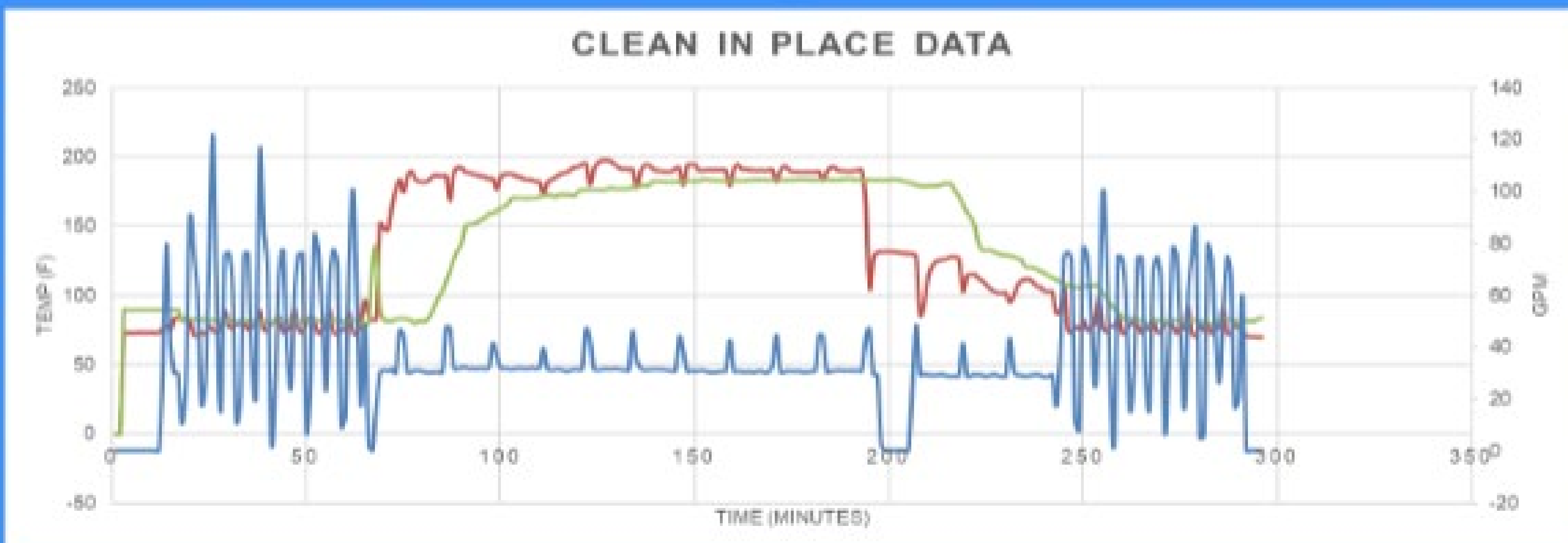
And to consistently clean with this industry standard!

	A	B	C	D	E
1			A	A	A
2	Miltary Time	Time in minutes	CIP supply flow	CIP Temp. supply	CIP Temp. return
3		increment	USgpm	°F	°F
4	14:26	0.00000	0.00	73.0	89.4
5	14:26	0.16667	0.00	73.0	89.4
6	14:26	0.33333	0.00	73.0	89.4
7	14:26	0.50000	0.00	73.2	89.4
8	14:27	0.66667	0.00	73.2	89.4
9	14:27	0.83333	0.00	73.2	89.4
10	14:27	1.00000	0.00	73.2	89.4
11	14:27	1.16667	0.00	73.2	89.4
12	14:27	1.33333	0.00	73.2	89.4
13	14:27	1.50000	0.00	73.2	89.4

Data in Graphical Formats







Use Math to determine:

1) the total volume in one circuit (volume of fluid to go through one complete pass)

2) The volume that should be sent to drain based on the industry standard (three times the circuit volume)

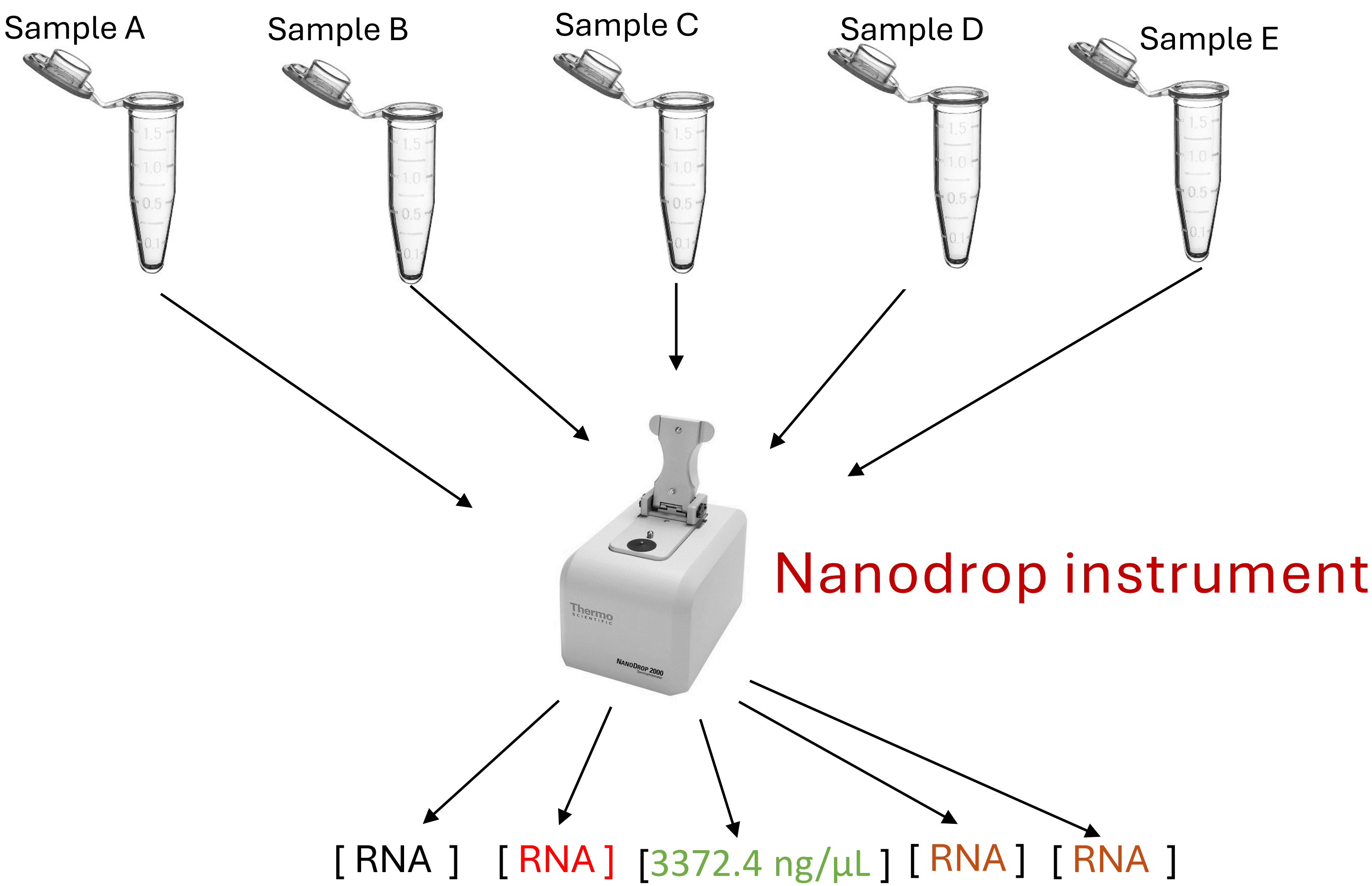
3) The amount of water sent to the drain in this data that exceeds the industry standard.

Biotechnology Scenario

Lisa Seidman, Madison Area Technical College

MICROARRAYS

- Type of assay that can be used to analyze gene expression in samples
- When a gene is expressed, its specific RNA is produced
- Therefore, Maddie is looking at RNAs


Sample A
Sample B
Sample C
Sample D
Sample E
Nanodrop instrument
[RNA]
[RNA]
[3372.4 ng/µL]
[RNA]
[RNA]

Objective:

Normalize the concentration AND the amount of RNA in all samples

Maddie says all samples should have
12 µg RNA at a concentration of 0.46875 µg/µL.

In her example, the sample RNA concentration is:
3372.4 ng/µL

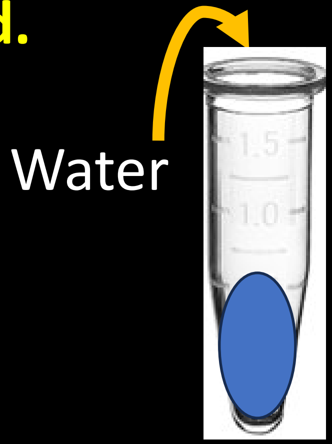
Step 1: Calculate volume needed to obtain 12 μg RNA

Pipette that volume RNA sample to fresh tube

Step 2: Calculate volume of water needed to have 0.46875 µg/µL RNA

Step 3: Recall that there is already some sample that has been put in the tube.

Therefore, subtract this volume to determine how much water is required.



Circuit Breaker Testing

During Fall of 2023:

Michael Hacker, Jay Martin, and Rodney Null met in Raleigh, NC and visited two companies:

Eaton Corporation and Siemens Corporation.

Rod Null, Rhodes College

Some things we observed

Fig 3. Breaker being Tested
(Rear of Breaker)

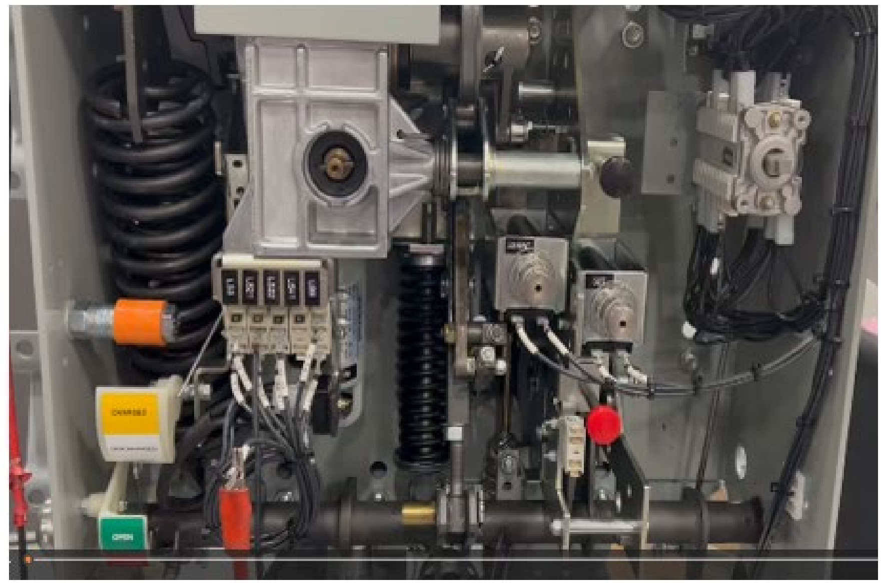


Fig. 4. Breaker being Tested
(Front of Breaker)

Some things we observed

Back View Video Link:
https://drive.google.com/file/d/1sUj9udP06aLIWWu0RQFmj6OSVGe_MK1d/view?usp=drive_link

Front View Video Link:
https://drive.google.com/file/d/1EZz5ZiG4r9JsUKvGbqoQalBheNzZ1hfM/view?usp=drive_link

Some things we observed

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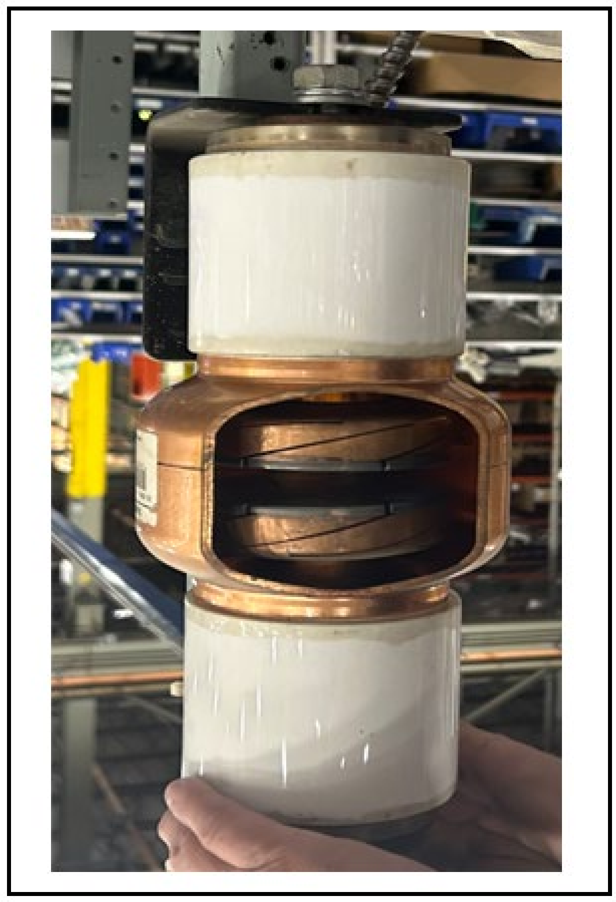
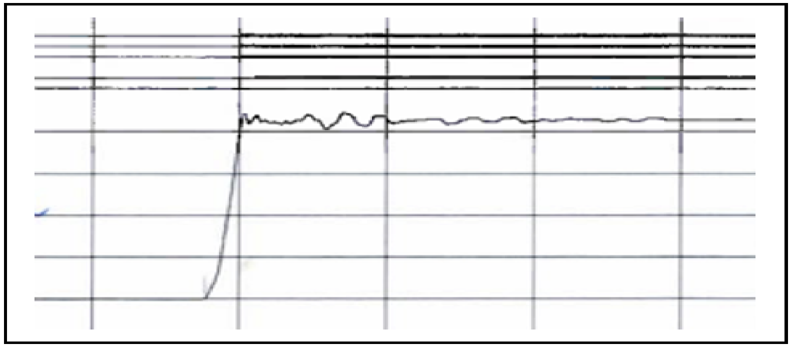
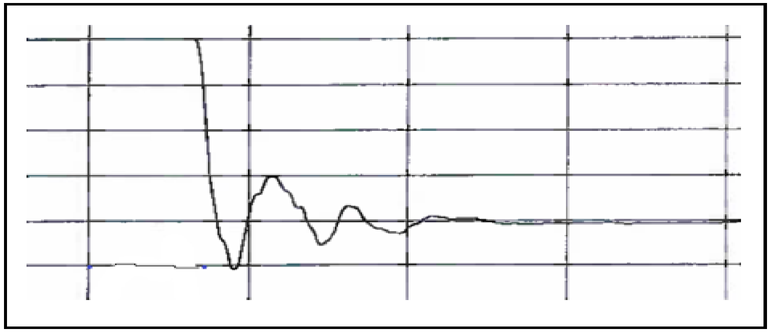


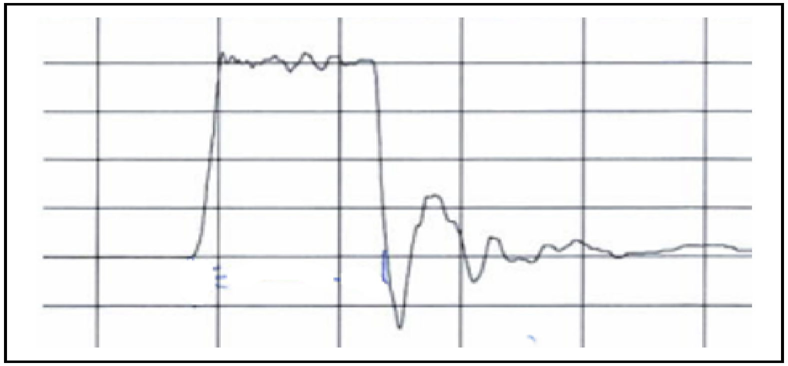
Testing Breakers



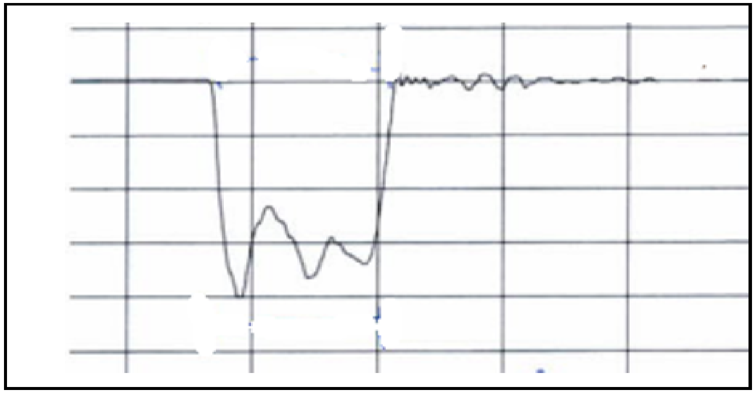
Closing the breaker



Opening/Tripping the breaker



Closing then Opening - CO



Opening then Closing - OC

Criteria for Passing

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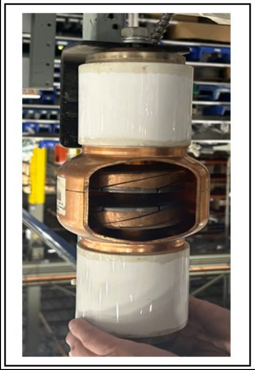
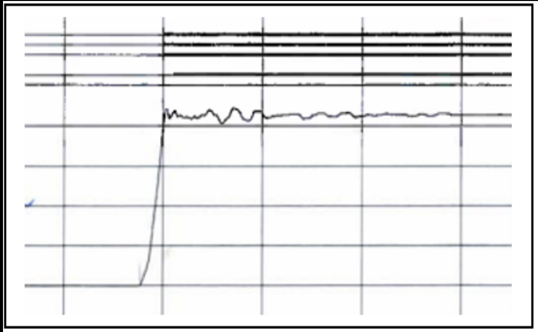
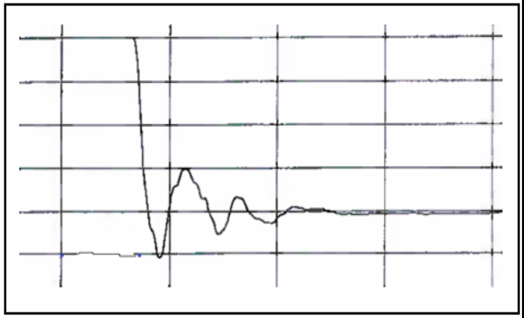
Type	H (mm)	Vc (m/s)	Vo (m/s)	C Time (ms)	O Time (ms)	O to C (ms)	C to O (ms)
B16-A-1200	5-7	0.4-0.8	0.6-1.2	62-85	24.8-41.6	130 max	140 max
C1-A-2000	10-12	0.8-1.3	1.0-1.8	51-77	24.8-41.6	130 max	140 max
E1-B-2000	7-9	0.4-1.1	0.7-1.4	51-77	24.8-41.6	130 max	140 max
D21-A-3000	18-22	1.1-1.7	1.3-1.8	63.8-83.8	24.8-41.6	130 max	140 max





Closing the breaker



Opening/Tripping the breaker

Circuit Breaker Testing

PROBLEM STATEMENT

A technician needs to test the critical design components of a medium to large circuit breaker to determine if all the manufacturing design specifications are met.

A Paradigm Shift: Artificial Intelligence

- Over the past four years of this project, there have been incredible developments in artificial intelligence, especially demonstrated by the software: ChatGPT.
- The acronym, GPT, stands for:
  - Generative
  - Pre-trained
  - Transformer

What Can We Do with GPT?

- We have been experimenting with ChatGPT and similar GPT software and found that we could ask the programs to:
  - 1) Create new survey items
  - 2) Interpret and classify existing survey items into meaning groups
  - 3) Suggest and generate tentative answers for interesting comparisons
  - 4) BETTER YET: As we will explain later, we can create new problem scenarios using the Scenario Generator developed by Drs. David Cassell and Rita Wang.

Guidelines for Interacting with the Scenario Generator

1. **Be Clear and Specific:** Provide detailed requests with specific roles or math concepts.
2. **Use Real-World Contexts:** Embed scenarios in tasks technicians face in the workplace.
3. **Focus on Technician Tasks:** Highlight specific tasks performed by technicians.
4. **Tailor to Specific Manufacturing Sectors:** Ensure sector relevance.
5. **Encourage Problem-Solving:** Create multi-step scenarios requiring critical thinking.
6. **Align Scenarios with Specific Curricula:** Tailor scenarios to course objectives.
7. **Request Additional Resources:** Ask for sample solutions or videos.
8. **Iterate and Refine:** Encourage scenario adjustments to suit needs.
9. **Incorporate Common Technician Errors:** Address common challenges and mistakes.
10. **Facilitate Reflection and Discussion:** Include group discussion questions.

Be Clear and Specific with your Request

Clear and specific requests allow the generator to tailor scenarios more precisely to your needs, whether it's for a CNC machine operator using trigonometry or a scenario involving fluid dynamics in the automotive industry.

Example: Instead of asking, "Give me a math scenario," ask, "Can you create a scenario for a quality control technician using statistical analysis in a packaging process?"

Use Real-World Contexts

Ask for scenarios embedded in realistic manufacturing situations, reflecting the actual tasks technicians face in the workplace.

The goal of the Needed Math project is to align educational scenarios with real-world technician roles in manufacturing. Scenarios are most effective when they simulate authentic industrial problems.

Example: “Create a scenario where a production technician needs to calculate the optimal speed of a conveyor belt to maintain product quality.”

Focus on Technician Tasks

- Request scenarios that highlight specific tasks manufacturing technicians perform (e.g., quality control).
- The scenarios are meant to reinforce math concepts that are directly applicable to technical roles. This makes it easier to design scenarios around math skills technicians must master to perform successfully.
- Example: “Can you design a scenario where a technician must assess the quality of the products produced?”

Encourage Problem-Solving and Critical Thinking

- Ask for scenarios that involve multi-step problem-solving or complex challenges that require critical thinking.
- Manufacturing technicians often face problems that require them to apply multiple skills and steps to reach a solution. Scenarios reflecting this complexity can better prepare students.
- Example: “Generate a scenario where a maintenance technician needs to troubleshoot a machine’s downtime by analyzing data and calculating the necessary adjustments.”

Incorporate Common Challenges & Errors

- Ask for scenarios that incorporate typical misconceptions or errors technicians might encounter.
- Identifying and addressing common mistakes can enhance learning by helping students recognize potential pitfalls and develop strategies to avoid them.
- Example: “What are some common mistakes when technicians convert between metric and imperial units? Can you create a scenario around that?”

Encourage Discussion and Reflection

- Request scenarios that include discussion questions or encourage group work to stimulate deeper understanding.
- Encouraging discussion helps students engage with the material, clarifies concepts, and promotes collaborative learning in technical environments.
- Example: “Can you include discussion questions for a scenario where a technician must balance cost and time efficiency in production?”

Request Scenarios Aligned with Specific Courses or Curricula

- Link your scenario requests to specific course topics or learning objectives.
- Aligning scenarios with your course goals ensures that they reinforce the relevant math skills needed for success in specific technical training.
- Example: “I need a scenario for a lesson on quadratic equations in a robotics course. Can you create one?”

Ask for Additional Resources

- Request extra resources like pedagogical tips, video links, or sample solutions to complement the scenarios.
- These resources can provide further support for educators and students, making the math concepts more accessible.
- Example: “Can you include any video resources or sample solutions to help explain the calculations in this scenario?”

Consider the Manufacturing Sector

- Specify the manufacturing sector (e.g., automotive, electronics, aerospace) to ensure the scenario reflects sector-specific applications.
- Different manufacturing sectors may have unique processes, tools, and math applications. Tailoring the scenario to a specific industry increases its relevance.
- Example: “Can you provide a scenario involving cost analysis in the electronics manufacturing industry?”

Encourage Follow-Up and Iteration

- Don’t hesitate to ask follow-up questions or request adjustments to scenarios.
- I can iterate on scenarios to better suit your needs or clarify points, ensuring they match your teaching objectives and the real-world problems technicians face.
- Example: “The scenario you created is great, but can you add a part that includes unit conversions and recalculating machine settings?”