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Making Mathematics Accessible to Non-Mathematics Majors

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ABSTRACT

The purpose of this workshop is to present alternative strategies of instruction that will make the subjects of mathematics and statistics more accessible to students with non-mathematics backgrounds. It is not surprising that introductory mathematics and statistics courses can seem a little overwhelming and inaccessible to students with non-mathematics backgrounds. As a result, these students tend to feel distanced from the course material, or even discouraged from approaching instructors or teaching assistants (TAs) for help. The audience for this workshop includes graduate student TAs, post-doctoral fellows, instructors, lecturers, and anyone who wants to make mathematics and statistics a more engaging subject for students without the technical background.

The focus of this workshop will be two-fold. First, we will examine how mathematics/statistics instructors can explain concepts to students of different backgrounds effectively via various role-play scenarios. Second, we will use the jigsaw technique to break up complex mathematical problems into pieces with the aim of encouraging collaboration and student engagement (Perkins & Saris, 2001). By attending this workshop, instructors will be able to help undergraduate students see mathematics as a more enjoyable learning experience that they can apply in their own respective fields. These two activities will help students with non-mathematical backgrounds feel more engaged with the material and become more confident when asking for help from an instructor or TA.

KEYWORDS

teaching mathematics; non-math majors; role-playing; jigsaw technique

LEARNING OUTCOMES

By the end of this workshop, participants will be able to:

- Communicate mathematical concepts effectively to students by clarifying technical mathematical vocabulary.
- Relate mathematical ideas to students using real-world examples.
- Create a fun and co-operative active learning environment.

ANNOTATED BIBLIOGRAPHY

Hersh, R. (1997). Math lingo vs. plain English: Double entendre. *American Mathematical Monthly*, 104(1), 48-51.

In this article, Hersh discusses the ambiguity that arises from using technical terms in mathematics. He provides examples where mathematical vocabulary can cause some confusion when someone is accustomed to the 'plain English' interpretation instead of the technical meaning that was intended. For instance, 'adding' in math means increasing a number by a positive number, a negative number, or zero. In other words, adding in math can mean adding, subtracting, or doing nothing to it. The same term in plain English just means increasing a number. One can see how someone with no or little mathematical background can be easily

confused. Hersh suggests that instructors should play an important role in lifting this confusion by clearly communicating and defining various mathematical terms and symbols.

This workshop emphasizes language ambiguity during the role-playing activity. Participants taking on the role of an instructor must clarify the meanings of any technical terms used, and participants in the role of a student must identify any terms that are unclear. The result is a shared effort between instructor and students to make mathematics more relevant by using clear and unambiguous terminology and to optimize the learning experience.

Perkins, D. V., & Saris, R. N. (2001). A "jigsaw classroom" technique for undergraduate statistics courses. *Teaching of Psychology*, 28(2), 111-113.

In this article, Perkins and Saris share some of the problems associated with approaching problem sets in the undergraduate statistics classroom. One of the problems with the standard approach to working on problems sets during class time is that students vary widely in terms of ability, motivation, and assertiveness. A lack of ability and motivation can arise if a student does not have the necessary background in mathematics or statistics to complete the problems in class and therefore feels discouraged. This student might prefer completing problem sets at home while consulting online resources, working with friends, or having the time to seek additional help from the TA or instructor privately.

Perkins and Saris present a solution to this problem by breaking down math problems into manageable chunks and assigning groups to work together on given chunks. The authors refer to this method as the jigsaw technique. The final activity of the workshop relies on this model to demonstrate how students can benefit from a collaborative approach to solving problems. The jigsaw technique applied in this workshop will not focus on mathematical problem sets but rather lesson plans and topics.

Peiris, S., & Beh, E. J. (2012). Where statistics teaching can go wrong. *International Journal of Innovation in Science and Mathematics Education (formerly CAL-laborate International)*, 15(1), 21-23.

In this paper, the authors discuss challenges associated with traditional methods of teaching statistics. The authors describe the approaches as "negative and unappreciable methods of teaching statistics that are currently being adopted by some individual teachers at universities" p. 21. One of the main issues addressed (which pertains to this workshop) is the lack of constructive and effective communication between instructors and students. The authors provide concrete suggestions for improving communication in statistics courses.

In this workshop, participants explore why traditional methods of instruction may not support students with non-mathematical backgrounds and how teaching approaches might be improved. One of the strategies suggested in the article is the implementation of real-world example statistical problems. The workshop will emphasize that students who may not yet have

the necessary background to solve problems might be motivated to learn the statistical skills required if the subject matter is relevant and relatable.

ADDITIONAL REFERENCES

Aronson, E. & Patnoe, S. (1997). *The jigsaw classroom: Building cooperation in the classroom*. New York, NY: Longman.

WORKSHOP CONTENT AND ORGANIZATION

DURATION (min)	SUBJECT	ACTIVITY	PURPOSE
20	Ice breaker & Introduction	<p>Present participants with graphs/descriptions of different probability distributions. Ask them to pick the one that best describes them. (List includes but is not limited to: Bernoulli, Binomial, Beta, Hypergeometric, Poisson, Negative Binomial, Exponential, Normal, Lognormal, Beta, Gamma, Student's t, Chi-Squared, F-distribution).</p> <p>In small groups, ask participants to explain why they like that distribution and why it pertains to them.</p> <p>Introduce the learning outcomes of the workshop and highlight the activities that will ensue.</p>	To get acquainted with fellow participants.
15	Activity 1: Brainstorm	In the first exercise, ask the participants to brainstorm some of the problems associated with explaining statistical concepts to students of non-mathematical background based on their own experiences. Record the responses.	To survey the current strategies used by instructors as a first step in the discussion.
40	Activity 2: Role-playing	<p>Introduce the following strategies for teaching statistical concepts:</p> <ol style="list-style-type: none"> 1. Using real-world examples that relate to various fields of study. 	To introduce approaches that explain mathematical concepts in a more relatable way.

		<p>2. Clarifying the meanings of technical terms (distribute Appendix A).</p> <p>Demonstrate an example by acting out one scenario (see Appendix B)</p> <p>Divide participants into five groups and provide each group with a role-play scenario (see Appendix B). In addition, provide groups with feedback sheets (see Appendix C).</p> <p>Ask each group to decide among themselves who will play the roles in the given scenario (i.e., instructor, student, and observers). Allow groups to act out their assigned scenarios.</p> <p>After a few minutes of role-playing, participants can provide feedback for the person in the role of the instructor using the feedback sheets.</p> <p>Rotate groups through the five scenarios. Encourage group members to take on new roles in each scenario so that everyone receives some feedback in the instructor role.</p>	To have participants practice teaching in a more relatable way.
15	Activity 2: Discussion & Summary	<p>Ask the following questions to summarize the previous activity:</p> <ol style="list-style-type: none"> 1. What strategies worked best and why? 2. Did the use of real-world examples help in making the subject accessible? 3. Did anyone have trouble while explaining the topic to the student? 4. Which scenario was the most difficult? 5. Would anyone like to demonstrate a specific scenario? 	To bring together participants thoughts on the activity and highlight successful teaching strategies.

40	Activity 3: Jigsaw Activity	<p>Divide the participants into four groups. Assign each group a topic or puzzle piece (see Appendix D). Refer to these groups as “Expert Groups”.</p> <p>Allow expert groups time to discuss their assigned topic. Each member of an Expert Group should prepare ~half-page summary on the topic that covers the following points:</p> <ul style="list-style-type: none"> • Ways of introducing the topic • Two distinct examples relating to the topic • Any limitations associated with this method <p>Now redistribute the groups so the new groups have a member from each original topic area. Refer to these groups as “Learner Groups.” Allow each member of the group to present their learned expertise to their new group members.</p>	To introduce a student-based approach to learning by employing the jigsaw technique.
15	Activity 3: Discussion & Summary	<p>Ask the following questions to summarize the previous activity:</p> <ol style="list-style-type: none"> 1. From the perspective of an instructor, why do you think that the jigsaw technique is an effective teaching method for your classroom? 2. How could you apply the jigsaw technique in your own teaching? For example, to solve math problems, or to learn about a new topic (similar to this workshop). 	To bring together participants thoughts on the application of the activity to their own classrooms.
5	Conclusion & Feedback	<p>Summarize the goals of the workshop.</p> <p>Devise and distribute a feedback survey to participants in the final minutes of the workshop</p>	To assess the overall effectiveness of the learning exercises within the workshop and look for areas of improvement.
Total Time: 150 minutes			

PRESENTATION STRATEGIES

Mathematics over the years has been branded as an inaccessible, mandatory, and complicated subject that only the elite can understand. However, mathematics can be appreciated by anyone, expert or not. The strategies presented in the workshop and the skills developed by participants can be applied in any setting, whether it is a classroom, electronic communication, or office hours.

Activity 1 Goal: Participant Experience Brainstorm

The main goal of this activity is to survey the participants and discuss their individual experiences with teaching students with little background in math. This short activity will have participants think about possible strategies that they currently employ or have employed in the past. The facilitator should synthesize participant responses and provide their own personal experiences as appropriate.

Activity 2 Goal: Role-playing Strategies for Communicating Mathematical Concepts

A non-math major enrolled in a math course can become demotivated for several reasons. One reason is that this person may not see the relevance of the subject to their home discipline. This is often the case when instructors do not provide relatable examples. A student in a Biology program may have difficulty learning statistics if, for example, the instructor does not demonstrate that a simple linear regression can be used to see which factors explain increases in blood pressure. A second reason is that many mathematical terms are ambiguous if not clarified.

The main objective of the role-playing activity is to prepare instructors with useful strategies for discussing math problems with students. These strategies include using real-world examples and clarifying ambiguous mathematical terms. Small groups act out an assigned scenario before rotating to the next example. Group members complete feedback sheets when they are not actively involved in the role-play. Although the feedback sheets are kept by the participants, the results are collected by the presenters in the form of discussion and it is the responsibility of the facilitator to record these responses for everyone to see (e.g., on a whiteboard, chart paper, computer projector, etc.) The facilitator can make the results available online to benefit participants after the workshop. The facilitator should be available to float around during the course of this activity to provide clarification as needed.

Activity 3 Goal: Use the Jigsaw Technique to Initiate Student Collaboration

The purpose of this exercise is to “level the playing field” by giving non-math students a chance to collaborate with other students of more experienced backgrounds (Perkins and Saris, 2001). By incorporating the jigsaw technique, the workshop demonstrates a fun and exciting way to make mathematics accessible. Moreover, this activity puts less emphasis on the instructor and offers a student-driven approach to learning the material. The facilitator should be available during this activity to provide clarification or guidance as needed. After the activity, the participants share their experiences with the rest of the classroom by answering facilitator questions.

APPENDIX A: Common Ambiguous Mathematical Terms

This handout contains some commonly used mathematical terms and some possible plain English interpretations according to Hersh (1997). This handout also relied on the Merriam-Webster Online Dictionary (<https://www.merriam-webster.com/>).

Distribute the handout during the role-playing scenarios activity. This sheet represents some common terms you can use while acting out the scenarios either as the instructor or student. You are welcome to add in any additional vocabulary or concepts that you may encounter.

Term	Technical meaning	Some examples	Possible plain English misinterpretations
Number	Any quantity	<ul style="list-style-type: none"> • -4 • 0 • π • $2 + 3i$ • 5 • 7.249987 	An integer quantity more than 2 (e.g., There are a <i>number</i> of reasons why I cannot do that...)
Function	A rule that assigns to each number in a domain a corresponding number in a range	<ul style="list-style-type: none"> • $f(x) = x^2$ • $f(x) = \sin x$ • $f(x) = 4$ 	What an object is used for (e.g., the <i>function</i> of the car is to get us places)
			To work or run (e.g., I cannot <i>function</i> without my morning coffee!)
			A social event (e.g., Are you going to the Mosque fundraiser <i>function</i> on Saturday?)
Curve	A continuous map from a subset of $\mathbb{R}$ to $\mathbb{R}^2$ or $\mathbb{R}^3$	<ul style="list-style-type: none"> • A parabola: $f(x) = x^2$ • A straight line: $f(t) = t$ • A unit circle: $f(t) = (\cos t, \sin t)$ 	A line that is not straight (e.g., the road is <i>curvy</i>)
Difference	A quantity being the result of a subtraction of one number from another number.	<ul style="list-style-type: none"> • $\pi - 1$ • $10 - 4$ • $-2 - 8$ • $1.2 - 5$ 	A point between two people or objects that is unlike or not the same (e.g., the <i>difference</i> between 4 and 3 is not

			that 4 is even and 3 is odd, but rather the difference is 1)
Adding	A quantity being the result of the sum of two numbers	<ul style="list-style-type: none"> • $1 + 1$ • $2 + (-4)$ 	An increase in a quantity (e.g., I have <i>added</i> gasoline to my car's fuel tank, so we should be good to go)
Product	A quantity being the result of two numbers being multiplied by one another	<ul style="list-style-type: none"> • 3×5 • 2π 	Something that is produced (e.g., one <i>product</i> of cars is carbon monoxide which is harmful for the environment)
Multiplying	The act of changing a quantity, either making it bigger or smaller or neither	<ul style="list-style-type: none"> • $2 \times 5 = 10$ • $1 \times 5 = 5$ • $0.2 \times 5 = 2$ 	Repeated adding (e.g., Those rabbits have <i>multiplied</i> !)
Dividing	To divide by a number is the same as multiplying by its reciprocal	<ul style="list-style-type: none"> • $33 \div 11 = 3$ • $\pi / 4$ 	Cut into pieces, usually equal pieces (e.g., In my will, I have <i>divided</i> my estate fifty-fifty)
Equal	Notion used to describe an equivalence relation between two values	<ul style="list-style-type: none"> • $\sin x^2 + \cos x^2 = 1$ • $2 = 2$ • $\frac{10}{5} = \frac{2}{1}$ 	The meaning can be interpreted as indistinguishable, identical, or that two quantities have the same values (e.g., my brother and I are treated <i>equally</i> by our parents)
Sequence	A list of terms	<ul style="list-style-type: none"> • 1,2,3,4,..... • 1,1,3,5,8,13,22,..... 	A list of items (e.g., a <i>sequence</i> of events)
Series	A sum of terms	<ul style="list-style-type: none"> • $1 + 2 + 3 + 4 + \dots$ • $\frac{1}{4} + \frac{1}{9} + \frac{1}{16} + \dots$ 	Some sort of collection (e.g., Let's watch the World <i>Series</i> ! Or, did you see that new comedy <i>series</i> on-line?)
Limit	A number whose numerical difference from a mathematical	<ul style="list-style-type: none"> • $\lim_{x \rightarrow +\infty} (1 + \frac{t}{x})^x = e^t$ 	A boundary or barrier which cannot be passed

	function is arbitrarily small for all values of the independent variables that are sufficiently close to but not equal to given prescribed numbers or that are sufficiently large positively or negatively.	<ul style="list-style-type: none"> $\lim_{x \rightarrow \infty} 1/x^2 = 0$ 	(e.g., I have filled my fuel tank to the <i>limit</i>)
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Hersh, R. (1997). Math lingo vs. plain English: Double entendre. *American Mathematical Monthly*, 104(1), 48-51.

APPENDIX B: Role-play Scenarios

Sample Scenario for Session Facilitator(s)

Kaley is a second-year biology major that needs to take first-year calculus. Kaley does not have the sufficient math background to understand first-year calculus. She comes to you after the lecture ends and needs help understanding trigonometric identities. Deliver a 5-minute crash course on this subject.

Instructions for Participants

In all the scenarios below, assume that you are an instructor or TA for a second-year undergraduate statistics or probability course. Please read the scenario that is on your table and choose among yourselves to play the following roles:

- Instructor/TA: The person trying to explain the concept
- Student: The person having problems with the concept
- Observers: People who are simply observing the interaction between the TA and the student. The observer does not participate in the scenario but takes notes and discusses the feedback afterwards.

After you have delegated the roles, please play out the scenario at your station. You will have a few minutes to play out the scenario and record feedback.

Scenario 1: Poisson Random Variable

Ahmed is a third-year Life Sciences student that is taking this course as part of his program requirements. He approaches you in your office hours and explains that he has always had a history of struggling with mathematics, and that the instructor went through Poisson random variables topic too quickly. How can you explain this topic to him in a way that he can relate?

Scenario 2: Hypothesis Testing

Sarah is a third-year software-engineering student that is re-taking statistics to upgrade her mark. She approaches you after class and informs you that as a software engineering major, she has no problem with mathematics. However, she is having trouble following the professor's lecturing style. How can you explain the concept of hypothesis testing in a way that is relatable?

Scenario 3: Conditional Expectation

Noah is in a Business program in his second year. Noah has always been interested in working as a consultant or a manager at a bank after he graduates. He can tell you about some stock-picking strategy and talk to you for an hour about behavioral economics. However, he sees this course as an obstacle and has always struggled with the technical aspects of it. He never really cared about statistics until he learned it was a mandatory component of his program. You are explaining the concept of conditional expectation in your tutorial; however, he keeps raising his hand and telling you "I don't get it". What do you do?

Scenario 4: Joint Densities

Crystal is a second year Earth Sciences student that needed an elective to graduate. Her friends had informed her that this statistics course would be an 'easy A' since it is with Professor So-and-So and he always uses last year's exams and never changes them. However, when confronted with reality, Crystal noticed that the course is different from expectations and that she needs to understand the material to do well. She is having a difficult time with the concept of a joint density for two continuous random variables and the midterm is tomorrow. She sends you a very distressed email asking for help. What do you do? How can you explain this concept in a relatable way?

Scenario 5: General Inquiry

Adem is a first-year physics major and must take a statistics course as part of his program requirements next year. He approaches you in your office hours because he has heard that you are one of the TAs for this course. He asks you about what the course is like and what he can expect to learn next year. He seems genuinely interested in the subject and wants to learn how it fits into the context of physics. How would you go about describing the components of the course to him?

APPENDIX C: Role-Play Feedback Sheet

Please answer the following questions using a scale from 1 to 5:

1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree

Scenario Description: _____

Field of student in the scenario: _____

Question	Rating
1. The instructor understood the topic really well	
2. The instructor was able to answer all of the student's questions	
3. The instructor was able to clarify all technical terms	
4. The instructor was able to relate to the student using real-world examples	
5. The examples used by the instructor were really strong examples	
6. The instructor used strategies outside of this workshop to connect to the student	
Other Comments:	

APPENDIX D: Jigsaw Activity Materials

Note for Facilitators

Create four puzzle pieces, numbered from 1 – 4. On the backside of each puzzle piece, indicate the name of one subtopic (see example below).

Example Topic

- **Techniques of Integration**

Example Subtopics

- Puzzle Piece 1 → Integration using u-substitution
- Puzzle Piece 2 → Integration by parts
- Puzzle Piece 3 → Integration by partial fractions
- Puzzle Piece 4 → Integration using trigonometric identities