Where Do They All Belong? Teaching Math for Belonging

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Abstract: *This paper presents an inquiry project by Danny, a high school mathematics teacher from Israel, who aimed to build a sense of belonging in at-risk youth by connecting the mathematics curriculum to the students' lives and interests. The project focused on improving students' performance on the matriculation exam through the three types of belonging: formal, social, and cognitive. An example of a Desmos activity is presented to illustrate the potential of inquiry projects to build cognitive belonging in at-risk youth.*

Keywords: *At-risk youth, mathematics education, inquiry project*

Introduction

In the Fall of 2022, the lead author (Danny) participated in the Fulbright Distinguished Award in Education program at Indiana University of Pennsylvania (IUP). Danny is a high school mathematics teacher in Israel. As part of the program, each Fulbright Scholar is matched with a faculty member in their field to create an inquiry project designed to serve the scholar in their future teaching. Danny was matched with Janet who is a professor in mathematics education at IUP. He chose to study how he could better connect the mathematics curriculum in his classroom to the matriculation exam that his students were required to complete at the end of their high school experience. Danny needed to find the right focus for teaching mathematics to at-risk youth. The purpose of this paper is to introduce how he found this focus within his inquiry project and to present one activity that he designed for his students.

Danny teaches at a high school that was developed to provide a unique learning environment for at-risk youth offering small intimate classes, on-campus therapies, and well-equipped art studios. Most of the students at this high school have interests in the arts, and share the experience of exclusion - they don't belong in the "regular school" they came from. Just like the Beatles' song "Eleanor Rigby" (The Beatles, 1966), even their parents, teachers, and guardians will often wonder where their teenager fits in the world, thus asking the question: Where do they all belong? The high school plays a major role in helping students find this sense of belonging while enabling them to pursue their artistic passion, and confront the matriculation exams. Currently, around sixty percent of these students pass the matriculation exam and earn a high school diploma. Fifty percent of the students who get a high school diploma study in higher education.

Mathematics is mostly learned at the lowest possible level at Danny's high school. The students were distressed by math in their first nine or ten years of schooling and many of them are somewhat skeptical about their ability to succeed on the matriculation exams. Although this does not seem as a promising starting point, it actually holds great opportunities for those teachers and students who are willing to take on the challenge. Changing the setting (new school, small classes) might do a lot to help these students, but the purpose behind this project is not just getting students to pass the test: it is about harnessing math as a learning field towards building confidence in oneself, creating a sense of belonging, and realizing yet unknown qualities.

Creating a Sense of Belonging

One of the main challenges that many teachers face is helping students gain the feeling of belonging in school.

> Not all students come to class wanting to learn... but they all come wanting to belong. And when they feel like they belong... they're much more likely to learn (Steel & Whitaker, 2019).

Students who are at-risk often question why they should come to school at all and thus even showing up to school is a daily struggle. The most extreme cases involve students wondering why they have to come to a building everyday and "listen to some stranger saying....things." They see no value in learning and have not found that feeling of belonging or even wanting to belong.

But what does it mean to "belong"? To belong is a complicated concept and people think of it in many different ways. The authors suggest three types of belonging that other teachers might understand. The first type is the idea of belonging to society or formal belonging. The norm for youth in Israel is to go to school, and most of them don't want to think of themselves failing that mission. They want to be able to say "I study at....". On a deeper level, these students know that schooling is what they need in order to belong to adult society. Therefore, not attending school is not only excluding oneself from the educational system (of which you might have some criticism about), it is also excluding yourself from the adult world that comes afterward.

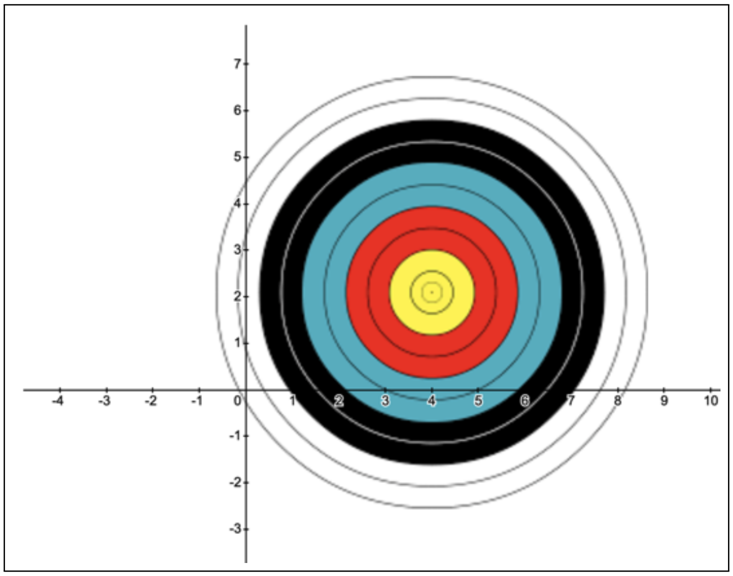
The second type of belonging is that of belonging to friends and community - the third tier of Maslow's pyramid (Maslow, 1943). Some of the students' best friendships started at school. It is a rather simple structured community where the students build their relative and subjective identity, and which they use to describe themselves to others. Students need to feel wanted and valued by their peers through these social contacts. Many of the kids in Danny's school left regular school because they did not fit in socially, and this school is the first school where they find friends and feel social belonging.

The third type of belonging, and the one that this paper focuses on, is that of cognitive belonging. In his book "rewiring education", John Couch describes a theoretical debate about the purpose of education, and eventually comes to a consensus that learning is at the center of it (Couch & Towne, 2018). The majority of students do not relate to that part, and merely learn in order to meet the requirements. Saying that, there are moments where students can enjoy a true cognitive development of the mind, and appreciate a new skill they just acquired. When those moments are followed by a teacher that can notice them, there is a new sense of belonging to the world—cognitive belonging. It creates a stronger sense of engagement to the school, and of the three different kinds of belonging, this cognitive belonging is the focus of the project.

Every teacher aims for students to have that "A-HA" moment: that moment of revelation, where students feel that they own a new knowledge and now it belongs to them, creates the strongest sense of cognitive belonging. It is the moment when the new knowledge is part of you and you are a part of that knowledge. It is more than getting the correct answer from the book or getting good feedback from the teacher. It has to include some part of research and exploration that provides objective evidence of this new understanding.

As an example we might look at the following Desmos activity. Desmos is a math teaching application that enables students to explore math phenomena. With the Desmos activity shown in Figure 1, the students are required to pinpoint the center of a dartboard that is situated on a Cartesian axis system [1].

Figure 1: *The dartboard.*



Whenever the students enter a coordinate the point appears on the axis and they can fix it until it gets to the correct spot (the center of the dartboard). Students reveal the logic of the axis system by active exploration, usually through trial and error. The above example might contribute a lot to the engagement of learning math through visual tools, and it certainly works. We can do even better by finding examples for math usage in the life of the students. Then, they can explore things that have relevance for their day-to-day life such as the example below.

An Example Using Mean

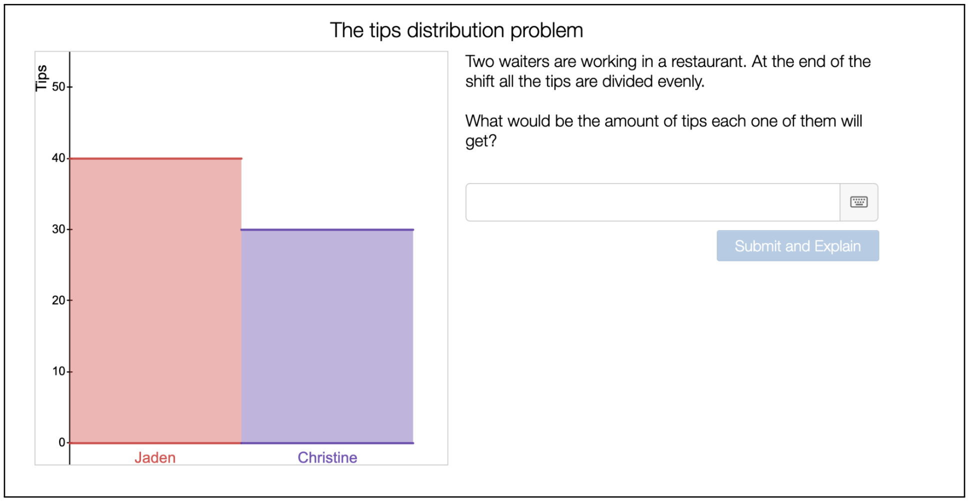
The matriculation exam in Israel requires students to understand the concept of mean (average). Students must understand how to calculate the mean of a data set, how to find the missing value in a data set for a given mean, and how the mean changes when the initial data is changed. The activity below involves using technology and a situation that is common to the students to help them understand the mathematical concept of average.

In Israel, it is customary that students in high school go to work after school, some do shop keeping but most of them work as waiters in restaurants. When the shift ends the waiters divide their tips evenly so all the waiters get the same amount in tips. Thus, they have to find the average of all the tips for the night. We will assume that all the waiters work the same number of hours for each shift. If there are only two waiters, this task is easy. As more waiters are added onto a shift, the task becomes more difficult. It requires the workers to analyze the effect of how adding more waiters will affect their tips for the night. Additionally, if one waiter does not do as well with tips during a shift, the entire wait staff will earn less money that night. Waiters soon learn that a single worker can really affect their income and they soon decide who they want to work with and who they would like to avoid.

Danny designed and created a Desmos activity to simulate this scenario. Here are the six slides that students will work through as part of the activity.

[1] Access Desmos Activity at: https://teacher.desmos.com/activitybuilder/custom/570fc688b5188c4207ed8b9b.

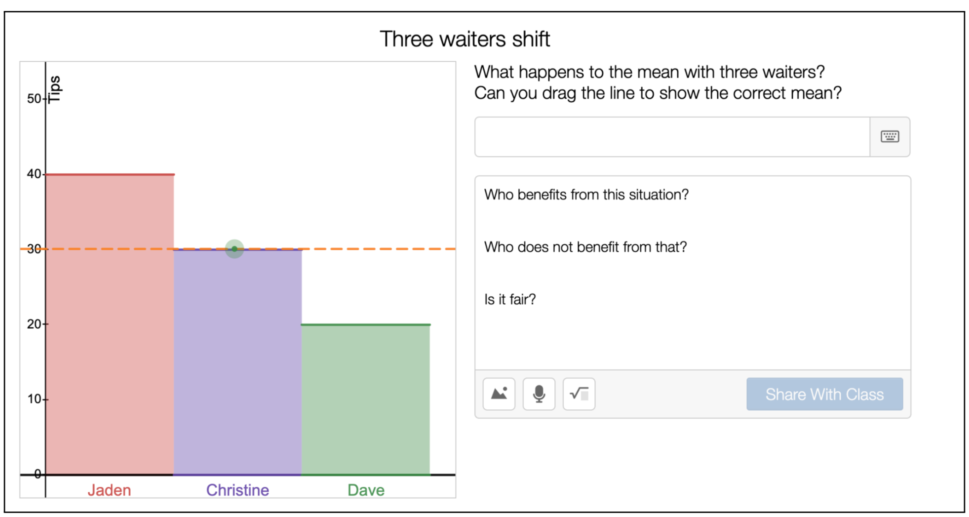
Figure 2: *Introduction to the activity (slide 1).*



In this slide, students are introduced to the scenario of waiters dividing their tips evenly. The slide sets up the problem and asks students to think about how they might go about calculating the average tips for the night. This slide sets the stage for the activity and works with the students' basic intuition. It consists of a diagram with two bars representing the tip amounts that two waiters earned during their shift. Finding the average for the tips of two waiters is easy, and the graphic representation can enhance the understanding. Students typically get this answer correct—the weaker students might tend to revert to doing the regular calculation for the average as they might not have the intuition of the full meaning of averages yet.

The second slide (Figure 3) adds another waiter, thus three waiters working the same shift. Now, students must determine the average(mean) for the amount of tips each will earn. After they determine the mean, they need to place a line that represents the average on the graph. This line might be confusing for the weaker students, but they need to look at this carefully and understand that the mean was lowered because of the third waiters' tips that were less than the other two workers. It helps for them to visualize this using the bars shown on the slide.

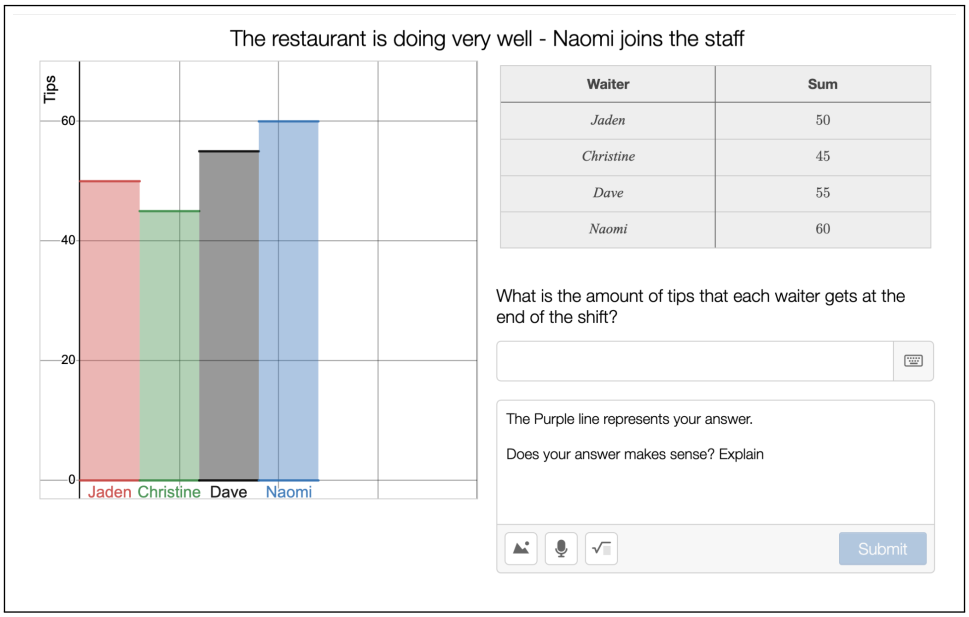
Figure 3: *Three waiters (slide 2).*



When this activity was presented to students it was confirmed that most of the students used the calculation of the average with numbers, rather than using the conceptual meaning of the concept. Even when the third waiter was added with the mean as the exact middle value, the students still did not understand the conceptual meaning of the average and used the arithmetic calculation $\frac{20+30+40}{3}$.

The third slide (Figure 4) adds another waiter, and now is the point where students need to understand the average and articulate that understanding by explaining the work. After students enter their guesses, an orange line will appear that crosses the diagram on the point of their calculated average. They will then decide if their answer makes sense to them and provide an explanation of the results.

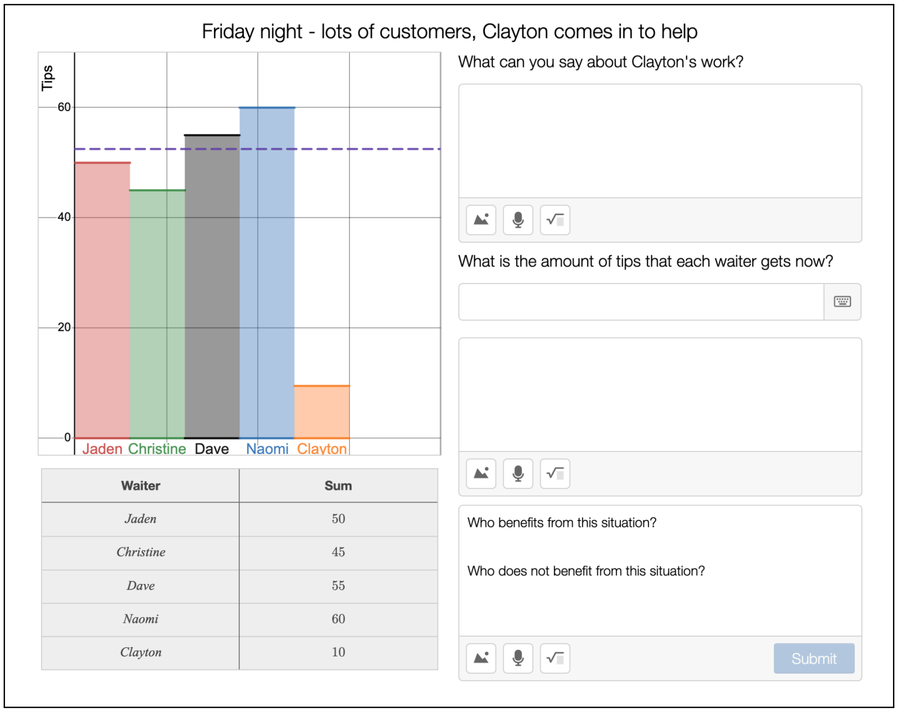
Figure 4: *Four waiters shift (slide 3).*



The fourth slide (Figure 5) adds one more waiter onto the shift. This waiter does not earn nearly the same amount of tips as the other four. The role of this slide is to bring some critical thinking to the way the students view the scenario. It does this by adding a worker who does not do their fair share of the work, so the tipping distribution system becomes extremely unfair and creates a place for the teacher to discuss the scenario even further. Asking students what they might do in this situation or how they might help this waiter, or if this system should change are vital discussions that students need to have. This adds a higher level of thinking (analysis on Bloom's Hierarchy) that can draw into the discussion other students that did not find their way to the lesson until now (Bloom, 1956).

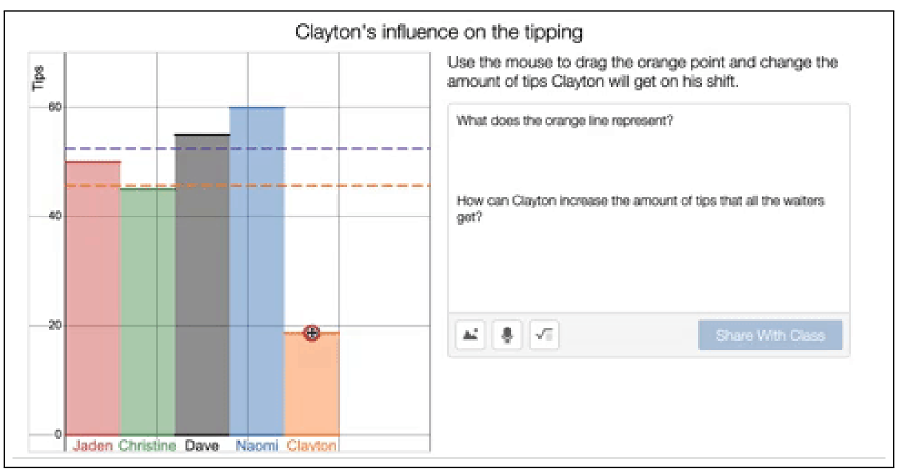
Students tended to have very strong reactions to Clayton's work ethic. One student stated "He is lame. He is declining the average tips for the other workers by 8.5 (shekels)..." This statement was actually true based on the slide that was given to the students. Another student indicated that Clayton was not good and was hurting the other waiters of the restaurants who are working very hard. Many thought Clayton should be fired.

Figure 5: *The slacker waiter (slide 4).*



The fifth slide (Figure 6) is all about transformation of learning by visualization, that is now enabled by the use of technology. The students can play with the tipping amount of the last waiter using their mouse, and simultaneously see how those changes affect the mean through the blue line.

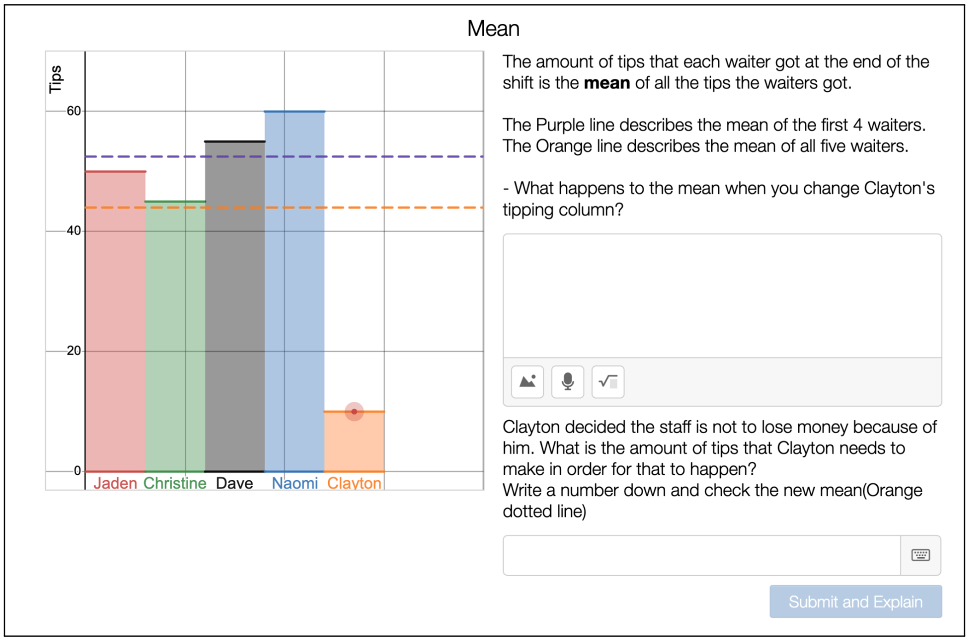
Figure 6: *Exploring the influence of new results on the mean (slide 5).*



Students in Danny's class seemed to start to understand the concept better as they started to use the slider on this figure. The students all knew that the amount the waiters earned rose when Clayton earned more tips and most of them figured out the value that Clayton needed to make in tips in order for the other waiters to make the same amount of money.

The last slide (Figure 7) reinforces everything the students did, adds the word "mean" to the math vocabulary and aims at the final, very important understanding—adding a result that is equal to the mean does not change it.

Figure 7: *Analysis (slide 6).*



From the teacher's perspective, Danny wanted the students to be able to articulate the meaning of the average in words. He found that none of the students did that. They all showed or explained the numerical procedure to finding the mean rather than describing the mean conceptually. Danny thought that perhaps the directions needed to be clearer for students to make sure that they explain their work in words.

Conclusion

Working with youth in complex mental situations sometimes requires teachers to simply help them find a reason to hold onto life- metaphorically and per se. There are a lot of ways to intervene such as direct dialogue, connecting with peers, creating empathetic settings in class, recruiting parents and many more. But in this project the emphasis is around the possibilities entrapped in pedagogy and specifically in math pedagogy. Most of Danny's students hate math and are so fixated about the fact that they are bad at it that they have no sense of belonging to the class or the school. The change in the students' perspectives requires some kind of invention that creates ground for belonging, to school and peers, but mainly belonging to one's self learning procedure and cognition. Techniques like rerouting the assessment procedure, finding relevant real life examples, praising student effort instead of results, and designing applications that intrigue learning can make the change. It could be on the engagement of the students, their ability to learn, their feeling of belonging, and even, their life force.

This work was intended for youth-at-risk, mainly the kind of students that Danny is teaching. Due to the rising amount in the reports of mental issues with youth, following the years of lockdown, it has a place for a broader audience. It is now time for teachers to develop the pedagogy that gives students the will to think, to struggle through hardship, and to cognitively belong.

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The co-authors together at a recent conference!