Community Engagement in Mathematics through Outreach Programs

by
Kerala Riley

A THESIS

submitted to

Oregon State University

Honors College

in partial fulfillment of
the requirements for the
degree of

Honors Baccalaureate of Science in Mathematics
(Honors Scholar)

Presented March 14, 2023
Commencement June 2023

AN ABSTRACT OF THE THESIS OF

Kerala Riley for the degree of Honors Baccalaureate of Science in Mathematics presented on March 14, 2023. Title: Community Engagement in Mathematics through Outreach Programs

Abstract approved:_____

Mary Beisiegel

Mathematics outreach typically consists of community events that show the exciting applications of mathematics, particularly to K-12 students. The goal of mathematics outreach events is to increase student interest and involvement in mathematics-related activities. Students start to develop a stigma against mathematics by the end of elementary school. Outreach events allow an opportunity for students to discover an enjoyment and interest in mathematics along with reducing the stigma associated with mathematics. My goal is to learn a bit more about the different perspectives when creating an outreach event and how I can apply these ideas about outreach to my future teaching practice in high school mathematics.

Keywords: mathematics outreach, stereotypes, STEM pipeline, diversity, equity, outreach

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APPROVED:

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I understand that my project will become part of the permanent collection of Oregon State University, Honors College. My signature below authorizes release of my project to any reader upon request.

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Kerala Riley, Author

Chapter 1 Introduction

1.1 The impact of mathematics on students

Mathematics has a bad reputation in academia and has a lot of stigma attached to it. As a result, many future students decide to avoid STEM fields because they have a fear of mathematics. From an early age, students categorize themselves into “math people” and “not math people.” Students begin to think that they are innately bad at math, and that their ability to learn math cannot change no matter what they do. They may use the excuse that they aren't smart enough to attempt to solve a math problem. Like the majority of the population, these individuals may be victims of a mindset that taught them to believe that they are not smart enough to learn mathematics. This is an example of the nature vs nurture theory; either you’re born with the ability to do mathematics, or you develop the skills to do mathematics through learned experience. It is accepted academically that the nurture theory applies to the ability to learn mathematics (Pantsar, 2021, p. 595). This means that sufficient facilitation and the learner's own effort can overcome difficulties in learning mathematics. Nevertheless, the stereotype that students are innately born being good or bad at math is what limits students from pursuing degrees in fields that require mathematics. In fact, motivation to succeed and pursue math has been shown to decrease from middle to high school, and unlike general academic motivation, remains lower over time (Garriott et al., 2016, p. 596).

When thinking of what they would like to pursue, students may ask themselves questions like: “How good am I at doing this?” or “How much do I like doing that?” and characterize themselves in certain groups (ie a math person, music person, computer person, etc). This is the beginning of a long process of building identity and the answer to these questions will play a critical role in whether students choose to enroll in specific classes during highschool, what

college major they will declare, and what occupation they will one day aspire to work towards (Wan et al., 2021, p.868).

Student achievement in mathematics classes is correlated to their enjoyment and likelihood of pursuing higher education in mathematics. Grades from tests and exams determine if a student feels as though they are succeeding in a subject area. According to a research study conducted with 95 secondary school students through a survey in Rwanda, "results showed that low marks and harsh and careless teachers can demotivate students to learn mathematics" (Ukobizaba et al., 2021). On the other hand, if students do well on exams and other assessments, they have more confidence and are more likely to pursue fields that require mathematical thinking and skills.

Stereotypes are another factor as to why students don't think of themselves as fitting into the "math people" category. Mathematics is stereotypically viewed as being only for "geeks" and "nerds" and is generally looked at as "messy." Research has shown that students have a negative image of what liking and excelling in math is (Garriott et al., 2016, Picker & Berry, 2000, Wan et al., 2021). These negative stereotypes have led to a decrease in motivation in math. Students have determined the "type" of person who would choose to pursue a higher education in mathematics. If they don't identify with these stereotypes, then they are less likely to become interested in mathematics. "Research also suggests that exposure to STEM career role models may be lacking for adolescents and that students may choose to forego STEM domains in high school" (Garriott et al., 2016, p. 586). These stereotypes lead people to believe that the mathematics community is very gatekept and that they cannot succeed. There needs to be a change in how students perceive mathematics and this change in perspective can be brought about by outreach programs.

1.2 One solution to this problem is outreach

One solution to these problems is outreach. Outreach is a particular activity or program presented to students for the purpose of supporting the understanding, awareness of, interest, and enjoyment of mathematics. These programs allow students to explore a particular subject of mathematics without the pressure of producing a correct answer or receiving a grade.

There are so many different types of outreach programs designed to connect to students, teachers, parents, and other stakeholders. A stakeholder refers to anyone who is invested in the welfare and success of a school and its students. These include administrators, teachers, staff members, students, parents, families, community members, local business leaders, and elected officials (such as school board members, city councilors, and state representatives). Outreach programs can be seen in the forms of camps, meetings with older students, conferences, fairs, and hands-on events. They are usually run by volunteers from the community or local universities/colleges, but some are supported by certain companies and schools.

Research has shown that outreach programs improve mathematical confidence in students, increase enjoyment of doing mathematics, lessen mathematical anxiety, remove the stereotype of who goes into mathematics, and help students to see and learn about deeper problem- solving resources (Waldrop, 2018, p. 274, Carpenter, 2015, Dubetz & Wilson, 2013). As a result, outreach programs encourage more students to pursue STEM and mathematical disciplines.

1.3 Why this is important to me

This topic is important to me because I have struggled with my relationship with mathematics in many periods of my life. All throughout elementary school, I used to hate mathematics- I thought I was not a “math person” and that is why I was struggling so much in

class. I didn't try to solve problems because I felt that I wasn't smart enough. It wasn't until I got into middle school where my teacher somehow made mathematics fun that I really started to enjoy it. I did applied problems, hands-on activities, and participated on the receiving end of outreach programs.

During this time from middle school into high school, I fell in love with the art of solving problems and mathematics. This newfound positive opinion of mathematics that I received from my middle school teacher is what motivated me to pursue a mathematics degree. But once I experienced courses in undergraduate mathematics, I started to struggle. Mathematics was no longer fun or exciting (maybe because I was no longer doing well), it was a chore to get done. My sophomore year was the most difficult because all of my classes were online due to COVID 19. I not only struggled with the material we were learning in class, but I was struggling with the online learning environments.

During this time, I regularly faced issues related to interactions with my peers. In particular, I began to find it difficult to meaningfully navigate a field that was, and still is, predominantly male. I was treated like I had no ideas worth sharing. Dominating the conversation, interrupting me to tell me that I am wrong, repeating the same idea I just stated and getting credit, and not respecting my voice/ideas are just some of the actions that were present in every math class that I took. At first, I was afraid to speak up and I let others collaborate without getting involved that much, but I finally got tired of it. There were so many times when I thought of dropping out or that I was not smart enough to pursue this major. The only reason I did not drop out was because of the sheer determination of proving everyone wrong. It wasn't until we were back to in-person classes that I found a community to connect with. I saw their table at a club fair and was introduced to the club *Association of Women in Mathematics*. Here, a group of

women and minorities just showed up and talked about the inequities and struggles that we were facing and I learned that I wasn't the only one who was struggling. I got to hear from all sorts of people about the different ways of thinking/ learning and solving problems. I had a safe space where I could ask for help, and see so many new and exciting things about math. I did not realize the full extent of how many different topics and research there were – and it was exciting.

Having mathematical confidence and courage are characteristics I am still working on, but the community of people I have met through classes, conferences, outreach events, and my club have helped me so much in rediscovering my love for mathematics. I hope that in the future, classes I teach I can bring awareness to social norms in the classroom and explore ways to structure group work so that it allows everyone to feel comfortable in sharing their ideas. Math is not always about having the correct answer; it's about the process of getting to an answer. Everyone goes through a process of trial and error to learn. I learned that failure is awesome in mathematics, and that having people with different mathematical backgrounds in a group can help minds grow and find connections. We are not taught this in school and I had to find seasoned mathematicians to finally understand that failing is a part of learning.

Having the people around me who are excited about mathematics and who like to share their thoughts and research is why I continued to finish my degree in mathematics. Although I struggled so much, I want to be like those people that helped me stay and pursue my passion. I know how effective seeing and interacting with people who share the same identity can be – and outreach is a way to do this. Hearing about others' experience, knowledge, and guidance showed me a path to loving math and I think this support needs to be available to all students.

In Chapter 2, I define outreach and then I review the research literature that investigates the impact of outreach on students. I then look into the effect of outreach programs on students.

In Chapter 3 of this thesis, I describe and reflect on my participation in an outreach activity at Oregon State University (OSU) and what I learned from that experience for my future teaching practice. In the Appendices, I have included the mathematical activity that I implemented in the Discovery Days (described in Chapter 3) outreach activity as well as directions and recommendations for folks who might want to use the activity in their own outreach.

Chapter 2 What is Outreach?

2.1 Definition and goals of outreach

Within the field of STEM education, the word *outreach* can take on different meanings depending on the parties involved or how outreach content is provided, which is why there is a need to define it.

Broadly, the online Oxford dictionary defines *outreach* as "the extent or length of reaching out." In this case, I think reaching out means making an effort to do something for other people. There are so many ways that everyone can participate in outreach outlined in the section below, "Types of Outreach Events." In my experience the "doing something for other people" part of the definition could be described as making others excited about what you are excited about. Some hold the belief that outreach is only directed to low-income and minority students because they don't have the same resources or support as the other students, but since there are so many different types of outreach programs, it can be directed to any student. You can do outreach in any subject, but in this paper I focus on STEM – specifically mathematics outreach.

To further broaden how outreach can be interpreted, the online Merrium Webster dictionary defines outreach as "the extending of services or assistance beyond current or usual limits." This definition requires us to define "the services" to whom and from who. In the context of mathematics outreach, the services are described by activities or talks, while the audience is generally the K-12 and college students, parents, and educators. The "who" would be defined by volunteers from the community that are involved in some sort of STEM profession, or organizations.

In the article *STEM Outreach: A Literature Review and Definition* by Tillinghast et al., (2020), the authors define outreach as "the act of delivering STEM content outside of the

traditional student/teacher relationship to STEM stakeholders (students, parents, teachers...) in order to support and increase the understanding, awareness, and interest in STEM disciplines" (p. 10). This is the definition I will use in this paper.

As the literature reveals, there is outreach aimed specifically at teachers and parents in addition to outreach that is geared towards students. There have been cases of outreach being implemented in classrooms or added into the curriculum at the K-12 level, but most outreach is aimed at students outside the traditional classroom.

In this paper, outreach is usually followed by the words "activities" or "programs" because it describes relatively quick and small interventions to the regular school curriculum and/or the community of stakeholders. With such an inclusive definition of outreach in regards to STEM (as defined above) there are many different assortments of activities brought to the community.

2.2 Outreach Events Methodologies

There are many different types of outreach events, each for different types of students and for the variety of people hosting the events. In the article *STEM Outreach: A Literature Review and Definition* by Tillinghast and colleagues (2020), they state that "Outreach delivery can take the form of various methodologies, can carry diverse scales of efforts and levels of focus, and can be uniquely tailored to the population targeted" (p. 2). Explained below are some of the different types of outreach.

Lecture-based events are those in which a speaker presents details about certain subjects in a lecture style aimed at a general audience. The purpose of lecture-based events is to promote mathematics by presenting real world mathematics problems, research, interesting aspects about the field, or by sharing inspiring stories. These events can be used in a classroom setting and are

easy to incorporate into the curriculum. Lecture-based events can also be seen at mathematics conferences across the world.

Active Learning/ Inquiry Based learning outreach events are characterized by students' participation in the learning process. Usually problem based, students are encouraged to explore ways to solve a problem, share ideas with their peers, and ask questions. This instead takes the place of the usual teaching process where teachers tell students what they need to know. This allows for students to think deeply about concepts and make meaningful connections.

Workshops/training events are usually directed toward educators as a form of professional development (Tillinghast et al. 2020, p.4), but are recently being introduced to be available to other stakeholders. These events are usually found outside of the classroom and focus on a specific theme or problem. Whether it is improving teaching pedagogy or learning about different opportunities to apply mathematics - there are many in person and online resources available. These are also used to workshop a problem and allow the audience to engage in self reflection and adjustment.

Camps usually focus on a more rigorous exploration of mathematics. In these events, students participate in varied and interactive games and activities. These activities may include solving puzzles, working in teams and groups to solve problems, completing math projects, exploring the application of math, or observing mathematical patterns.

Hands-on events are usually focused on exploring the "fun" of math topics. These involve active personal participation in an activity. It sometimes combines both play and education to make students more receptive to the material. It can be found both inside and outside the typical classroom setting.

Near-peer mentoring is a type of outreach that focuses on getting pairing students close in age to talk about their experiences about pursuing mathematics. This is usually seen as college- high school student mentorship. Since they are so close in age and experiences, students are more likely to develop closer relationships with their near-peer mentors and listen to them more than they might listen to someone who isn't as close to them in age and experience. This type of outreach program is usually used to promote students going into college STEM fields. Mentoring may involve activities such as giving advice for the college application process, showing mentees how to sign up for classes, and building a sense of community between near-peers.

Even students can facilitate outreach activities by presenting a project or problem to the community. This is beneficial because the students themselves learn ways to make a problem digestible, and community members get to learn about the problems/projects that the students are presenting on. An example of this could be something like a math fair. My high school did something similar in which each student completed a STEM related project and then presented the project to the community in the form of a STEM fair. In my experience, this gave students an opportunity to share their projects with teachers, other students, parents, and others in the community.

Outreach events can consist of a mixture of different methodologies to better target their audience. Some examples of these are:

- SNAP math fair would be characterized as a hands-on and active learning/inquiry based program. It involves the participation of both students and community, where students do their own project, answer a certain question, and then present a tabletop display to the community.

- Advocates for Women in Science, Engineering, and Math **(**AWSEM) clubs would be characterized as peer-mentoring and hands-on activities. They are designed to nurture girls' interest in STEM by providing a program of hands-on activities paired with female undergraduate students studying STEM. They host several different outreach programs with their club, but all focus on the same methodology.
- STEM Academy at OSU would be categorized under the Camp category. These day camps are directed to K-12 students and are held at the OSU campus every summer. Each camp class has a certain grade criteria for joining and specifies a different topic in each. These camps allow students to learn more about a subject area, and to create a related project.
- Discovering the Scientist Within (DSW) would be characterized under workshop/training, hands-on, and near-peer mentoring events. This is a workshop designed to nurture girls' interest in the sciences by providing a program of hands-on activities led by positive adult women STEM role models. During the workshop, students hear from a current woman scientist before breaking into small groups and participating in activities.

There is a wide variety of people who facilitate outreach events such as volunteers from the community, local college/schools, or professional organizations. In an effort to gain an understanding of outreach activities that are supported locally at Oregon State University, I talked with the student engagement coordinator in the College of Science at OSU. The student engagement coordinator, who has seen and participated in many outreach programs, said that outreach programs are mainly run by volunteers, but it is not uncommon for organizations such

as Oregon Museum of Science and Industry (OMSI) or the Oregon Coast Aquarium to come down and participate. They believe that experiencing learning outside the typical day in a classroom makes outreach even more exciting and special (i.e. going to a new environment to learn, or seeing someone new in the classroom)

The importance of identifying the previously mentioned categories of outreach methodologies is to better tailor the activities to the target audience. Vista (2015) states that the "less lecture and more hands-on activities the better. Knowing your audience is vital for creating your message, and different age groups will react to different methods of communication." So, for younger students there are more active learning and hands-on opportunities and less lecture based and peer-mentoring because younger students will get bored more quickly and will not be receptive to the information and knowledge contained in the other outreach methodologies.

2.3 Why is Outreach Important?

One of the main objectives of outreach is to motivate learners' interests and curiosity in mathematics – motivation to pursue higher mathematics, motivation to make sense of mathematics, and motivation to enjoy mathematics. If implemented correctly, outreach has the ability to change the way mathematics is perceived in popular culture. This is important because it has shown to have a positive effect, not only on students but also on the other stakeholders as well. These all encourage the population to be more accepting of mathematics and the belief that everyone has the ability to succeed in mathematics.

During our conversation, the student engagement coordinator at OSU mentioned the "STEM pipeline." I had never heard of the pipeline before, so I decided to do some more research on the subject. The "leaking STEM pipeline" refers to the dropout of students pursuing a STEM education, starting at the beginning of high school. Figure 1 below shows a visual

representation of the leaking pipeline between the years 2001 and 2011. Out of 4 million 9th graders, only 2.8 million graduate high school. About 1.3 million students go on to college each year, but only 278,000 choose to major in STEM, and only 167,000 students graduate with a STEM degree. Of those STEM graduates, only 15,000 graduated with a degree in mathematics (*Digest of Education Statistics,* 2019). Why do so many people "leak out" of STEM fields? This question is one that motivates my inquiries related to mathematics outreach in order to "catch" the thousands of students who slip through the cracks.

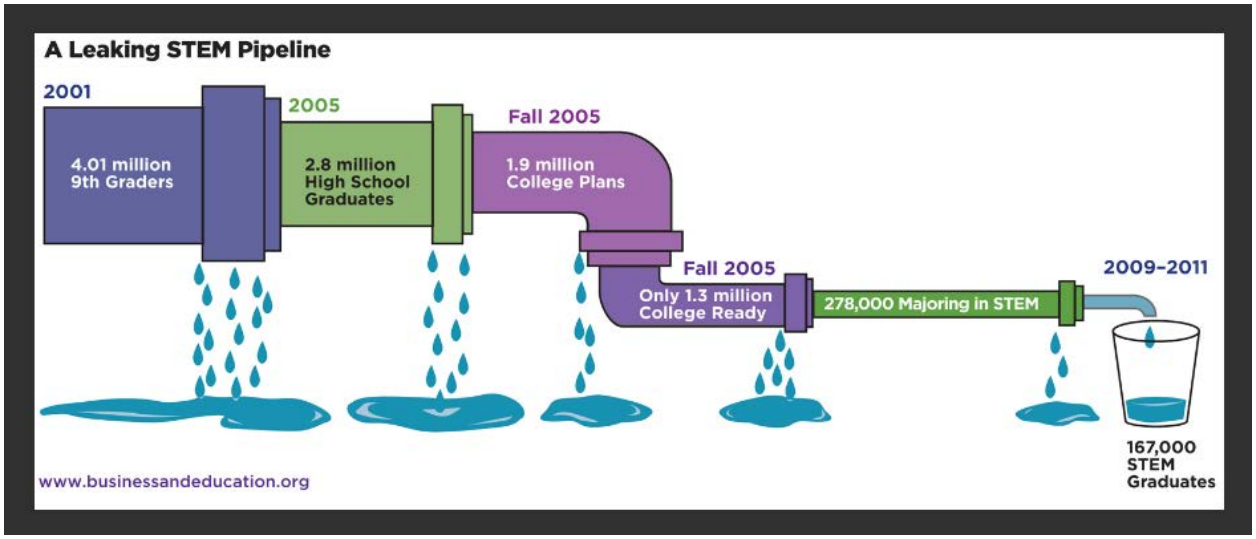

Figure 1: (*Stem pipeline*, Sustainable Horizons Institute, n.d.)

Mathematics is the basis of almost all STEM fields, so those who dislike mathematics may shy away from pursuing occupations in STEM and consequently drop out of the pipeline. As previously stated, students acquire a certain mindset when it comes to mathematics – that they are "math people" or not "math people." There are many reasons why students may take on such a mindset. They might be experiencing math anxiety, not feeling confident in doing mathematics, or feeling uneasy because of their previous test scores in school mathematics.

When it comes to changing the student mindset about mathematics and STEM, math anxiety is one barrier that can be directly addressed through outreach. Research has shown that

parents and teachers with math anxiety are more likely to spread it to their children and students by endorsing stereotypes, making negative comments, and overall providing bad experiences with mathematics (O'Leary et al., 2017). And so, the attitude held by those people who are close to a student can have a direct effect on the studen''s own attitude regarding math. Finding creative ways to show how mathematics can be fun, challenging, and useful to all parties can help alleviate this anxiety and improve confidence overall. In my own experience, hearing from someone who was passionate about mathematics was much more exciting than a stale lecture from a droning professor. Hearing from passionate speakers helped with my own anxiety about mathematics because I knew that if someone else can succeed in mathematics and find it exciting, then I could as well. In my experience, outreach activities have the ability to change the perception and attitude a person has about mathematics, and as a result can help the retention of students pursuing higher education in mathematics.

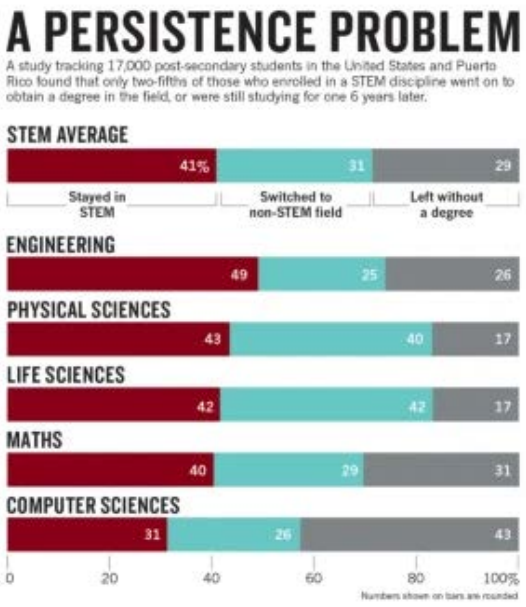

Figure 2: A persistence problem (Waldrop 2018, p. 274)

Figure 2 shows that undergraduate mathematics only has a 40% retention rate. And of the 60% that switched or left without a degree, 80% are minority groups and women (Waldrop,

2018, p. 274). So why are the majority of those who drop out of mathematics women and minorities? There are a multitude of reasons for this that stem from issues of social status, culture, and lack of outreach in our schools.

There are also both economic factors and interest factors that contribute to the "leak out." Some students cannot afford to go to college, have to drop out of high school to work, or they just have other interests like going to a trade school- which are also reasons for the loss of students in the pipeline that were not mentioned in the literature.

Mathematics has been notoriously gatekept by the stereotypes and societal standards, preventing students from pursuing degrees in STEM. Picker and Berry (2000) conducted a research study where students aged 12-13 in the USA, UK, Finland, Sweden, and Romania were asked to draw what a mathematician looks like. They found that students drew images of mathematicians that were "overwhelmingly negative." Students drew and described mathematics as a center of power, foolish, crazy, one that has magical powers, and predominantly "white, middle aged, balding or wild-haired" (Picker & Berry 2000, p.89). These stereotypes are cemented in popular culture and social media across the world as is part of the reason that students don't pursue mathematics.

Having more mathematics outreach in all schools K-12 will help the stereotype of who goes into mathematics, illustrate the work that mathematicians actually do, and hopefully show that minorities and women can go into mathematics. It was said by Picker and Berry (2000) "And for the pupil who wrote, 'I drew a woman mathematician because there seems to be only men mathematicians...,' such a visit and interaction with a female mathematician would probably have a lasting encouraging effect" (p. 90). Thus, just seeing people who share their identity succeed in mathematics will help students with their anxiety and confidence in doing

mathematics, which is why showing a diversity of identities and ways of thinking about mathematics are important.

Outreach is one important step to fix the leaky pipeline and make the mathematics community more equitable and diverse. Outreach allows an opportunity for the mathematics community to connect with students and show them that they can succeed. It allows students to be able to explore their curiosities without the anxiety of getting a grade or fear of doing things wrong. It also helps build confidence in mathematical thinking/skills for all parties involved - parents, teachers, and students. Aguirre and Gross (2018) found that parents were resistant to mathematics teaching because of their own experiences in math. Therefore, "increasing adults' positive approach would improve the community's perception of mathematics" (Aguirre & Gross 2018, p. 64-65). It helps the community become aware of mathematics being a field to go into and helps the ways in which students connect to and improve their attitude about, and better their performance in mathematics.

In addition to students and parents, outreach programs can also help teachers. Outreach programs like talks and conferences allow teachers to learn as a form of professional development. Some programs can be applied in the classroom setting- either as an activity added on to the curriculum, or as a talk or presentation.

Mathematical outreach has the ability to reach all stakeholders. Students, teachers, and parents all have something to learn from outreach programs if they participate, whether it be a mathematical concept or an appreciation for problem solving. It is also important to those who lead outreach programs because it helps them gain a deeper understanding of mathematics and its applications, and helps them develop valuable communication skills in the context of mathematics. If one can successfully explain a subject to the general audience, their own level of

understanding is greatly increased. In a study of undergraduate perceived gains from participating in outreach programs, Carpenter (2015) found that leaders of outreach programs learned to integrate scientific information across disciplines, increased their understanding of science concepts, and increased their confidence in sharing scientific knowledge. They also developed transferable professional skills such as communication, leadership, teamwork, and organization (Carpenter, 2015).

2.4 What makes outreach successful?

There are lots of ways in which outreach is considered successful because outreach has so much to offer in different disciplines. The overarching goal of mathematics outreach is to increase interest in mathematics and STEM fields. After reviewing the literature, outreach is measured as successful if the audience takes something out of the experience – whether that be learning more about mathematics, learning about group skills and dynamics, engaging in thoughtful discussion, making meaningful connections, gaining a sense of value for math, or restoring the sense of self-confidence in mathematics.

In a talk about mathematics outreach, "TMWYF: Mathematical Outreach: Defining a New Research Field in Mathematics," the speakers had an audience of mathematicians and mathematics teachers answer the question of "what makes outreach successful?" (Hancock & Wiegers, 2021). Among the responses were words like fun, curiosity, exploring, interactive, collaboration, and inclusivity. So defining a successful outreach program would be determining if a student had fun, worked collaboratively, and gained more interest in mathematics. Using activities that are interactive, inclusive, and that allow students to explore their curiosities will help with the success of the outreach program.

The Girls in Engineering, Mathematics and Science (GEMS) program is a science and math outreach program for middle-school female students and consists of a week-long camp filled with lots of activities. Dubetz and Wilson (2013) wanted to measure the difference this camp made, so they set up a survey before and after the students' experience in camp and compared the results. They found that "Survey results indicating the interest in science before and after attending a GEMS outreach event shows that overall, students had a drastic increase in interest and attitudes about science" (p. 46). This is shown in figure 3 below. This is an example of a successful outreach program because it directly increased the students' interest in the field of science and mathematics.

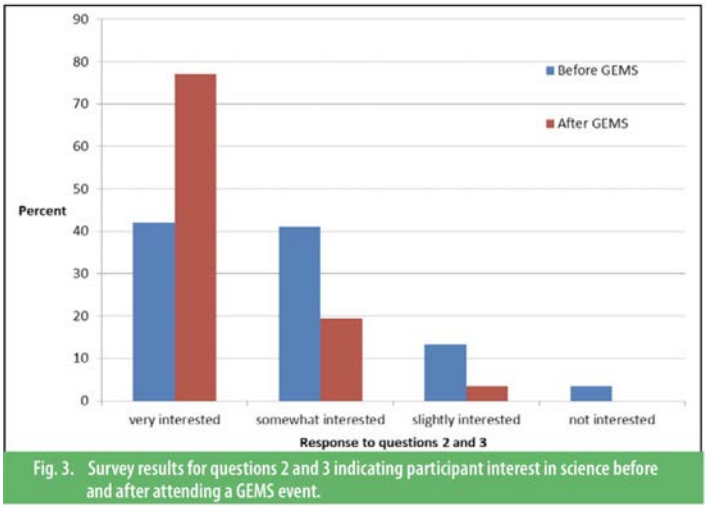

Figure 3: A comparison between before and after participation in GEM outreach program surveys (Dubetz & Wilson, 2013, p. 45).

Other research also concludes that there are so many positives to gain from participating in outreach programs, and that outreach programs are effective and continually succeed in their goals. For example, Wilson and Grigorian (2018) conducted a research study on how outreach programs using MathShows influence high school students' attitudes towards mathematics. MathShows consisted of several "acts" – interactive mathematical demonstrations and

investigations designed to be mathematically attainable to the grade/subject-level of the audience, followed by testimonies from college students about their experience in getting into college and studying mathematics. The authors wanted to see the difference of impact before and after the MathShows, so they gave a survey a few days before the MathShow and then immediately afterwards. They found that "after the MathShows students reported that their sense of the Value of mathematics, their Enjoyment of mathematics and also their Motivation to pursue further studies in mathematics had all slightly increased" (Wilson & Grigorian 2018, p. 52). This is shown in figure 4 below. The authors also found that these shows had a greater impact on those who had lower interest at the beginning. They noted that a "comparison of impact between the high and low subgroups shows, in general, that the MathShows had a greater positive impact on students who had low initial values in any of the categories" (Wilson & Grigorian, 2018, p. 54).

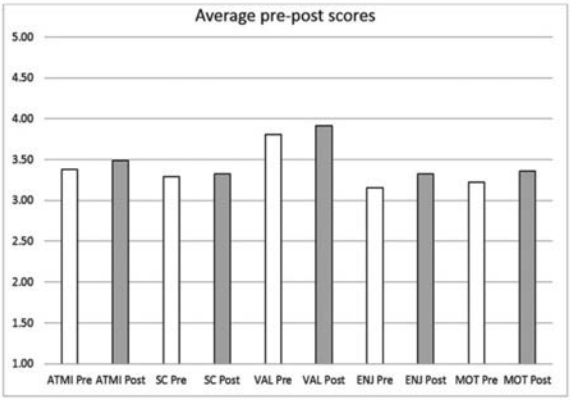

Figure 2. Differences of average pre-post ATMI and subscale scores.

Figure 4: Results of survey given to students before and after participation in the MathShows outreach program (Wilson & Grigorian, 2018, p. 54).

Vennix and colleagues (2017) conducted a study that used a questionnaire directed to 729 high-school students and 35 teachers to assess the effect of outreach activities on learning environments, motivation, and perception of said activities facilitated at outreach events. Each

student was exposed to 12 outreach events – all with different methodologies throughout the year. They found that awareness of STEM in regards to applicable problems, jobs and relatable skills in real life will increase positive attitudes toward STEM as well as increase the likelihood for choosing to pursue STEM in the future. By participating in outreach, the learning environment of the regular classroom is extended with new elements via the unique collaboration with the industry and higher education. As a result of the involvement of the corporate world, outreach adds real-life components and incorporates twenty-first century skills such as multi-disciplinary tasks, team work, problem solving and critical thinking (Vennix et al. 2017, p. 23).

Tillinghast and colleagues (2020) have also shown that outreach programs increase the confidence of students approaching mathematics. They stated that "the opportunities for life-changing experiences where students are exposed to STEM activities through field trips, camps, workshops, mentorship and other activities all serve to build students confidence that they can succeed in STEM" (p. 10). Because outreach programs are not graded, students don't have the pressure of always being right. This allows them opportunities to explore their curiosities, think deeply about the material, ask questions, and collaborate with others- which all play a factor in increasing confidence and reducing anxiety.

All of the studies mentioned in this paper indicate that outreach is effective in making a positive impact on students. It not only helps with learning mathematical concepts, but it also allows students to engage in and develop meaningful conversations and establish confidence when working with mathematics.

Chapter 3 Participating in an Outreach event

3.1 Designing the activity (the mathematics, the intention, the plan for student engagement)

To gain an understanding on what outreach experiences mean, I decided to participate in an outreach event held at Oregon State University. *Discovery Days* is an outreach event hosted by the College of Science. It involves many mathematics, science, and engineering department clubs and sororities. This two day event, run by all student volunteers, is held in the Fall and Spring and is known to feature hands-on activities that are suitable for all ages, but targeted to grades 1-6. In 2022, this event took place on November 1st and 2nd.

To prepare for this event, I created a mathematics activity for students to work on. I wanted to make an activity that was fun, challenging, and got the students excited about mathematics. To do this, I researched pre-existing mathematics activities and found one with a pirates theme (called *Barbanegra the Pirate)* that I liked from Galileo Education Network. Taking this theme, I created a story and incorporated more problems into it. The mathematical ideas expressed in this problem are graph theory, number operations, variables and equations, system of equations, and applied mathematics.

There was a wide variety in the amount of mathematical knowledge of the students in these grade levels, so I made three different versions of a worksheet, version A, B, and C – each that are intended to give to a pair of students. I wanted each pair of students to get involved, so every version had two worksheets that would lead the students to two different spots on the grid and from there, they would use the string to connect the two spots to make a line (shown by just the blue line in figure 5 below). One worksheet had counting directions for students to follow. Another version had addition and subtraction mixed into the directions. The last version had multiplication and order of operations directions. It was set up so older students could be in

groups with the younger students to provide extra assistance if needed. Examples of these versions of the worksheet can be found in Appendix B.

The directions for setting up the activity were as follows:

Set up a 15x15 square that will look exactly like the graph they are given on the worksheet, but on the ground with tape. Mark one square near the middle left side with a special marking (this will be the "palm tree") and is where students will begin the activity.

Depending on how many students there are and what age group they are, split into 2-3 groups (preferably three groups) and give students the appropriate handout for the different grade levels in attendance. This means that if there are older students, give them the worksheet with the more complicated mathematical problems and give younger students a worksheet with just counting (if they can't do multiplication yet).

On the 15x15 box square made with tape, have one student complete blackbeard's path from the palm tree, then another student complete the other path from the palm tree. Maybe incorporating more movement by having students hop from each box on the ground. They will stay in the ending spot as the "flag." After the groups have completed all of Blackbeard's directions, they will connect the same color flags together (they should have been in the same group) with string. Then, the intersection of the strings is where the treasure is buried! An example of this can be seen in figure 5. The point is that the different groups will get a different path of Blackbeard (3 different worksheets), but when they work together, the intersection of their lines will find the treasure!

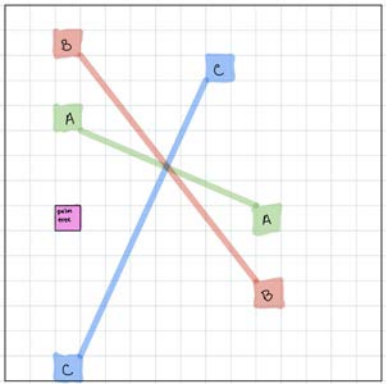

Figure 5: Example of the box with flags and strings intersecting.

Before the outreach event, myself and three other college students tested out the activity. It worked pretty well, but we adjusted the size of the square to fit the space we had on the day of the outreach event (to 10 x10) and also adjusted how the worksheets were formatted.

3.2 Implementing the activity

During the first day, we quickly realized that giving the worksheet directly to students was not going to work. This outreach event was too fast paced and there were so many students in and out of the room. It was unlike previous outreach events, where a certain number of students went to each activity and had a structured time limit to complete the activity. Instead, students just went to where they wanted – which is great because it allowed students to explore the topics and activities they were interested in.

The Blackbeard activity turned out to be really flexible. Instead of handing out worksheets, I first asked each student what they were comfortable with- addition, subtraction, multiplication, or division. Then, I verbally gave each student a math problem according to what they knew. I only facilitated 2 two sets of strings (instead of the previous three) so I knew they would almost always intersect and I could make up the problems on the fly. Almost each problem was different, so this made it even more fun. For example, I would say “Blackbeard went 5 times 4 minus 13 steps east.” This made this activity accessible and equitable to the

different age groups and each student. I noticed that students were more willing to engage in the activity when I gave them problems they recognized. More students (and even some of their parents) got involved with this activity because of the adaptability .

I would characterize this event as a success because it looked like many students were engaged with the activities, smiling, laughing, and overall having fun. In fact, Blackbeard's treasure was popular because each student was rewarded with a cool eraser once they found the intersection – a part of Blackbeard's treasure they found. I do not have the data to tell if this activity increased their interest or not, but from my own observations I overheard some students saying "this is the coolest thing ever" and one of the parents said "they loved these activities because it brings her back to her childhood." Breaking down people's stereotypes of what it can mean to solve mathematics problems was so interesting, and showing students that mathematics is "cool" and fun was the goal and from my observations, it looked like this goal was met.

3.3 My takeaways from the Discovery Days experience

From this experience, I realized that facilitators need to be very flexible when creating an outreach activity, or maybe any classroom activity. Things may not always go as planned, so it's important to be able to quickly adapt. To categorize this event in terms of the literature, this would be considered a Hands-On Event. Every year this event is a bit different. In previous years, the event consisted of individual classrooms coming in and having allotted time in each section, so I was under the impression that it would be appropriate to design an active learning/inquiry based activity. However, it ended up being too time consuming and complicated for students who were just stopping by, and that is why it was necessary to adapt it into a more accessible activity.

I also realized that it is important to make sure students are having fun when engaging in an outreach activity. There is already so much stigma around mathematics and students usually already have a set opinion on math; it is a goal of outreach to change these set stigmas and stereotypes. Many of these students have not seen mathematics outside of the academic setting, so it is important to show them that mathematics can be exciting. I think that showing them how engaging, cool, and beautiful mathematics can be was the point of Discovery Days. There are different types of mathematical outreach, but for Discovery Days, this type of event is to make sure students enjoy and have fun with mathematics.

As a future teacher, I now know how important it is to have different activities available for students. Some students skipped our booth because it didn't look interesting, and that is totally okay! There were so many activities present at Discovery Days, so there was something for every learner. There were activities where students were given full reign to explore, and some that had directions for students to follow – so there was something for every learner.

3.4 My takeaways for my future teaching practice and engaging in outreach for my students

From my experience, I have learned that I want to work towards making mathematics a more equitable and inclusive environment. Researching and participating in these outreach events allowed myself to give back to the community and share about the subject I love. This experience helped me improve my teaching, planning, and organization skills. I am still learning ways to communicate math and make it exciting, digestible, and relatable – so as a math teacher, reaching out to the community to help my students see the value and excitement of mathematics is something that I feel like I have to do to help my students succeed. I have seen the excitement that comes with combining play with education, and I would like to incorporate these into my future classroom.

This opportunity allowed me to reflect on my own experiences in mathematics. Since I have personally struggled with mathematics, I have learned empathy and can provide more resources and differentiated teaching styles to help students succeed. Now knowing the extent of the impact of outreach, I have learned skills to advocate for my students and hopefully help them receive a meaningful and enjoyable education, not just for the students that are in my classes, but hopefully for students within the entire school and community.

Everyday, I still see the challenges women and minorities face in mathematics. If we don't advocate for the future generation, the pipeline will continue to leak out students who are interested in STEM. We will be stuck in a system of inequity and under-representation in mathematics. I have been a part of having a lack of role models in mathematics and know the difference it makes in confidence.

Outreach gives students and teachers the opportunity for not only self development but for creating connections to the community. Making outreach events available for students and stakeholders to engage in should be a part of every classroom, but sadly, this is not the case. The purpose of this paper is to raise awareness among educators of the potential impacts of outreach in mathematics. I hope to use this research and experience to one day be a person that shows that mathematics is everywhere, it is extremely useful, and it can be fun!

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Appendix A Directions for Outreach Activity

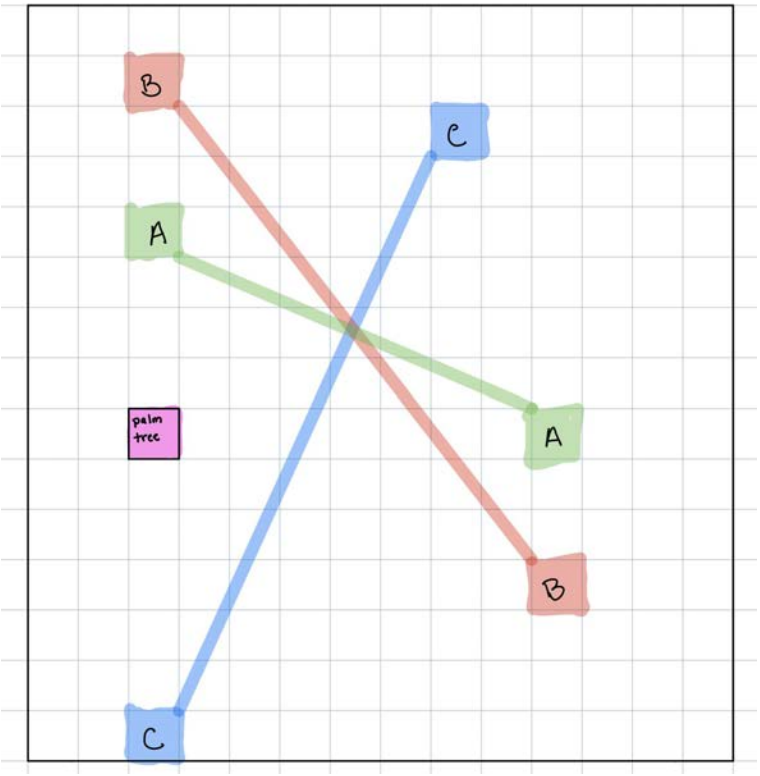
To set up for activity:

To set up for this activity, create a 15 by 15 square grid on the ground with blue tape.

Then mark a box to be the "palm tree" (see below picture to find the spot of the palm tree- if starting from the top left corner, it should be 9 down from the top and 2 boxes left.

Next, I would cut the strings to make it easier for the students (this might be a 2 person job, so find a friend)

To cut the strings, I would look at the solution: A=green string, B=red string, C=blue string.



- The point is that the different groups will get a different path of blackbeard (3 different worksheets), but when they work together, the intersection of their lines will find the treasure!

Directions for facilitators:

Depending on how many students there are and what age group they are, split into 1-3 groups (preferably 3 groups) and hand out the appropriate handout. Each group is going to have a different handout (labeled A, B, or C) (probably 1 per group). They first are going to figure out

and map blackbeard's path on their worksheet. Then they are going to speak to another group (which should have another colored paper)
After they have spoken to the other groups (maybe you could ask each group to share what they got), have them act it out!
On the 15 box by15 box square that you have taped onto the floor, have one student complete blackbeard's path from the palm tree, then another student complete the other path from the palm tree. (I am thinking of making it fun by having them hopping from each box on the ground) They will stay in that spot as the "flag." After the groups all have their people as flags, connect the same color flags together (they should have been in the same group) with string. Then the intersection of the strings is where the treasure is buried!

As the person running this activity, you should:

- First determine the age range of students and give them the correct handout for their expected level of mathematical knowledge. Because of the large difference of age ranges of Discovery Days, I made different problems for the higher grade groups vs lower. One version has equations, while the other only has steps.
- Help any students who need it
- **Adapt the activity** if you notice students are not having fun, if it is too hard, or too confusing

My goal was to make this activity as flexible as possible.

- If there aren't enough students who want to work on the activity, you can downsize to two groups, or place a string on the ground and do one group.
- Think of any ways to adapt the activity if it does not seem to engaging students as intended.
- For students whose reading abilities might be an obstacle to understanding the activity, you can read the directions to them and have them hop around the grid following those directions. For example: you could say "Blackbeard hopped 4 boxes up from the palm tree then he went back to the palm tree and hopped 8 boxes to the right from the palm tree." and have them act it out, without giving them the worksheet.

Appendix B- Outreach Activity Worksheets

There are 3 different versions of worksheets labeled in the left top corner A, B, and C. This was designed for older students to partner with younger ones.
Each version of the worksheet has just counting numbers to make the activity more equitable to the participants.

- Worksheet A has just counting on one worksheet and multiplication on another worksheet. Which could be a first grader paired with a 3rd grader
- Worksheet B has a bit more complicated multiplication paired with adding, which could be 4th grade paired with a 1st or 2nd grader.
- Worksheet C has order of operations paired with a tricky adding and subtracting problem, so this is intended for older students.

A

Blackbeard's Treasure

The crafty British pirate, Blackbeard, had a keen mind for mathematics. You and your crew mates find a bottle floating in the ocean. Upon opening it, all you find is an excerpt from a Diary titled Blackbeard's treasure. They read as follows:

"November 23, 1718: Tonight we anchored at a lonely island of sand and little foliage."

"November 24, 1718: Woke up before the crew and had the idea to bury the treasure on the island. It has a lone palm tree, and I used it as my reference point. The treasure is buried according to the following instructions:

"From the palm tree, I walked **8 steps north, 2 steps south, another 1 step north, and then 3 steps south again.** I marked this spot with a green flag and

then **returned to the palm tree.**

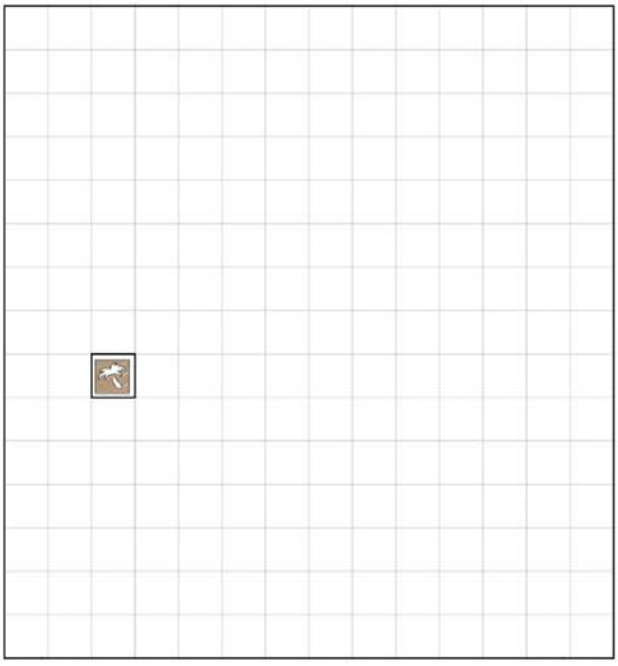
From the palm tree, I walked **4 steps east, 2 steps west, then 6 steps east again**. I marked this spot with another green flag. Then I connected these flags by tightly stringing them together with string."

To find the treasure, draw Blackbeard's path and mark where the flags are located:

Was there a shorter path Blackbeard could've taken to get to the spot of the flags?

Talk with other groups and combine all of your paths! What does it look like?

- What is Blackbeard doing when he first walks east and then goes west?
- Could you have found the treasure without sharing your information with the other groups?
- If one of the other groups was swept overboard with their information, could the other two groups find the treasure?



A

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"November 24, 1718: Woke up before the crew and had the idea to bury the treasure on the island. It has a lone palm tree, and I used it as my reference point. The treasure is buried according to the following instructions:

"From the palm tree, I walked **8 steps north, 2 steps south, another 1 step north, and then 3 steps south again.** I marked this spot with a green flag and

then **returned to the palm tree.**

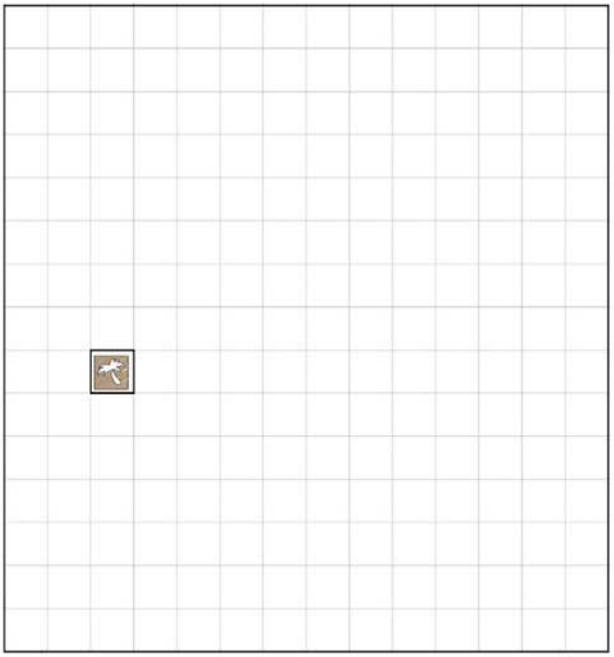
From the palm tree, I walked **(6x2)-4 steps east**. I marked this spot with another green flag. Then I connected these flags by tightly stringing them together with string."

To find the treasure, draw Blackbeard's path and mark where the flags are located:

Was there a shorter path Blackbeard could've taken to get to the spot of the flags?

Talk with other groups and combine all of your paths! What does it look like?

- What is Blackbeard doing when he first walks east and then goes west?
- Could you have found the treasure without sharing your information with the other groups?
- If one of the other groups was swept overboard with their information, could the other two groups find the treasure?



B

Blackbeard's Treasure

The crafty British pirate, Blackbeard, had a keen mind for mathematics. You and your crew mates find a bottle floating in the ocean. Upon opening it, all you find is an excerpt from a Diary titled Blackbeard's treasure.
They read as follows:

"November 23, 1718: Tonight we anchored at a lonely island of sand and little foliage."

"November 24, 1718: Woke up before the crew and had the idea to bury the treasure on the island. It has a lone palm tree, and I used it as my reference point. The treasure is buried according to the following instructions:

"From the palm tree and walked **(5x2)+3-6 steps north**. I then marked this spot with a red flag

then **returned to the palm tree.**

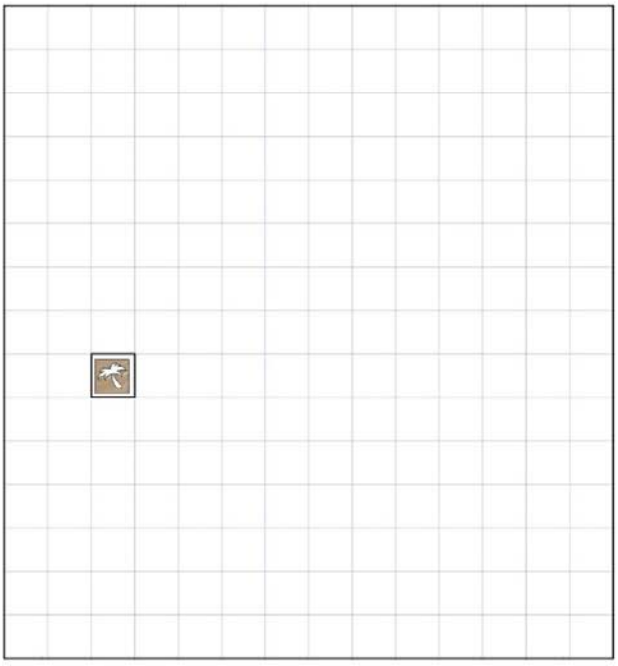
From the palm tree, I walked **6 steps east, 1 step west, 3 steps south, then 3 steps east again**. I marked this spot with another red flag. Then I connected these flags by tightly stringing them together with string."

To find the treasure, draw Blackbeard's path and mark where the flags are located:

Was there a shorter path Blackbeard could've taken to get to the spot of the flags?

Talk with other groups and combine all of your paths! What does it look like?

- What is Blackbeard doing when he first walks east and then goes west?
- Could you have found the treasure without sharing your information with the other groups?
- If one of the other groups was swept overboard with their information, could the other two groups find the treasure?



B

Blackbeard's Treasure

The crafty British pirate, Blackbeard, had a keen mind for mathematics. You and your crew mates find a bottle floating in the ocean. Upon opening it, all you find is an excerpt from a Diary titled Blackbeard's treasure.
They read as follows:

"November 23, 1718: Tonight we anchored at a lonely island of sand and little foliage."

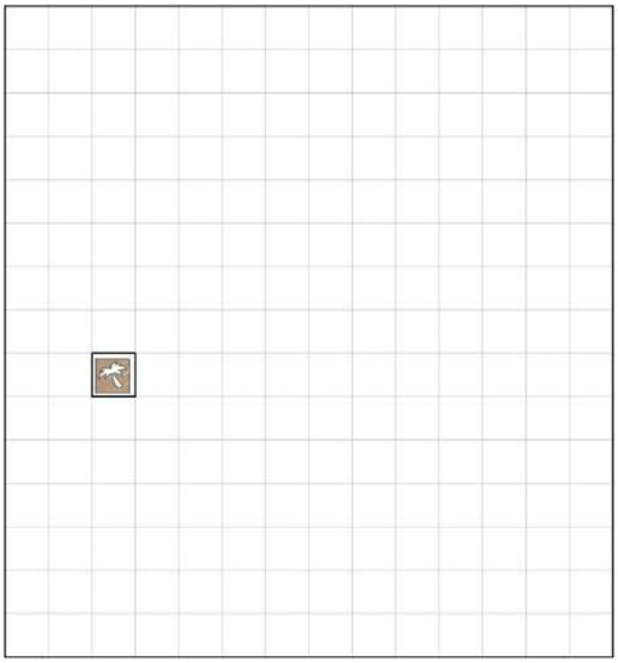
"November 24, 1718: Woke up before the crew and had the idea to bury the treasure on the island. It has a lone palm tree, and I used it as my reference point. The treasure is buried according to the following instructions:

"From the palm tree and walked **3 steps north, 1 step east, 3 steps north, 1 step east, 1 step north, 2 steps west**. I marked this spot with a red flag

then **returned to the palm tree.**

From the palm tree, I walked **6 steps east, 1 step west, 3 steps south, then another 3 steps east**. I marked this spot with another red flag. Then I connected these flags by tightly stringing them together with string."

To find the treasure, draw Blackbeard's path and mark where the flags are located:



Was there a shorter path Blackbeard could've taken to get to the spot of the flags?

Talk with other groups and combine all of your paths! What does it look like?

- What is Blackbeard doing when he first walks east and then goes west?
- Could you have found the treasure without sharing your information with the other groups?
- If one of the other groups was swept overboard with their information, could the other two groups find the treasure?

C

Blackbeard's Treasure

The crafty British pirate, Blackbeard, had a keen mind for mathematics. You and your crew mates find a bottle floating in the ocean. Upon opening it, all you find is an excerpt from a Diary titled Blackbeard's treasure.
They read as follows:

"November 23, 1718: Tonight we anchored at a lonely island of sand and little foliage."

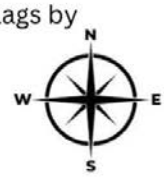
"November 24, 1718: Woke up before the crew and had the idea to bury the treasure on the island. It has a lone palm tree, and I used it as my reference point. The treasure is buried according to the following instructions:

"From the palm tree, I walked **(2x4+2)-4 steps south.** I marked this spot with a blue flag and

then **returned to the palm tree**

From the palm tree, I walked **3 steps south, 4 steps east, 9 steps north, then another 2 steps east**. I marked this spot with another blue flag. Then I connected these flags by tightly stringing them together with string."

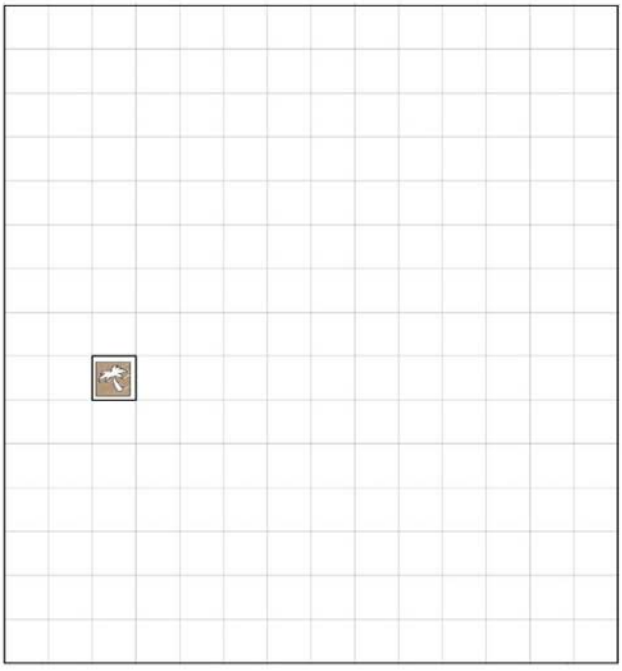
To find the treasure, draw Blackbeard's path and mark where the flags are located:



Was there a shorter path Blackbeard could've taken to get to the spot of the flags?

Talk with other groups and combine all of your paths! What does it look like?

- What is Blackbeard doing when he first walks east and then goes west?
- Could you have found the treasure without sharing your information with the other groups?
- If one of the other groups was swept overboard with their information, could the other two groups find the treasure?



C

Blackbeard's Treasure

The crafty British pirate, Blackbeard, had a keen mind for mathematics. You and your crew mates find a bottle floating in the ocean. Upon opening it, all you find is an excerpt from a Diary titled Blackbeard's treasure. They read as follows:

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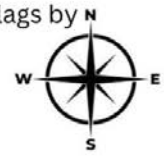
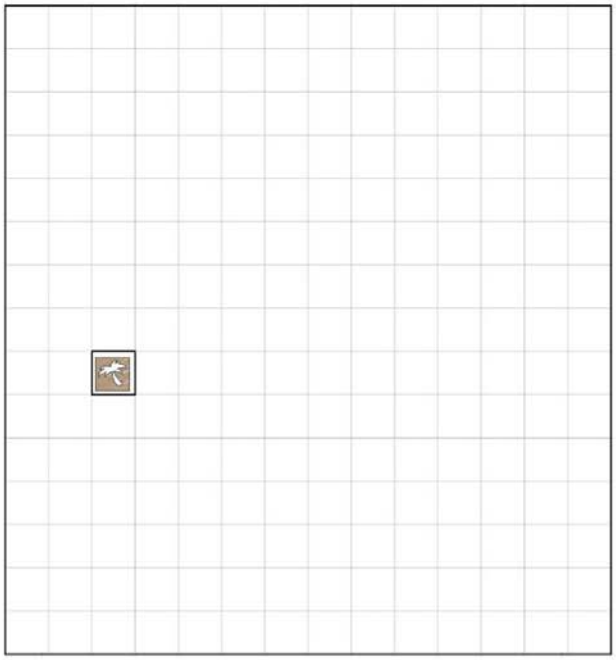
"From the palm tree, I walked **2 steps east, 4 steps south, 2 steps west, and then another 2 steps south. I** marked this spot with a blue flag and

then **returned to the palm tree.**

From the palm tree, I **walked 3 steps south, 4 steps east, 9 steps north, then another 2 steps east**. I marked this spot with another blue flag. Then I connected these flags by tightly stringing them together with string."



To find the treasure, draw Blackbeard's path and mark where the flags are located:



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Talk with other groups and combine all of your paths! What does it look like?

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