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ABSTRACT
The manuscript describes a community-based mathematical modeling task that was implemented in a Calculus I classroom to engage students in mathematical modeling. Twenty-five undergraduate students engaged in this activity. These students selected a context that they found interesting, posed questions, developed constraints, came up with solution strategies, checked their strategies for effectiveness, and revised their work. In going through the various parts of the modeling activity, the students experienced the various characteristics of community-based mathematical modeling. The task, its implementation, and opportunities for students' learning are shared.

KEYWORDS
Undergraduate mathematics education; community-based mathematical modeling; Calculus

1. INTRODUCTION

Mid-semester, instructor X asked their Calculus I students:

Instructor X: What does derivative of a function at a point mean?

Student A: Slope of the tangent line at a point.

Student B: Instantaneous rate of change.

Instructor X: What does that mean? Can you explain it to someone who has not taken Calculus before?

How can we equip students to transition from mere memorization of facts and procedural checks to truly grasping the underlying meaning and significance of the content? This hypothetical scenario inspires us, Calculus instructors, to think of contexts close to students' lived experiences that can be utilized for making sense of Calculus contents.

We involved undergraduate students in a community-based mathematical modeling activity in the first author's Calculus 1 course at a public university in the west coast of the United States of America. The framework for community-based mathematical modeling (CMM) instruction aims to promote equity and develop civic empathy, with goals such as (1) facilitating connection–helping students relate mathematics to their own lives and the world around them; (2) fostering engagement–encouraging students to solve complex problems; (3) promoting rigor through high cognitive demand tasks that enable students to observe, critique,

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and analyze; and (4) cultivating civic empathy – helping students learn to think beyond themselves, see multiple perspectives and begin to take civic action [2]. This framework is guided by research literature on mathematical modeling [7], culturally responsive mathematics teaching [3], and civic empathy [14,16]. According to the Guidelines for Assessment and Instruction in Mathematical Modeling Education (GAIMME) report [7], the mathematical modeling process consists of the following components: Identifying the problem; Making assumptions and identifying the variables; Doing the math; Analyzing and assessing the solution; and Iterating. Engaging in CMM allows students to experience iterations of mathematical modeling where they pose a modeling problem, create modeling solutions, and connect mathematics to a social context that is relevant to students and their lives. At the same time students start to build awareness about community-based contexts and potentially take action.

Here, we discuss a three-part activity series that utilizes the CMM framework to establish community connections both within and outside the classroom, starting from Day 1 of the course. This three-part activity was introduced during a summer session that convened four days a week for 2 hours and 20 minutes over a period of 6 weeks. Later in a standard 15-week semester, this activity series was incorporated into the curriculum during three distinct weeks: week 1 (Photo Activity 1), week 4 (Photo Activity 2), and week 8 (Photo Activity 3). This schedule provided the students with time to engage in the low-floor tasks (Photo Activities 1 and 2) and grasp the concepts of the rate of change in Calculus before culminating in the final Photo Activity 3. We share the details of how each of these activities was implemented, facilitating students in the integration of Calculus with their lived experiences. The design of the photo activity 1 was modified based on CMM modules developed by EQStemm [15]. The Institutional Review Board determined the study to be Exempt from 45 CFR 46 (IRB Protocol number: 21-22-157).

2. PHOTO ACTIVITY 1 – IF I KNEW ..., THEN I COULD ...

As we began the semester and greeted students in a Calculus course, we introduced a "get to know you" activity (see Appendix). This activity aimed to initiate conversations and help students grasp the concept of a **quantity**. Here, a quantity refers to a measurable attribute that can be expressed numerically, such as length, area, volume, temperature, price, size of a population, etc. The class started with students randomly selecting one image card from a stack of image cards featuring images from the local community, including a local bridge over a river next to the campus, an aerial view of townhomes in the city where the university is located, accumulated garbage at the riverbank close to campus, smog in the city where the university is located, and a view of the sunrise facing the city. Students were asked to identify quantities that changed with time and to discuss how those quantities relate to the photo situations. First, students were allowed to think on their own and later they were instructed to find students with similar cards and discuss the "If I knew (of this quantity) ..., then I could (say something about)..." sentence (see Figure 1).

PHOTO ACTIVITY

For this activity, you will identify important quantities and discuss how they relate to the photo situation. Choose a photo. Write down:

Individual: If I knew , then I could

Group: If I knew , then I could

Figure 1. Photo activity used on the first day of class.

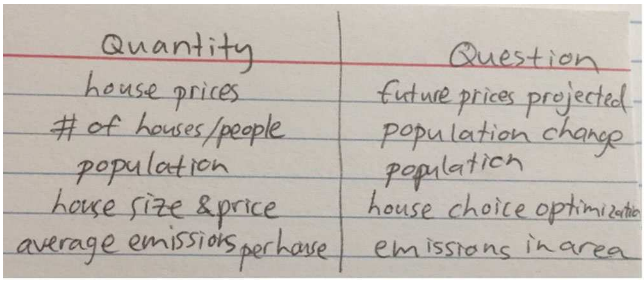


Figure 2. Students brainstorming quantities and questions related to the photo scenario of townhomes in the city where the university is located.

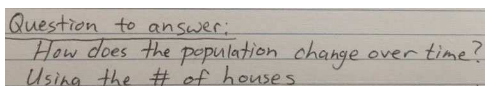


Figure 3. A student group's question related to the photo scenario of townhomes in the city where the university is located.

This activity initiated student engagement, setting the stage for understanding the essence of Calculus and what they would be learning in this Calculus course. Beyond this, the activity enabled students to discern changing quantities in their surroundings, illuminating how recognizing these quantities aids in addressing questions about their lives. In terms of the social dynamics of this exercise, functioning as an icebreaker, it fostered fruitful discussions among students. They shared insights and affirmed their familiarity with the depicted photo scenarios, drawing from personal experiences or observations. These interactions enabled students to clarify distinctions between quantities that undergo continuous change and those that remain constant, such as the flow of water in a river versus the height of a building. The conversations led to the formulation of various questions by students, including inquiries about changes in sunrise time, the rise or fall of homelessness, and the annual accumulation of trash. A few examples of these questions are illustrated in Figures 2–4. At the end of Day 1 in the Calculus course, students had a comprehensive understanding of the significance of quantities and the implications for those that change over time.

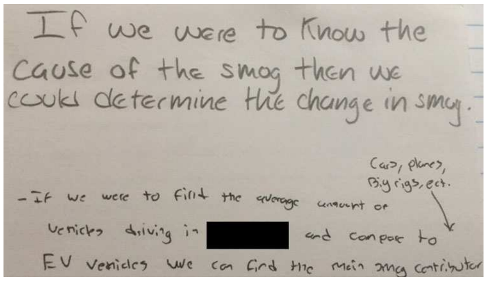


Figure 4. Another group's ideas on the context of smog in the city where the university is located.

3. PHOTO ACTIVITY 2 – MY PHOTO MY QUESTIONS: EXPLORATION THROUGH IMAGERY!

On the second day, students went outside to capture pictures around campus that they found interesting, with a focus on exploring quantities that change over time. The goal of this activity is for students to select their own areas of interest and develop questions around these contexts. Some of the chosen contexts from the Calculus course included the rate of growth of rosemary bushes on campus, the rate of change of the squirrel population on campus, the rate of change of student diversity on campus, and the rate of change of student enrollment on campus during different terms. Below, we share some examples of students' work from the summer implementation.

Rosemary Bush Growth Project: One of the groups walked outside and found rosemary bushes (Figure 5). They wrote, "*I have a bush at my house and use it in my cooking a lot, so I started thinking about what we could do with it.*" The group further wrote, "*If we knew what year this rosemary bush was planted, as well as having measurements for this bush since it was planted, then we could determine the rate of growth of the rosemary bush over time.*"

Changing Demographics Project: Another group explored the question of how certain ages and ethnicities at the [University] change over time. They wrote, "*If I knew the demographics for the previous 6 years I could be able to see a slight change*

Figure 5. Group's photo of rosemary bushes outside class.

Figure 6. Image of Redwood tree near one of the campus buildings.

in ethnicity, and age. The quantities we will use is the number of student each year of a particular age, and the number of students each year of a particular ethnicity, which relates to how diverse the student population is."

Redwood Tree Project: Another group took a picture of the Redwood tree near one of the campus buildings (Figure 6). The group wrote, "*As I was standing at the top of* [Building Name] *I noticed how much green there is and how big the trees were. ...if we knew how big the trees get then we could infer if the trees will get even bigger and if we knew how thick redwood bark is we could see if the tree is thick and well protected.*"

One group expressed the intention to compute the average attendance at the local basketball game held at the community arena. The final group aimed to determine the average number of pedestrians and cyclists crossing the local bridge. Each of these groups concentrated on identifying specific quantities of interest for further exploration. Students also conducted research on data to assist in their exploration of the question. In the second part of the activity, students also reviewed each other's scenarios. Responding to the Rosemary Bush Growth project submission, one student wrote in their review,

"*This was a cool project from y'all. I am very intrigued of how y'all did this by measuring the height of the plants and calculating the different stages of heights. I have seen that bush around and never really thought of it that way. ...I now will go around and think of the rate of how bushes or any plants be growing!*"

Responding to the Changing Demographics project submission, a student commented,

"*I like the idea of analyzing the different ethnicities of students attending* [Institution Name]! [Institution Name] *is a good example, as it is one of the most diverse campuses. You provided a nice data set, and I can see some of the groups change over time. I wonder if there are any events that cause different ethnic groups to be more common on campus versus others, and maybe the festivals and celebrations have something to do with it. I know that every semester we have a cultural heritage fair for pacific* *islanders, yet the rate of them attending* [Institution Name] *is low. I wonder why that is!*"

In addition to reviewing each other's scenarios, students actively engaged with their peers' contexts. They not only examined the scenarios presented but also sought to understand the underlying reasons behind the various situations depicted in their classmates' projects.

4. PHOTO ACTIVITY 3 – RATE OF CHANGE IN THE COMMUNITY

In the third phase of the photo activity series (see Appendix), students actively analyzed data to address questions regarding the rate of change of quantities. This activity was done after completing the section on "Rate of Change." Here, we share two examples of students' work to illustrate their engagement in this task.

The first activity is in reference to the Rosemary Bush Growth project. Figure 7 shows students' work on this problem. Students attempted to answer the growth rate question using two different methods and arrived at the same answer. They shared,

"*We estimated the rate of growth for the rosemary bush in days/cm on day 90. We tried two methods and both methods got us the same slope. It is safe to say that the rate of growth for the rosemary bush on day 90 was 0.0727 cm/day.*"

Students worked together as a team to come up with an answer for a question that they had developed. They verified their answers using two different methods and communicated their answer with precision.

The Redwood Tree project group changed their project to investigate the average rate of growth in the number of people that visited the campus planetarium between 2019 to 2021, 2021 to 2023. They also estimated the instantaneous rate of growth in the number of visitors in 2021. As shown in Figure 8, students in this group calculated the instantaneous rate of growth using the idea of comparing the slope of the tangent line and the secant line.

When describing their work, the group shared,

"*We used the slope formula to find the tangent of a smaller line. The line was for the instantaneous rate of growth in 2021. We can conclude that the number is 7,355*

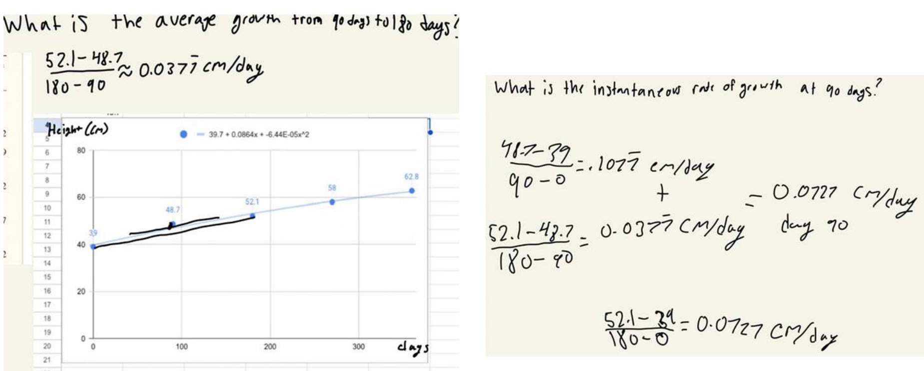
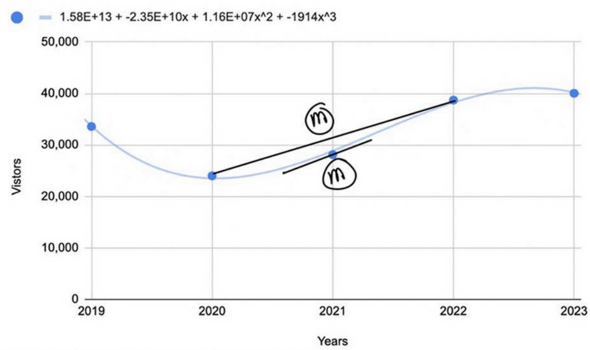


Figure 7. Two different ways to calculate the growth rate of rosemary bush.

Year	Vistors
2019	33,582
2020	24,009
2021	28,116
2022	38,719
2023	40,036



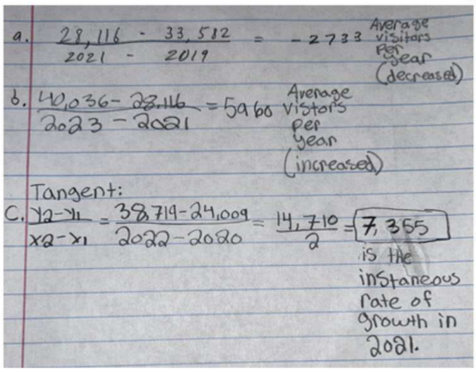


Figure 8. Group's work on the average rate of growth in the number of planetarium visitors.

for 2021 and that it is accurate because we used the slope formula.... The meaning of the number is the average amount of people that used the planetarium during that set year."

5. INSTRUCTOR'S REFLECTION

Here, we provide a reflection to offer the reader insights into the experience of implementing this activity, as well as the perceived benefits for the students. The photo project consisted of three parts: the first part involved students analyzing photos from the local community chosen by the instructor; the second part involved students taking photos from the community, generating questions for investigation, and gathering data; and the third part involved students analyzing data and finding answers to their questions.

In terms of developing the activity, the instructor shared that, "finding contexts for the Day 1 activity was not difficult because I was choosing contexts from the local community that I was familiar with." The process of selecting context allowed the instructor to guide the students as well. During the implementation of the activity, the instructor planned for group work. This approach was modeled on Day 1 to promote student buy-in. As a result, "students were excited to work together for the rest of the project."

Once the students had selected their own contexts, the challenge for the instructor was to help students find relevant data. The instructor commented, "After students chose their context it was challenging for some groups to find reasonable data that they wanted to explore. For example, the Redwood Tree project group had to change their context because they could not find relevant data." Another challenge appeared in the form of unpacking the concept of quantity. When the instructor first introduced the Day 1 activity, their students needed some time to unpack this concept. The instructor explained, "For the first day activity, when I brought the photo contexts the students had confusion about quantities. When we talked about it as a class they understood what quantities actually mean. What changing quantities are, such as height of a building versus height of a tree." The instructor emphasized taking the time to allow the students to understand quantities because, "if they don't understand changing quantities versus fixed quantities, they will have a difficult time understanding the whole concept of Calculus." The instructor stressed going slowly during the first day to develop a strong foundation for students to understand changing quantities.

The instructor found this project beneficial for two reasons. First, students were able to bring their own examples of what changing quantities meant. In contrast to the initial hypothetical dialog (shared at the beginning of this article), this experience allowed the students to connect a Calculus concept with some real-life scenarios. Students now had several examples they had worked with and reviewed. Second, students got first-hand experience of how Calculus can be used in the real world from the contexts they chose to bring to class. This shift in perspective from theoretical to practical application fosters a deeper understanding and appreciation of the subject matter. Research suggests that when academic knowledge and skills are situated within students' lived experiences, students exhibit greater interest and learn more easily, enhancing their motivation and engagement with the material [8]. The instructor felt that this photo activity provided students with an opportunity to bring their identity into the classroom, fostering a sense of ownership in what it means to engage with mathematics. Not only did students actively participate in mathematical discussions, but they also gained insight into how mathematical content is interconnected with their lives.

6. VOICES FROM THE CLASSROOM

Each group developed a question related to their selected context and developed solutions for their questions. Other groups were then asked to review the work of their peers and provide comments. They were asked to post their observations and questions about their peers' work on the same learning management system where students uploaded their work earlier.

When students were reviewing their peer's work, various students were able to notice different things about the work itself and share questions that others could learn from. Reviewing the work of the planetarium project, one student commented, "*It's interesting to see the large plummet in visitors in 2020, which is most* *likely due to Covid, on a graph. Luckily, the average amount of visitors returned to its original amount and is even expected to surpass it this year.*" In this example, the student tried to make sense of the analysis that there was a decrease in the number of visitors in 2020 because of the widespread of COVID-19. Another student wrote in their review, "*I like how organized all the information is. I think the only thing missing was finding the mean between the two averages in the first method.*" In this review, the student provided a second technique to estimate the instantaneous rate of change of visitors. In another review, one student commented, "*I'm very intrigued with the idea of the decrease population of squirrel. ... Other than the math part I do wonder what happened to the squirrels population.*" This student expressed a deep curiosity about the decreasing population of squirrels. They were particularly intrigued by the reasons behind this decline.

Students valued their peers' decision to focus on various contexts, e.g., gas prices, student enrollment, and sports. A student wrote, "*I also love the way that you guys decided to pick gas prices, as it is clear that there is a clear trend in the prices of gas in the past few years.*" Another student wrote, "*I'm an engineering major myself so it's pretty interesting to see that less students are actually enrolling.*" This student's personal connection to the field of engineering added an additional layer of interest and relevance to the selected context. Commenting on a group's project, one student wrote, "*You did a good job finding the instantaneous rate of change! Doing that for a basketball player is an interesting idea. It makes me think that by finding averages and analyzing how good a player is over a rate of time, you could use that information to pick the best choice to win game day bets.*" They found the idea of analyzing a player's performance over time and using that information to make informed game day bets intriguing. This suggests that the student saw potential value in using mathematical analysis to predict sports outcomes.

This activity also enabled students to contemplate their comprehension of the material. One student found it fascinating that the rate of change shifted from negative to positive when the interval was altered. This observation prompted the student to reflect on the distinction between average and instantaneous rates of change. They wrote, "*It is interesting to see that the rate of change went from negative to positive when the interval was changed. I suppose that shows the important difference between an average and instantaneous rate of change: a lot can happen locally within a larger interval.*"

These comments highlight that students were able to experience how peers from their own class were able to develop a variety of questions and answer them using Calculus. When reviewing peer work, students were able to compare multiple ways of organizing data, connect results to context, and offer alternate techniques.

7. DISCUSSION

We observed that the experience of implementing this community-based mathematical modeling task provided various opportunities for students' learning and for them to build their mathematical identity. Aguirre and colleagues define students' mathematical identity as "the dispositions and deeply held beliefs that students develop about their ability to participate and perform effectively in mathematical contexts and to use mathematics in powerful ways across the contexts of their lives" ([1], p. 14). When instructors design experiences that allow students to engage in high cognitive demand tasks while affirming multiple ways of approaching a problem such experiences can impact the development of positive mathematical identities [1].

The CMM activity provided an opportunity for the students to notice their surroundings (for example, the campus or their neighborhood) and select contexts that could be mathematized. This means they were looking for contexts where mathematics could be used to answer some questions. In [19], Suh and colleagues found that mathematical modeling activities based on contexts that were relevant to students proved to be effective because students felt a sense of ownership when working with such tasks. Such experiences position the students as doers of mathematics. Research in mathematics education has gradually shifted towards viewing students as creators of knowledge as opposed to passive learners; this shift requires that students become proficient in creative and critical thinking, problem posing, generating data, quantifying information, sharing solutions, and communicating findings [6,9,13,19]. We noticed that engaging in the CMM task we described here supported this shift.

Through this CMM task, we were able to reach the four goals of community-based mathematical modeling shared in the introduction. The design of the activities allowed the students to make connections between the content learned inside the classroom to the world outside the classroom. This experience allowed the students to engage in "doing mathematics" [17]. Doing high cognitive demand mathematics tasks are ambiguous in nature and students are not provided a set of strategies that they can follow. Students developed their own solution strategies and also reviewed peer developed questions and strategies. This allowed them to engage in solving complex problems, making observations, critiquing, and analyzing their own work as well as the work of their peers.

We found that the time that our students spent to develop a problem statement forced them to think about the mathematical concept itself, the precision of the problem statement, the ways in which they could answer that question and how the phrasing of the question in fact connected to the real world situation that they had selected. In mathematics a question can be perceived as a non-routine query where the solution procedure is not known to the learner. Such questions can aid learning [18]. The ability to generate questions can be considered a tool for learning mathematics or as a goal of mathematics itself [5], whereas analyzing the problems that learners pose can be connected to their problem solving ability [12]. There is a need for research on the ways in which learners pose their own problems and pedagogical methods that can support learners to effectively develop their own problems [5]. There is also a need for research on the connections between problem posing and problem solving [5].

Lastly, the contexts discussed in class ranged from homelessness to diversity on campus. Students had the opportunity to see multiple contexts that they may or may not have been personally involved in. This experience provided an opportunity to notice how for the same task various groups might select a context that is similar or different to their own preference. Students analyzed the various selected contexts with respect and objective critique. Further, engaging with contexts such as homelessness or diversity on campus provided an opportunity for students to notice and perhaps even gain awareness about issues they might not had considered important before. We feel that while students were able to connect classroom mathematics to the world outside of the classroom, they have yet to learn how to make these connections work towards taking action against bias and injustice in the world. This experience may provide a first step in making explicit connections between classroom contexts and the world outside but our future work will include asking students to develop actionable steps that can be taken outside the classroom by using the mathematics content they learned inside the classroom.

8. CONCLUSION

Mathematical modeling is a great tool to engage students in mathematizing their world or using mathematics to answer questions about the world [19]. These CMM activities allowed students a chance to see how mathematics can be used as a tool to answer a variety of questions around them. These tasks allowed us to be mindful that the classroom norms, task directions, and the task itself allowed students to engage respectfully with their classmates and consider the diversity in their contexts and mathematical ideas. This activity provided problem ownership on the contexts that students wanted to investigate. Once students chose their context, they searched for data that they could analyze to answer their questions. Students were also able to participate in group settings, negotiate, and use appropriate communication.

Our goal in implementing this activity was to have the students experience the mathematical modeling process. Our students engaged in the mathematical modeling cycle from identifying a problem to sharing out their solutions. Some groups iterated the processes to refine their models but others did not. Authors of the GAIMME report stress that instructors should focus on students' experience of the process even if their initial engagement is not perfect [7]. In particular, "WHEN STUDENTS ARE MODELING, THEY MUST BE MAKING GENUINE CHOICES. The best problems involve making decisions about things that matter to the students, and help them see how using mathematics can help them make good decisions" ([7], p. 21). Community-based mathematical modeling allowed our students a chance to learn about the process of mathematical modeling and apply the mathematics they learned in class to contexts they selected. Future iterations of our implementation will stress greater adherence to the mathematical modeling process. With guidance and support from instructors, students can learn to use mathematics as a tool for social change [4,10,11]. We find that CMM tasks can allow students a chance to develop the mathematical skills needed to solve real world problems that connect to their lives and their communities.

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APPENDIX: PHOTO PROJECT

The objective of this project is to initiate student engagement in authentic problem-solving experiences and to formulate potential questions by observing quantities that are changing in community-based scenarios.

This photo project has three parts. The first part involves photos chosen by the instructor; the second part involves students selecting photos, generating questions for investigation, and gathering data; and the third part involves students analyzing data and finding answers to their questions.

PHOTO ACTIVITY 1- IF I KNEW …, THEN I COULD …

In-Class Time: 30 minutes

Materials Needed: Index cards/ scratch paper, pencil/pen, a student copy of the activity, pictures from the local community

Preparation Prior to Class: The instructor selects images from the local community and creates a collection of picture cards. Depending on the class size and preferred group size, the instructor can decide on the number of picture cards. For example, in a class of 24 students and a preferred group size of three, the instructor can have 3 sets of 8 different pictures.

Activity Pitch (2 minutes): The world around us is changing every moment, from the stock market to the climate. Calculus helps us to analyze quantities or processes that are undergoing continuous change. In the following activity, students will be able to identify quantities that are changing every moment and connect Calculus with their lived experiences.

Activity Launch: Each student picks one picture card from the collection of cards randomly and completes the following tasks.

Task 1 (5 minutes): a) Identify important quantities that are changing at every moment and discuss how they relate to the picture situation.

b) Complete the sentence

If I knew (of this quantity) …, then I could …

Task 2 (10 minutes): Form a group (students with the same picture belong to the same group).

a) Share your name, something you are interested in learning in this class, and share your "If I knew…, then I could …" sentence.

b) Revisit the picture once again. Complete the following sentence as a group on the index card.

If I knew (of this quantity) …, then I could …

Task 3 (5 minutes): Exchange your index card and the photo card with another group. Review another group's index card, and make suggestions and additional statements. Finally, decide on a spokesperson for the group who should be ready to share Task 3 edits with the whole class.

Task 4 (5 minutes): The spokesperson from each group will share the "If I knew…, then I could …" sentence from another group and their edits with the whole class.

Variations: a) Students can self-select to be in a group or the instructor can form random groups and have a group review one picture card.

b) Task 2 could be done independently in 15 minutes if less time is available. After groups are formed, students can review and complete the "If I knew…, then I could …" sentence in their group.

c) Students can review a third picture and complete an "If I knew…, then I could …" sentence as an exit ticket activity.

Notes for Instructors:

- This activity is intended for the beginning of Week 1. This activity could be used as a "Get to Know Your Peers" activity.
- Explain the meaning of quantities (i.e., what is meant by quantities) and give one or two examples of quantities that are changing over time (e.g., temperature, squirrel population, etc.) and quantities that are constant (e.g., height of the library building, etc.) before starting this activity.
- Listen to students during Task 2. Facilitate conversations toward identifying quantities that are changing with time as needed.

PHOTO ACTIVITY 2- MY PHOTO MY QUESTIONS: EXPLORATION THROUGH IMAGERY!

Learning Outcomes: Students will be able to identify quantities that are changing over time. Students will be able to pose real-world questions, make assumptions, and gather data related to their chosen context. Students will demonstrate the ability to lead and productively participate in group settings. Students will demonstrate an ability to use oral communication effectively.

Activity Time: 30–45 minutes

Devices Needed: A phone or camera and a laptop

Preparing the Class for the Activity: The instructor forms groups of size 3 or 4 and goes over the instructions and the group expectations for this activity. The instructor creates a discussion assignment in their Learning Management System (LMS) where each group can post their work and each student can review posts individually.

Activity Pitch (1 minute): Calculus can be used to study continuous change and motion. The world around us is changing every moment, from the stock market to climate change. Calculus helps us to analyze quantities or processes that are undergoing continuous change. The goal of this activity is to initiate student engagement in authentic problem-solving experiences and to formulate potential questions by observing quantities that are changing in community-based scenarios. Students will go outside the classroom and find something on (around) campus that they are interested in exploring.

Task 1: Take a picture of something on (around) Campus that you are interested in exploring using concepts from Calculus.

Task 2: Use a minimum of 50 words to describe your picture.

Task 3: Identify important quantities and discuss how they relate to your photo situation.

Task 4: Complete the following sentence: If I knew (this quantity) …, then I could …

Task 5: Use Task 4 to generate one or two questions your group would like to examine in your chosen context.

Task 6: What kind of data you will need to answer your questions?

Task 7: Gather at least two data sets. Include a copy of your data. You might use Google Search, Statista, or other resources. Cite your data sources.

Task 8: (Individual Work) Review at least one of the group's posts and post your own noticing and wonders about the group's questions and gathered data. This review should be done individually.

Variations:

- Students can self-select to be in a group or the instructor can form random groups.
- Students can upload a picture in the LMS before class. Then the rest of the task could be done in class.
- Instead of using class time, this could be given as a Week-1 assignment that needs to be completed outside of class time.

PHOTO ACTIVITY 3- RATE OF CHANGE IN THE COMMUNITY

Learning Outcomes: Students will be able to analyze real data to answer rate of change questions. Students will demonstrate the ability to lead and productively participate in group settings. Students will apply quantitative knowledge to solve problems and make decisions. Students will demonstrate an ability to use oral communication effectively. Students will demonstrate the ability to communicate effectively in writing.

Activity Time: 30–45 minutes

Materials Needed: A laptop, an Excel spreadsheet

Preparation Prior to Class: The instructor creates a discussion assignment in the Learning Management System (LMS) where each group can post their work and each student can review posts individually.

Activity Instruction: Students work with the same group from the Photo Activity 2.

Task 1: Revisit your questions from the Photo Activity 2. Rewrite questions to align with the idea of the rate of change.

Task 2: Using an Excel spreadsheet, calculate the average rate of change over different periods from the data.

Task 3: Sketch a scatterplot from the data. Find a reasonable polynomial function that fits the data. (Hint: Select the two columns of the data, click on "scatter" icon. Right-click on any one of the points in the scatterplot and click on "Add Trendline." Under "Trendline Options," select polynomial and play with the "order" of the polynomial.)

Task 4: Using the slope of the tangent line for your polynomial function approximate the instantaneous rate of change. Write a sentence that explains the meaning of the number, including the units, in the context of the data.

Task 5: Draw a graph representing rate of change of the chosen quantity. Determine the intervals where the rate is negative and where the rate is positive.

Task 6: Write a summary of your conclusion.

Task 7: (Individual Work) Review at least one of the group's posts and post your own noticing and wonders about the group's posting. This review should be done individually.

Notes for Instructors:

- Review how to use scatterplots in an Excel spreadsheet and how to draw trendlines.

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BIOGRAPHICAL SKETCHES

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