COORDINATE AN ATTACK
Using the Calculator

Sharie R. Kranz, Carlo A. Amato, and Eric A. Freudenthal
In this culture of instantaneous technology, students are familiar with immediate feedback. To maintain student engagement, it is vital for teachers to create similarly interactive experiences. Student-centered instruction is important in connecting students to key mathematical concepts. If the connection is not obvious, they may be unaware of exciting mathematical applications. When students recognize that math is relevant and comprehensible and that it connects to their own life or experiences, they become excited about learning.

The Cartesian coordinate system is one area of study that can be customized to align with student expectations of technology. Students often experience difficulty understanding this topic because they often focus on rote memorization of a procedure and miss the big ideas of the system. Without a deeper understanding of this system, students are often confused about a coordinate’s specific notation and location. If a student memorizes $x$ and $y$ as place values only, without knowing why they are both needed and relevant, then future concepts regarding functions and rate of change will also be difficult to comprehend.

**OBJECTIVES AND GOALS**

The word iMPaCT is an acronym referring to Media Propelled Computational Thinking. iMPaCT-Math recognizes the relevance of both STEM concepts and hands-on applications. Ninth-grade algebra teachers implemented an iMPaCT-Math activity on Cartesian coordinates at two urban and predominantly Hispanic high schools in El Paso, Texas. Their stories and experiences are explored here. As described in Amato et al. (2012), these iMPaCT-Math hands-on activities and games are intended to enable students’ discovery of concepts and connections essential to algebra 1 (see table 1).

Teachers were eager to implement this activity in hopes of achieving the following goals:
1. Increase student engagement
2. Promote familiarity and mastery of plotting and reading Cartesian coordinates
3. Introduce graphing calculators and develop calculator fluency

The calculator’s ability to provide immediate feedback, even when used as a programming tool, attracts and holds students’ attention. Students with no prior exposure to graphing calculators or programming delve immediately into the graphing and programming functions of the TI-84 calculator. The engaging activities motivate students to practice their newly learned skills while they solve problems closely tied to algebra topics.

Within iMPaCT lessons, programming is used to focus student attention on mathematics learning goals and free them from getting bogged down in otherwise tedious work involved in setting up some problems. For example, once a program is created that draws a picture as a series of points, the program can then be easily modified or replayed. Coordinate points do not have to be tediously re-entered. If a point is drawn at an unintended location, the student receives immediate feedback and can easily correct it by editing the program.

Since students create pieces of computer programming in the algebra classroom, their ability and understanding of programming increases. Technology and mathematics are seamlessly combined in a compelling, problem-solving context that students can easily access. After the activity, teachers report that many students develop a propensity for programming, in place of their initial trepidation. It is hoped that students who experience success will be involved in STEM in the future.

### Table 1 Activities from iMPaCT-Math involve Cartesian coordinates.

<table>
<thead>
<tr>
<th>Task</th>
<th>Summary</th>
<th>Duration</th>
<th>Engagement Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battleship</td>
<td>Students play Battleship by plotting their coordinates and using Point-On ((x, y)) to record their attacks.</td>
<td>70 minutes</td>
<td>Medium</td>
</tr>
<tr>
<td>Missing Piece</td>
<td>Students modify programs to complete simple pictures.</td>
<td>70 minutes</td>
<td>Medium</td>
</tr>
<tr>
<td>Draw a Picture</td>
<td>Students design coordinate art and replicate their picture while programming on the calculator.</td>
<td>80 minutes</td>
<td>High</td>
</tr>
</tbody>
</table>

**Fig. 1** To become familiar with points on the calculator, students play a version of the game Battleship.

Once you have recorded your shot, it is now your opponent’s turn to fire at you. Record all your hits on your Hit Record Sheet. The first player to hit all of his or her opponent’s battleship coordinates wins. Have fun, and good luck.

### DESCRIPTION OF TASKS

The activity’s first task, **Battleship**, leads students through the traditional game using \(x-y\) coordinate pairs that are plotted on the graphing calculator. Students are active participants and receive immediate feedback after viewing the calculator screen. Competition and individual recognition create a sense of urgency when students are learning the coordinate system. They need to effectively communicate their shots and current location, both on paper and on the graphing calculator, using the Cartesian coordinate system.

If students are confused about notation or the location of a point, it becomes immediately apparent when they either miss their opponent or observe that the point was not plotted where expected (see **fig. 1**). This task allows them to experience an intellectual need (Lim 2009) for the Cartesian coordinate system. Student engagement is naturally improved because (1) the task is in the form of a game, and (2) students have fun with technology in math class.

The second task, **Missing Piece**, presents students with most of the coordinates of a partial image and...
challenges them to find the missing coordinates. The class must replicate the puzzle on paper and on the calculator and then determine which points are missing. The first puzzle (see fig. 2) is an incomplete heart, which students can complete either by recognizing the pattern between points or by plotting the points by hand and then transcribing and entering them into the calculator. Once the missing points are determined, students make the additional programming adjustments. They can visually check to see if their point choices are correct after they have formed a complete image on the calculator screen. This task builds on the concepts addressed in Battleship, but then leads students to complete a preset pattern.

The next task, Draw a Picture (see fig. 3), presents students with a house that is missing a floor and door. To identify the missing pieces, students must form vertical or horizontal lines in the pattern that exists among the points. Students may also recognize that although similarities might exist between the missing pieces that individual students choose, ultimately many solutions will work. Doors might be in different shapes and sizes, but all would have vertical and horizontal components. The calculator reinforces the student’s hypothesis and provides instant feedback if a coordinate or pattern was not drawn as intended.

The Draw a Picture task allows for differentiation. When it was used in an inclusive algebra course, the special education teacher reported that although advanced students could add more details to their houses, the task’s step-by-step instructions enabled those who initially struggled to successfully complete the assignment. Since students were self-directed, the teacher could easily help students individually.

In contrast to Missing Piece, in which students are required to complete a preset image, the Draw a Picture task allows students to have full creative control. This task presents students with the challenge of designing their own coordinate art by drawing plans on paper, then implementing the drawing on the graphing calculator. A rubric provides guidelines to follow, but its flexibility gives students full control of the final product. They can add points or designs to match the depth of their own creativity. Students are given time to plan and design their own patterns while the teacher ensures that the process runs smoothly.

As the activity progresses, each task incrementally expands student understanding, provides freedom for individual expression, and increases student engagement:

- With Battleship, students explore the concepts of the Cartesian coordinate system while battling an opponent. Although students must follow game rules and basic guidelines when placing ships, they ultimately are free to experiment with placement and firing patterns.
- With Missing Piece, students solve a puzzle within more structured parameters. This task, which can be conducted in small groups or individually, also provides opportunity for differentiated instruction.
• In Draw a Picture, students are given some creative freedom and choice in the complexity and scope of their design.

Although the tasks are created to be used in order, the instructor can choose where, when, and how to implement them. The task is hands-on and intended to be integrated with an otherwise unmodified algebra course. The task contains built-in assessments and questions, and the teacher’s guide includes all answers and programming.

Before implementation, instructors were excited about the logic introduced in programming, but as is typical with new technology (Jones 2001), many felt their own weaknesses might prevent its successful use. After teachers were introduced to the activity and the programming concepts were explained, they realized that the concepts were very basic and did not require any programming experience. To help with this activity, teachers were given notes on how to implement the programming activities.

IMPLEMENTATION OF ACTIVITIES

This coordinate activity can be used in a prealgebra or algebra classroom; however, in this implementation, nine teachers used the activities in a first-year algebra course. Students were not given any special calculator training before the activities, and teachers were encouraged to use the activities where they fit best in their curriculum.

Teachers at each school used them at different times, although they all generally followed the order described here. All teachers completed the activity in the fall semester and observed no differences in outcomes.

The procedures to set up Battleship and the explanation of rules were arduous because students needed time to become familiar with the calculator. Teachers led students through step-by-step instructions to set up their “battleships” as statistical plots and to explain the rules of the game. Instructions were given orally and visually using a document camera, interactive whiteboard, or virtual calculator. Teachers had to repeat instructions and provide assistance often. Battleship introduces students to the calculator and functions that are used later in programming activities, but the game itself does not involve any programming.

Students were paired and took turns using the calculator’s Point-On (x, y) command to record their shots. Students logged coordinates on paper of their hits and misses. Teachers noted that students had problems remembering the steps on the calculator, and would incorrectly graph x- and y-coordinates. Although teachers reported a slower-than-expected learning curve, they also experienced high participation rates in Battleship and even higher student engagement in subsequent tasks.

Teachers observed that the initial tasks built students’ calculator literacy. As a result, subsequent tasks required less explanation. When asked to reflect on the overall effect of the task, the teachers observed an initially unintended and welcome outcome: The lengthy calculator instruction normally required later in the year was no longer necessary.

For the Missing Piece task, students plot coordinate points on paper, and then plot the points on the calculator using the Point-On command within a simple program. Missing Piece is very structured, and students can work individually or in small groups. Advanced students add additional pieces, and struggling students are able to work at their own pace.

The Missing Piece task has one correct answer to complete the mystery heart correctly. In contrast, the Draw a House task enables more variation and creativity. Although all students are expected to draw the same floor, their door or window could be placed in multiple locations, which provide an opportunity to discuss properties of horizontal and vertical lines.

Students were excited to see that their program had actually drawn a picture, and enjoyed the opportunity to creatively edit their program to change and move the door. They were proud of their creations and eager to show off their picture to the class. Educators reported that Missing Piece took approximately 70 minutes, and that students were engaged at a higher rate than with Battleship.

The Draw a Picture task allows students to design coordinate pictures by creating calculator programs. Students who had complained about the tediousness of entering coordinates for Missing Piece did not complain about this job when drawing a house. They enjoyed creating their own representative work of art. One English language learner struggling in algebra found Draw a Picture as her moment to shine. She designed a detailed flower, going above and beyond the assignment’s requirements, and was
Teachers reported that students enjoyed the freedom and creativity of the assignment and were eager to share their designs with others (see fig. 4), rating it at the highest level of engagement. Students working on their project requested additional time to complete their designs, and students who normally struggled in math were able to excel in this math and technology project.

**REFLECTION**

Battleship proved the most difficult task because both the calculator and programming concepts were new to many in the class. Key instructions, which forced repetition, were missed by some students. To help with this potential repetition, teachers should go over important calculator keys and terminology before the activities begin. If a student presses the wrong button, educators should have key steps written on the board and encourage students to follow along on the task sheets. Despite management issues, students enjoyed the task. One student noted that “Battleship was the most fun I had all year.”

Missing Piece leveraged student familiarity with the calculator previously established by the Battleship task. Since a very specific outcome was required (finding the missing pieces), students were more focused on this goal. During Missing Piece, students learned that they could design pictures on the calculator, which prepared them to work with Draw a Picture. Many of the misconceptions regarding calculator use encountered in Battleship were not repeated in the remaining two tasks. Students and teachers had found a way to interact with the calculator.

Although educators and students were at first apprehensive about exploring math using programming concepts, they were successful in the end. This set of three tasks was especially successful because students who had previously struggled could find success and comprehend the creative and technological aspects. The schools using these activities moved on to other areas that further developed mathematical and computer programming concepts. Although lessons can always be improved on, the combination of technology, computer programming, and math appears to be a solid vessel through which to sail to other fields of mathematics study.

**REFERENCES**


Sharie R. Kranz, skranz@episd.org, is the mathematics instructional coach at Coronado High School in El Paso, Texas. She is interested in project-based learning, technology, and student engagement.

Carlo A. Amato, camato@canutillo-isd.org, teaches ninth-grade mathematics at Canutillo High School in El Paso. He is interested in using technology to engage students to explore algebraic concepts.

Eric A. Freudenthal, efreudenthal@utep.edu, is an associate professor of computer science at the University of Texas at El Paso. His educational research examines the design of creative activities that use programming to promote an analytical engagement with mathematics.

More information on iMPaCT-MATH and downloadable tasks from this activity are available at http://impact-math.org.