CTE Workcell Teacher Facilitation Guide

Unit 5 - Drawing Shapes

A Note about Implementing VEX CTE STEM Lab Units:
STEM Lab Units are designed to be an interactive Unit of instruction that you can use with your students to implement the VEX CTE Workcell in your setting. STEM Lab Units are student-facing content that is designed for students to directly interact with the videos, resources, and instructional materials to complete the activities. This Facilitation Guide is the teacher-facing companion, like a teacher's manual, providing the resources, materials, and information needed to be able to plan, teach, and assess with the VEX CTE Workcell. For more detailed information about implementing STEM Lab Units in your classroom, visit VEX PD+ for videos, expert tips, and more.

Unit Overview

In this Unit, students will code the 6-Axis Arm to move along multiple axes. Students will learn about why moving in multiple axes simultaneously is important in an industrial context, and will practice that skill by coding the 6-Axis Arm to draw shapes with diagonal lines. Students will first learn to draw a triangle with the 6-Axis Arm. Using a starting point and side lengths they will be able to find missing coordinates and draw more complex shapes. By the end of the Unit students will code the 6-Axis Arm to draw multiple shapes in the same project.

Unit Essential Questions - *These open-ended, thought-provoking questions are designed to guide inquiry and encourage deeper understanding. They can provide context and relevance for students, and help them to see the bigger picture or the real-world applications of what they're learning.*

- How does the choice of End of Arm Tooling (EOAT) impact a robot's functionality and its ability to perform specific tasks?
- How can coding a robot to draw shapes help us to understand more complex robotic movements and applications?
- In what ways does the ability to manipulate objects or tools in a linear path expand the capabilities of a robot in industrial applications?

Unit Enduring Understandings - *These understandings reflect the big ideas you want students to understand and be able to use several years from now, as well as identify predictable misunderstandings.*

- Students will understand that changing the End of Arm Tooling can significantly expand the range of tasks a robot can perform, making it adaptable to various industrial needs.
- Students will develop problem-solving skills and an understanding of how robotics can be used to optimize and improve processes in manufacturing and other industries.

Lesson Overview

- The **Introduction** page introduces students to the importance of moving a robotic arm along multiple axes simultaneously in an industrial setting, and how they will learn to do that throughout the course of the Unit. The page also covers key vocabulary and required materials. Additionally, guidance for students on how to co-create learning targets for the Unit is provided.
- The **Power and Connect the 6-Axis Arm** Lesson reminds students how to connect the cables of the 6-Axis Arm to a power source and a computer. It also reviews how to connect the 6-Axis Arm to both web-based and app-based VEXcode EXP. Students can skip this page if they do not need these reminders.

- **Lesson 1: Moving Along Multiple Axes** gives students an opportunity to predict the movement of the 6-Axis Arm based on a project that is shown. They then compare their predictions to the observed movement of the 6-Axis Arm, and break down how it is moving along the x and y-axes.
- **Lesson 2: Drawing a Triangle** teaches students how to code the 6-Axis Arm to draw the triangle they observed in Lesson 1. Students also learn about the purpose of comments in their project, and how to add **Comment** blocks in VEXcode. By the end of the Lesson, students use given coordinates to code the 6-Axis Arm to draw two triangles.
- In the **Mid-Unit Reflection and Goal Adjustment** students will check-in about their learning and progress towards the learning targets you co-created at the start of the Unit. They will complete a Mid-Unit Reflection, discuss their progress with you, and adjust learning targets as needed for the remainder of the Unit.
- In **Lesson 3: Finding Missing Coordinates** students learn how to use a starting coordinate and side lengths to find missing coordinates, and then use those coordinates to code the 6-Axis Arm to draw a triangle. They then build on what they have learned to code the 6-Axis Arm to draw a square.
- **Lesson 4: Drawing a Diamond** expands on the process used in Lesson 3 as students code the 6-Axis Arm to draw multiple triangles to draw a square, further cementing their understanding of how the 6-Axis Arm moves in 3D space.
- The **Putting It All Together** activity challenges students to apply their learning to create a project to draw a parallelogram and a rectangle on the Whiteboard with the 6-Axis Arm.

Materials Needed for this Unit (per group)

- CTE Workcell Kit
- VEXcode EXP
    - Students can download the app-version of the software to their Windows or Mac device at code.vex.com.
    - Students can also use the web-based version on a Google Chrome or Microsoft Edge browser at codeexp.vex.com
- A Computer
- Engineering Notebook (per student)

All Materials needed for this Unit can also be found in the Master Materials List.

Teacher as Facilitator in this Unit

This Unit is designed to be student-facing so that students can directly interact with the Unit content. This places the teacher in the role of facilitator of learning, rather than a supplier of information, in the classroom. As such, you can choose how you want the students to move through the Unit content, based on the needs and interests of your students, and the places where you think they may need more or less direct instruction. You know your students best, so tailor your teaching and implementation to best suit your students.

Troubleshooting Tips for this Unit

- **'Unreachable' positions -** If students are getting errors that a position is 'unreachable' with the Pen Holder Tool, have them adjust their coordinates by 5-10mm. Due to the way that the 6-Axis Arm moves in order to draw effectively, the range of motion of the 6-Axis Arm is different than it was with the Magnet.

- Students will need to have access to VEXcode EXP on their computers. For more information about accessing VEXcode EXP, go to code.vex.com.

Group Size

- A group size of 2-4 students per VEX CTE Workcell Kit is recommended for all activities. This recommendation can vary depending on the needs of your classroom.
- Read this article to learn more about supporting student collaboration throughout the Unit.

Unit Vocabulary

The suggested vocabulary for this Unit is meant to offer teachers a vehicle for establishing a shared language in the classroom when working with VEX CTE. Encourage students to work vocabulary words into their conversations throughout the Unit, so that they can use the terms confidently and correctly not only in this Unit but also in future VEX CTE experiences. You can use these words as a base list, and adapt them to best meet the needs of your students.

- **Comments** - Blocks in VEXcode that are added to projects to explain what a programmer wants parts of the program to do.
- **Waypoint -** An intermediate point between two locations on a line of travel.
- **Multi-Axis Movement** - The ability of the robotic arm to move in more than one direction or along more than one axis at the same time.
- **Right Triangle** - A triangle with one 90 º angle. The side opposite this angle is the longest side, known as the hypotenuse. The other two sides are called the legs.

Preparing Your Classroom

- All students must have access to VEXcode EXP on their device before beginning the Unit.
    - The app-version of the software can be downloaded to Windows or Mac devices at code.vex.com.
    - The web-based version is available on Google Chrome or Microsoft Edge browsers at codeexp.vex.com.
- In order to code with VEXcode EXP, the 6-Axis Arm and computer must have a wired connection.
    - Make sure that each group is in a space where the 6-Axis Arm can be plugged into a power source and have a wired USB-connection to a computer with VEXcode EXP access.
    - To further support students as they are getting started and connecting their 6-Axis Arm to VEXcode EXP, you can use the following resources.
        - For help connecting the 6-Axis Arm to web-based VEXcode EXP, select the article that matches your device:
            - Windows
            - Mac
            - Chromebook
        - For help connecting the 6-Axis Arm to app-based VEXcode EXP, see this article.

- Each 6-Axis Arm should have had its firmware updated prior to starting the Unit. However, if a message in VEXcode EXP appears when the 6-Axis Arm is connected to update the firmware, follow the steps here:
    - App-based VEXcode EXP
    - Web-based VEXcode EXP

Teacher Tips

Lesson 1: Moving Along Multiple Axes

- You may want to complete this Lesson as a whole class activity, where you look at the project together, and discuss the predictions so that the class comes to consensus about how they think the 6-Axis Arm will move and what it will draw.
    - Be sure that students look at the project and make a prediction about the movement of the 6-Axis Arm **before** they watch the video of the 6-Axis Arm moving.
- If you have not already done so, read this article to learn more about supporting student collaboration throughout the Unit.

Lesson 2: Drawing a Triangle

- **Be sure that students use the marker that comes in the CTE Kit with the Pen Holder Tool.** The **Set end effector** block in VEXcode EXP uses the marker from the Kit as the default offset.
    - If the Pen is drawing faint lines, remind students to check that the marker is correctly inserted in the Pen Holder Tool. The repetitive act of drawing can sometimes cause the marker itself to shift in the attachment. Be sure the marker is fully seated in the attachment and try the project again.
- In this Lesson students will follow along to build the project to create what they observed in Lesson 1. Through this process, they will be introduced to using comments in their code as a way to identify what each part of the project is intended to do. You can have students use their comments to help them document their projects in their engineering notebooks throughout the course.
- **A Note About 'Unreachable' Positions -** Students may notice that the 6-Axis Arm moves differently with the Pen Holder Tool than it did with the Magnet. This is intentional, as it enables the 6-Axis Arm to draw straight lines effectively. As such, the range of motion of the 6-Axis Arm with the Pen is different than it was with the Magnet.
    - If students are getting errors that a position is 'unreachable' with the Pen Holder Tool, have them adjust their coordinates by 5-10mm. This should be enough to enable them to draw the desired line.
    - Students can also use the Teach Pendant to further explore the limits of the motion with the Pen Holder Attachment.
- If students need extra support to understand how the 6-Axis Arm and Pen are coded to draw, have them use the **Using the Pen** Example Project for extra practice. Have students test the example project, then adjust the parameters in the project to see how that affects the line that is drawn.

- Remind students to look at the 'Pro Tip' section of the Activity for this Lesson for important information about how to draw two distinct triangles on the Whiteboard.
By incorporating movement along the z-axis in this project, students will further develop their understanding of how the 6-Axis Arm moves in 3D space.

- If students complete the activity early and need an additional challenge, have them try to add a third larger triangle to their project.

Mid-Unit Reflection and Goal Adjustment

This Unit contains a Mid-Unit Reflection and Goal Adjustment, to enable you and your students to check-in about their learning and progress towards the learning targets you co-created at the start of the Unit. This is an opportunity for students to self-assess their progress and discuss the reasoning for that assessment with you, so you can address misconceptions or misunderstandings in the class, and together, adjust students' learning targets to ensure they can effectively progress toward them for the remainder of the Unit.

1. **Be sure students understand how to engage in the reflection process.** Similar to the Wrap-Up Reflection and Debrief Conversation, students will self-assess their progress towards their learning targets, give evidence to support that assessment, and then discuss their assessment with you in a student-teacher conference. Discuss the content in the direct instruction as a whole class, to be sure that students understand what is expected of them when they begin the self-assessment.
2. **Students complete the Mid-Unit Reflection organizer**. In this organizer (Google Doc / .docx. / .pdf), students will give themselves a rating for each of the learning targets, cite evidence for that rating, and can make notes about any questions they have about their learning. The goal of the organizer is to give students a framework for reflection, so they can think about what they are learning, how they are learning, and what they can do with their learning more deeply.
3. **Discuss the Mid-Unit Reflection with students.** Once students have completed the self-assessment, they should share it with you, so that you can (in a brief conversation) see how they perceive their progress towards their learning targets. In these conversations you should:
    a. Look at the rating for each learning target. Do you agree? If not, why not?
    b. Look at the evidence students note for their rating. Does it reflect the full picture of what they are doing and learning in class?
    c. Talk about whether or not the student feels the target is achievable by the end of the Unit. If not, why not? What questions do they need to answer? Does the learning target need to be adjusted with that student?
    d. Mark any learning targets that should be adjusted with the student, and be sure they understand how to edit them effectively (e.g. do they need to be broader or more specific).
4. **Debrief with a whole class discussion.** After meeting with all students, have a whole class discussion about their learning and progress. Address any common misconceptions or misunderstandings, have students share successful strategies, and give them an opportunity to ask questions that will help them reach their goals.
5. **Have students adjust their goals as needed.** Based on the reflection and conversations, students should then adjust their learning targets as you discussed in your conference. Check in with students to be sure you have a shared understanding of their new learning targets.

Lesson 3: Finding Missing Coordinates

- In this Lesson, students will learn about how to use a starting coordinate and a triangle's side lengths to find the necessary coordinates to draw a triangle. Be sure that students are documenting not only the coordinates they find, but also **how** they found them in their engineering notebook so they can refer back to this process for future projects.
- To help students focus on the calculations in this Lesson, be sure that they are documenting their math in their engineering notebook. If students are struggling to understand how the math works, you can

use the grid overlay in the engineering notebook to help them make sense of the formula. Be sure that students are not *only* using the grid to guess and check coordinates.

- Remind students to erase the Whiteboard between each run of their project, so that they can clearly see what the 6-Axis Arm is drawing.
- If students' projects do not work as intended, remind them to double check the coordinates they added in the **Move to position** blocks. Be sure that the parameters for x, y, and z are correct and match what they have documented in their engineering notebooks.

Lesson 4: Drawing a Diamond

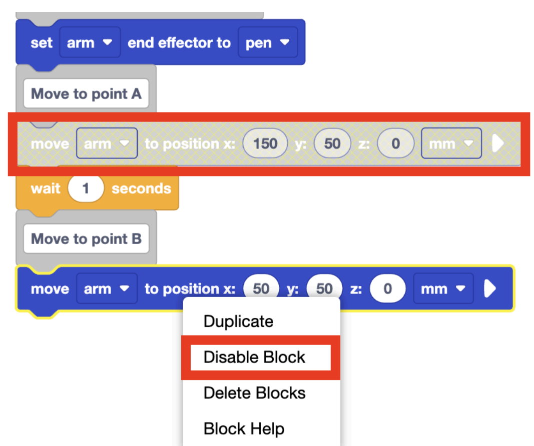
- As you circulate around the room while students are completing the Lesson's activities, ask them to show and describe the movement of the 6-Axis Arm in relation to the x, y, and z-axes to you. The goal of this Unit is to give students a solid foundation of how the 6-Axis Arm moves – what axis or axes it is moving in, as well as whether it is moving in the positive or negative direction. The more practice students get with verbalizing or demonstrating this to you, the better they can solidify their understanding.
    - Encourage students to be specific with their language. Rather than saying things like "the Pen needs to lift up", remind them to refer to movement in relation to axes – so "the Pen needs to move in the positive direction on the z-axis."

Putting It All Together:

- Because students are coding the 6-Axis arm to draw multiple shapes, guide them to create and test their project in small increments. Frequent testing of the project will help students determine whether the project is working as intended before moving on. For instance, be sure that each triangle is drawn correctly before moving on to the next.

- Remind students to erase the Whiteboard between each run of their project, so that they can clearly see what the 6-Axis Arm is drawing. Be sure that the project is stopped before moving the 6-Axis Arm manually.

As students code the 6-Axis Arm throughout this Unit, they may inadvertently enter incorrect parameters and find their 6-Axis Arm is not traveling the path they expected. Here are some tips you can share with them to make the process of locating a bug in their projects less frustrating.



- Students can also disable blocks in a project to isolate a specific block. Blocks can be disabled by right clicking them, and selecting **Disable Block** in the dropdown menu. A disabled block will appear grayed out. Now when the students run their project, they can see the 6-Axis Arm enact only the behavior of the block or blocks that are still enabled, allowing them to determine which block or blocks need to have their parameters adjusted.

- Use the **STEP** button to execute the project one block at a time while they are building and testing their projects. This helps students to identify the block or blocks in the project where the 6-Axis Arm is not behaving as expected, so they can correct the bugs in those particular blocks.

Engineering Notebooks

Incorporating engineering notebooks into your classroom offers a dynamic and collaborative way for students to document their learning journey in engineering and robotics. As a facilitator, encourage students to regularly use their notebooks to record self-assessments and note coordinates during activities. This tool not only aids in project management and problem-solving but also prepares students with essential life skills in documentation and collaboration, pivotal in both academic and future professional settings.

Using Engineering Notebooks

- Continue in the **same** Engineering Notebook students have been using since Unit 1, whether it is a physical notebook or the CTE Digital Engineering Notebook.
    - This gives students a comprehensive view of their learning over the course, and makes it easier to reflect, rethink, and revisit their learning throughout the course.
- If you have not done so already, view the video in the Teacher Portal and read this article to learn more about using engineering notebooks as a learning tool in your classroom.
- Use the following links only if you need to create a **new** CTE Digital Engineering Notebook for a student.
    - CTE Digital Notebook template (Google Slides) (Microsoft PowerPoint)
    - Digital CTE Parts (Google Slides) (Microsoft PowerPoint)
    - CTE Digital Notebook instructions (Google Slides) (Microsoft PowerPoint)
        - If using the Google Slides version, you will be required to make a copy when opened.

- For more information on customizing resources view these two articles from the STEM Library:
    - Customizing Resources Using Google Drive
    - Customizing Resources Using Microsoft Office

- **Documenting in this Unit:** Students should use their engineering notebook to record the coordinates of the triangles and shapes, draw their Whiteboard layouts, plan their projects, answer Check Your Understanding questions, and complete the Mid-Unit Reflection and Wrap-Up Reflection.
    - Students should document their project planning processes, roles they took on within the group, and any and all changes they make to their projects as they work through the Lessons and activities. This will make it easier for them to justify their answers in the Mid-Unit Reflection, and in the Wrap-Up Reflection on the Putting It All Together page.

- **Using Engineering Notebooks in Student Self-assessment:** Engineering notebooks are an important tool for student self assessment. They provide a record of students' learning over time, making their progress visible to both you and the students. In this Unit, students will use their Engineering Notebooks as they self-assess by:
    - Recording their Learning Targets
    - Recording answers to Check Your Understanding Questions

  - Recording their Mid-Unit Reflection
  - Recording their reflective rating in the Wrap Up Reflection
  - Using them to support their answers as they discuss their progress with you in the Debrief Conversation

Read the following section for more information on how engineering notebooks are an important part of assessment and reflection.

Assessment and Reflection

Check Your Understanding Questions (CYU)

At the end of each Lesson, a set of CYU questions are provided as formative assessment to check student understanding before moving on with the rest of the Unit.

- The Answer Key for the questions can be found here. (Google Doc / .docx / .pdf)
- If you have not done so already, read this article to learn more about incorporating CYU questions into your teaching practice, and making the most of the formative assessment opportunities they present.

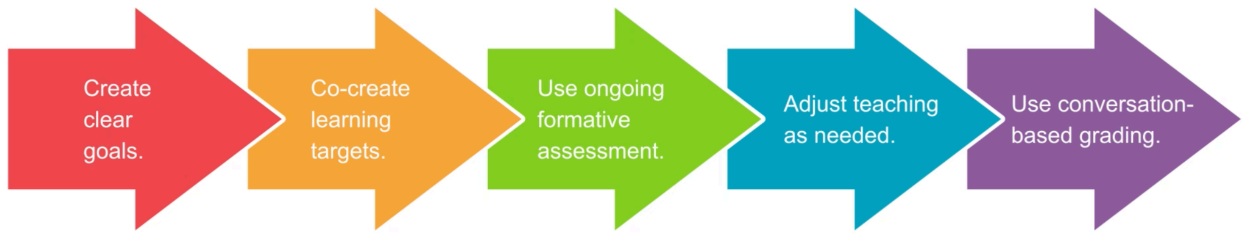
Two types of Check Your Understanding Questions are provided for students to answer in their engineering notebooks throughout the Unit.

- **Content-Related Questions**: Students can use these questions to determine how well they understand the essential concepts of each lesson, and you can use their answers to be sure students have grasped the material fully before moving on. As the lessons in this unit are sequential, be sure to reteach any concepts or knowledge gaps prior to having students continue to progress through the lessons.
- **Student Engagement Questions:** These questions prompt students to reflect on whether or not they are reaching their learning targets and how they are feeling about their learning throughout the Unit. They help students to remain active participants in their learning process. They should be used as discussion prompts as you are facilitating the Unit and during the Debrief Conversation, as students' answers to these questions can help you make decisions about how to best support them moving forward.

For more information on formative assessment, view these videos from the VEX Video Library:

- Connecting Research and Teaching: The Purpose of Formative Assessment
- Connecting Research and Teaching: Formative Assessment Strategies
- Connecting Research to Practice: Eliciting Student Understanding
  - To view additional CTE videos as well as a wealth of professional development resources, join PD+! Find out more and become a PD+ subscriber here.

Student Self-Assessment



Student self-assessment has been shown to intrinsically motivate students and keep them engaged. It is woven throughout the Unit, following the process depicted in the graphic above.

- In the Introduction Lesson, you will establish a shared goal with students, and co-create learning targets.
- Ongoing formative assessment occurs throughout each lesson in the form of Check Your Understanding Questions that allow you to check students' conceptual understanding and progress towards their learning targets, allowing you to adjust your teaching to meet student needs as needed throughout each lesson.
- Additional formative assessment is provided in longer units, such as this one, in the form of a Mid-Unit Reflection and Goal Adjustment, giving students the opportunity to check on their progress in reaching their learning targets.
- In the "Putting it all Together" section, formative assessment continues with the Wrap Up Reflection, which encourages students to consider their engagement and learning across the whole Unit.
- The Debrief Conversation provides an opportunity for conversation-based grading as you discuss the Wrap Up Reflection with student groups along with the rubric provided.
- Students' engineering notebooks are used throughout the Unit to document their learning process, and are a rich source of information about students' evolving thinking and learning.

Read more about student self-assessment components in the Unit below.

Co-creating Learning Targets

Co-creating learning targets helps students to feel a sense of ownership and responsibility towards their learning, leading to a more engaged and motivated classroom environment. You will co-create learning targets with students in their groups in the Introduction Lesson of the Unit. You will then use them to guide students to monitor and reflect on their progress and learning throughout the Unit, and to reflect on them during the Debrief Conversation as well. If you have not already done so, read this article to learn more about co-creating learning targets with your students.

Follow these steps with your students when co-creating learning targets:

- **Step 1: Establish a shared goal.** A video in the Introduction Lesson provides information about what students will be learning and doing in this Unit. Use this video as a basis for establishing a shared goal with students. This is a crucial first step - without a shared goal it will be difficult for students to create learning targets that are guiding them towards the essential understandings of the Unit.

- **Step 2**: **Help students to determine the essential knowledge they need in order to be successful in reaching that shared goal.** What things will students need to learn and do in order to successfully complete the Putting It All Together Activity at the end of the Unit? Guide students to brainstorm a list and record them in their Engineering Notebooks. Because students will be attaching the Pen Holder Tool to the 6-Axis Arm, identifying waypoints to move around obstacles, and coding the 6-Axis Arm to move around obstacles and through a maze, their lists will likely include things like:
    - Calculate a missing coordinate of a triangle using a starting point and side length.
    - Code the 6-Axis Arm to move in the x and y-axes at the same time.
    - Add a **Comment** block to a project.
    - Work collaboratively with my group to build and test our project in the activity.

- **Step 3**: **Co-create learning targets based on the brainstormed list.** Guide students to take each of the list items and frame them into a learning target. Students can phrase them in the form of "I can" statements, such as "I can code the 6-Axis Arm to draw shapes". This template (Google Doc / .docx / .pdf) has been provided to students to help them write their learning targets in their Engineering Notebooks.

It is important to encourage students to create learning targets that address all of the following domains, to ensure that they are creating targets that address deeper learning as well as surface level knowledge:

- **Knowledge** - What do I need to know in order to successfully complete the Putting it All Together Activity?
    - Example: "I can use a starting coordinate and the lengths of the sides of a triangle to find the missing coordinates needed to draw a triangle."
- **Reasoning** - What can I do with what I know and understand about a concept in order to successfully complete the Putting it All Together Activity?
    - Example: "I can code the 6-Axis Arm to draw shapes."
- **Skills** - What can I demonstrate to show that I understand the concept and will be able to use it to successfully complete the Putting it All Together Activity?
    - Example: "I can collaborate with my group to create a project that draws a parallelogram and rectangle with the 6-Axis Arm successfully."
- **Products** - What can I make to demonstrate my learning of the concept?
    - Example: "I can document the process of finding a missing coordinate using a starting coordinate and side length of a triangle."

The Wrap Up Reflection

A Wrap Up Reflection is included at the end of the "Putting It All Together" page in the STEM Lab Unit. This reflection prompts students to reflect on their learning and self-assess their understanding. During the Wrap Up Reflection, students will rate themselves as novice, apprentice, or expert on each of the essential concepts covered in the Unit in their Engineering Notebooks. Then they will reflect on the progress they made towards the learning targets they co-created with you at the beginning of the Unit.

The Debrief Conversation

The Debrief Conversation at the end of the "Putting It All Together" page is an opportunity for students and teachers to sit down together to discuss the student's progress towards the co-created learning targets over the course of the Unit, using the Debrief Conversation Rubric (Google doc / .docx / .pdf) provided as a tool.

Students should support their assertions in the Debrief Conversation with documentation from their engineering notebooks. Read this article to learn more about having effective Debrief Conversations with students.