

VEX^{EXP} Teacher Facilitation Guide

Clean Water Mission STEM Lab Unit

Note: This Unit Requires the AI Vision Sensor

The Clean Water Mission Unit is an open-ended challenge STEM Lab Unit in which students use the AI Vision Sensor with the EXP Clawbot to carry out a series of challenges in an automated water treatment system. This is an advanced coding Unit, and it is recommended that students complete other coding EXP STEM Lab Units prior to beginning this one. If you do not have the AI Vision Sensor, [learn more about purchasing the sensor here](#).

Open-Ended Challenge Overview

In this Unit, students will apply what they have learned about VEXcode EXP and the AI Vision Sensor to complete a series of open-ended challenges as they work to solve the Clean Water Mission. Over the course of the Unit, teams will work up to developing a fully automated water treatment system, in which a robot equipped with the AI Vision Sensor identifies and transports water through treatment, purification, and distribution areas. The Mission as a whole is broken up into smaller stages, with each challenge building on the previous. The stages grow in complexity, and require students to collaborate in a team to brainstorm, plan, and execute projects.

Jump to Specific Information on:

[Stage 1](#)

[Stage 2](#)

[Stage 3](#)

[Stage 4](#)

Teaching and Learning in an Open-Ended Challenge

Each team of students will address the Clean Water Mission in their own unique way. Therefore, your role as a teacher is to act as a responsive facilitator as students move through and among each stage of the challenge. **This challenge should and will require students to engage in productive struggle.** It can be tempting to step in and solve problems for students when they are frustrated, but successful facilitation of these Units requires asking questions to guide students out of frustration, rather than solving problems for them.

[Read this article to learn more about student learning and teacher facilitation in open-ended challenges.](#)

- Additional facilitation guidance is provided in the “Challenge Phases” section of this document.
- [View this article](#) to learn more about building resilience with effective feedback.

Because of the nature of open-ended challenges, student-facing content does not include direct instruction. Instead, it provides students with all the information needed to complete the challenge.

Animations of one possible way the robot could move to solve each challenge can be found in the [Teacher Portal](#). You can use these for reference as you facilitate each challenge.

The Unit Overview contains three sections.

- The **Clean Water Mission Overview** page describes the scenario, setting the context for the Unit. It provides basic information about the AI Vision Sensor, and links to the build instructions for the EXP Clawbot.
- The **Rubric Overview** provides a link to the Clean Water Mission Open Ended Challenge Rubric, and gives students a summary of each category they will be assessed on. Students can refer back to this page as needed throughout the Unit.
- The **Process Overview** outlines the stages of the problem solving process students will use to solve the Clean Water Mission. A video and a summary of the process is provided to support students as they work through the Unit.

Each Stage follows the same format as a **Challenge Briefing**:

- Overview of the challenge, and how it connects to the larger Clean Water Mission.
- The water treatment system setup and details needed to solve the challenge in the **Challenge Document**.
 - This document provides Key Information and Criteria for the challenge and can be used to clarify logistical information for the challenge.
- Links to resources available to help students solve the challenge.
- A final review section, reminding them to check in with their teacher
- A wrap-up reflection, which provides questions to answer in their engineering notebooks to help them reflect on their progress and process.

Students will be evaluated on their progress and process using the **Clean Water Mission Open-Ended Challenge Rubric**. High-level information on each of the rubric's categories is provided on the page, along with a link to the rubric. It is essential to ensure that students fully understand the criteria in each category.

- Review the rubric as a class before students begin.
- Use the Check-ins to answer students' questions about the evaluation criteria related to each phase of the process.
- Remind students to document their brainstorming, plans, pseudocode, iterations and changes in their engineering notebooks. These will be essential tools for them to share their progress during the Final Review.

Using the Assessment Rubric

Each team is evaluated on the following categories: planning and brainstorming, pseudocoding, coding and execution, teamwork and collaboration, and accurate completion of the task. Study the rubric before beginning the Unit.

Document students' progress in an ongoing manner throughout the challenge. Carry a copy of the rubric for each team with you as you circulate throughout the room, observing their work. Make notes on students' teamwork and collaboration as you go.

Bring the rubrics to each team Check-in. This way, you can discuss student progress with them during the Check-in for that particular phase (e.g., planning and brainstorming during the Phase 1 Check-in) and make notes on the rubric. This will make it easier to evaluate all of the groups on each category, as

opposed to trying to do it all during the Final Review. Making notes also gives you a jumping off point for discussion during both the Check-ins and the Final Review.

Final Review

During the Final Review, meet with student teams to review their progress throughout the challenge, and complete the rubric together.

- Allow students to share where they think their rating should fall on the rubric. Encourage them to back up their assertions with documentation from their engineering notebooks.
- Share your own rating, and the reasoning behind it, taking their assessment into consideration.
- Treat the rubric as a collaborative assessment effort between the students and yourself, so students see it as an opportunity for constructive feedback rather than something punitive.
 - When used positively, the Final Review can be a tool for students to use to improve in future challenges.
- Read this article to help keep the Final Review productive and positive: [Having Effective Debrief Conversations with Students](#).

A **Wrap Up Reflection** with prompts is provided on the student page. Instruct students to complete the reflection either while waiting for their Final Review, or after the Final Review is completed.

- Once students answer the prompts individually in their engineering notebooks, they should be given time to meet once more as a team to discuss their answers.

Challenge Phases

Students are guided to solve the challenge using a three-phase process. During each phase, students will focus on a particular aspect of the problem-solving process, and are instructed to check-in with you for approval before moving on.

Phase 1: Planning

The first step to solving a challenge is understanding the challenge and making a plan. The goal of Phase 1 is for students to document and present possible solutions to solve the challenge.

What to look for during the Planning phase:

- Students spending time reviewing the Challenge Document, discussing the challenge criteria, and asking clarifying questions about the challenge itself.
- Active discussions and brainstorming between all members of the group around possible solutions.
- Groups should be talking to each other, actively documenting and/or manipulating the EXP Clawbot, Buckyballs, and Rings by hand, so that they can explain their ideas fully when they meet with you.
- Students working with the AI Vision Sensor and the Utility to learn about the data the sensor is reporting and discussing and brainstorming how to use that data effectively in their projects.

During the Phase 1 Check-in:

- Students present several thoughtful, detailed, collaborative ideas that explain how the task will be completed.
 - Students can identify and describe how the AI Vision Sensor data will be used.
- All students in the group understand the plans presented, and can offer pros/cons of each.
- Guide students to choosing one idea or plan to begin with. Be sure that you and the students are on the same page about how they are moving forward to Phase 2.

- Make notes on the rubric about the group's planning and collaboration.

Phase 2: Pseudocoding

The next step is to break down the plan into the component steps. The goal of Phase 2 is for students to document and present detailed pseudocode showing the steps and behaviors (including AI Vision Sensor data) needed to enact their plan to move water through the treatment plant successfully. [View this article](#) for guiding questions to help you facilitate this phase.

What to look for during the Pseudocoding phase:

- Students discussing and coming to consensus on the high-level steps needed to complete the plan. They document these effectively in their engineering notebooks.
- Students work on breaking down each step into the smallest possible behaviors needed to complete it.
 - The AI Vision Sensor data to be used is identified and documented.
 - **Pro-Tip:** Students may want to manipulate challenge elements on the Field (ie. Buckyballs, Rings, AprilTags) while using the AI Vision Sensor and Utility to help them better understand how the data relates to the behaviors of the robot.
 - **Note:** The high-level steps of the plan should become the comments in students' projects in Phase 3. The individual behaviors within those steps correspond to the blocks to be used in the project.

During the Phase 2 Check-in:

- Students share a logical, detailed sequence of steps that clearly communicates how the plan will be put into action with the EXP Clawbot and AI Vision Sensor.
- All students in the group understand how the pseudocode relates to the idea from Phase 1, and can answer follow up questions about it.
- Ask students about questions they have before they begin Phase 3. Do they know where to find resources to help them build and test their project effectively?
- Make notes on the rubric about the group's pseudocoding and collaboration.

Phase 3: Building and Testing

The next step is to build and test a VEXcode project to solve the challenge. The goal of Phase 3 is for students to create a project that completes the challenge task, based on the plan and pseudocode they created previously.

What to look for during the Building and Testing phase:

- Students incrementally building and testing each step of their pseudocode with their robot on the Field setup.
 - Students may need to take turns testing with the water treatment system setup(s) in the classroom, to ensure that the AI Vision Sensor is working as intended. Be sure that students are testing their projects in a consistent way throughout the challenge.
- Groups revisiting their plans and pseudocode to refine it based on their experience.
- All students in the group actively participating in coding and problem-solving processes.
- Students documenting their iterations and testing in their engineering notebooks.
- Students iterating on their projects to actively improve the accuracy and timing.

Final Review

The Final Review serves as the Check-in for Phase 3. At this point, students should have a functional project that completes the task accurately.

During the Final Review:

- Observe the project in action and document how accurately the water was moved through the treatment plant.
- Discuss how students built and tested the project together, and the role students played in that collaboration.
- Complete the Clean Water Mission Open-Ended Challenge Rubric together with the students. Use the notes from Phase 1 and 2 to help recall planning and pseudocoding phases.
- All members of the group and the teacher should reach consensus about the rubric completion.

Wrap Up Reflection:

The reflection should set the stage for students to build on this experience in subsequent challenges. You can have students share the results of their reflection with you individually, or as part of a whole class wrap up discussion.

Making Check-ins Work for You

During an open-ended challenge, students will be in different phases of the challenge at different times, and will need Check-ins frequently. In order to keep Check-ins fruitful and to prevent frustration, set up a system for student Check-ins and share it with the class before beginning the Unit.

Have students sign up on the board to indicate that they are ready for a Check-in. You can then visit with groups in the order they are listed. Remind students that they should be refining their documentation and considering the rubric for each phase while they are waiting to meet with you.

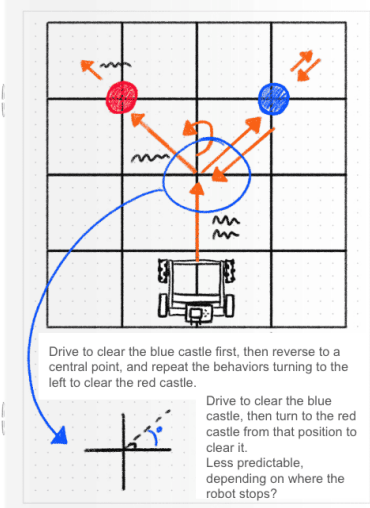
You can meet with students multiple times within one phase as well. They are instructed to Check-in with you before moving on, but students (or you) can request a Check-in at any point.

Following the Three Phases through an Example Task

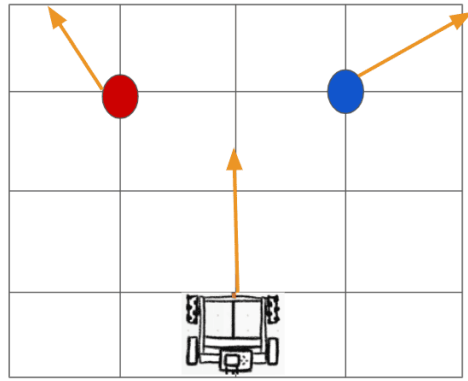
To help understand how this three phase process functions to complete a challenge, let's look back at a task from the Castle Crasher STEM Lab Unit Lesson 2 Castle Crasher No Sensors – clearing two castles.

Phase 1: Planning

An Exemplary plan for this task could look like:

 Drive to clear the blue castle first, then reverse to a central point, and repeat the behaviors turning to the left to clear the red castle. Drive to clear the blue castle, then turn to the red castle from that position to clear it. Less predictable, depending on where the robot stops?	This engineering notebook example shows the path of the movement of the robot, and has a written description of several ideas to complete the task, with potential issues notes. Students' contributions are indicated in the documentation. During the Check-in, as one student shared their engineering notebook, a second described the movement of the robot and the third moved the robot on the Field setup to further illustrate their favorite idea. They described how they reached consensus on the first idea listed.
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A Beginner plan for this task could look like:

 Drive to crash the red castle. Then crash the blue castle.	This engineering notebook shows one idea for completing the task, but is minimally documented. During the Check-in, only one student in the group participates in the conversation, and the others cannot speak to how they contributed to the brainstorming process.
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Phase 2: Pseudocoding

Exemplary pseudocoding for this task could look like:	
Clear Two Castles - Clear the blue castle. - Drive forward to get closer to the castles - Turn right to face the blue castle - Drive forward to clear the castle - Drive reverse to the starting point - Clear the red castle. - Turn left to face the red castle - Drive forward to clear the castle	This engineering notebook example shows the steps needed to complete the task. Each larger step is broken down into the smallest possible behaviors, which are sequenced effectively to communicate the plan. During the Check-in, all students in the group were able to answer questions about the sequence of behaviors, and could talk about which blocks they thought they would need to code each step.
Beginner pseudocoding for this task could look like:	
Clear Two Castles Clear first castle.	This engineering notebook example shows a partial description of the steps of the plan. The steps are not

a. Drive forward b. Turn to clear the castle 2. Clear the next castle. a. Turn to face a castle b. Drive to clear the castle	specific or the smallest possible behaviors needed to accomplish the task. During the Check-in, the group could not describe what blocks or behaviors would be needed to complete the project.
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Phase 3: Building and Testing

An Exemplary project for this task could look like:	
	This project uses the larger steps from the pseudocoding phase as the comments. The blocks are sequenced as needed to effectively complete the task and clear both the blue and red castle from the Field. During the Check-in, the students run their project and clear both castles. One student explains how they found the distances needed for the project, while the second describes their role in using VEXcode, and the third shows their documentation strategies to complete the task collaboratively.
A Beginner project for this task could look like:	
	This project does not contain any comments. Blocks are sequenced so that a critical error occurs, and the castles are not effectively cleared from the Field. During the Check-in, one student does all of the talking and complains about how the others were not helpful in solving the challenge.

Using the AI Vision Sensor in Your Classroom

The following suggestions will help you make the most of using the AI Vision Sensor in your classroom:

- **Set up your classroom for success by planning ahead.** You will need to decide where you will place your students' testing setup(s) in your classroom. It will be helpful to choose a spot with adequate lighting and limited visual interference. [Read this article for guidance setting up your classroom.](#)
- **Build Instructions are a starting point.**
 - As students are developing their plans for meeting each challenge in the Unit, they may decide to change the placement of the AI Vision Sensor. Students should be encouraged to consider how the placement of the Sensor affects the quality of the data they collect, and to move it if needed. [See this article for more information on the placement of the AI Vision Sensor.](#)
- **Additional Sensors can be used with the AI Vision Sensor.**
 - Students may want to add additional sensors to their robot to give them more options when coding their project. For example:
 - The Distance Sensor could be mounted in the Claw and used to code the robot to get as close as possible to a Buckyball or Ring, as shown to the right.
 - The Bumper Switch could be used in a project where when it is pressed, it triggers a specific stack of code to execute.
- **The AI Vision Sensor must be configured using the AI Vision Sensor Utility.**
 - For information on how to connect the AI Vision Sensor, see the following articles:
 - [Connect the AI Vision Sensor in App-based VEXcode EXP](#)
 - [Connect the AI Vision Sensor in Web-based VEXcode EXP](#)
 - For information on how to configure the AI Vision Sensor to detect and report data about the color of an object, see the following article.
 - [Configure Color Signatures with the AI Vision Sensor in VEXcode EXP](#)
- **The AI Vision Sensor can report AprilTag data.** [See this article for more information about configuring and using AprilTags with the AI Vision Sensor.](#)
- **The AI Vision Sensor can detect and report data about pre-trained objects**, such as Buckyballs and Rings. [See this article for more information.](#)
- **Resources** to help students understand the data reported by the AI Vision Sensor are available in the VEX Library as well as the VEX API.
 - If students need information about coding with the AI Vision Sensor, share the section of the VEX API that matches their coding environment.
 - [Blocks](#)
 - [Python](#)
 - [C++](#)



Stage 1: Contaminated Water Challenge

The Challenge for this stage is contextualized and introduced at the top of the Stage 1 page, and is summarized in the Challenge Doc. ([Google Doc](#) / [.docx](#) / [.pdf](#))

The Clean Water Mission Challenge Rubric can be accessed here: ([Google Doc](#) / [.docx](#) / [.pdf](#)).

Materials Needed for this Unit - Per Group

Have the following materials ready prior to the start of class for each group:

- VEX EXP Kit (1 per group)
- VEX AI Vision Sensor (1 per group)
- Computer (1 per group)
- VEXcode EXP (1 per group)
- Engineering Notebook (1 per student)

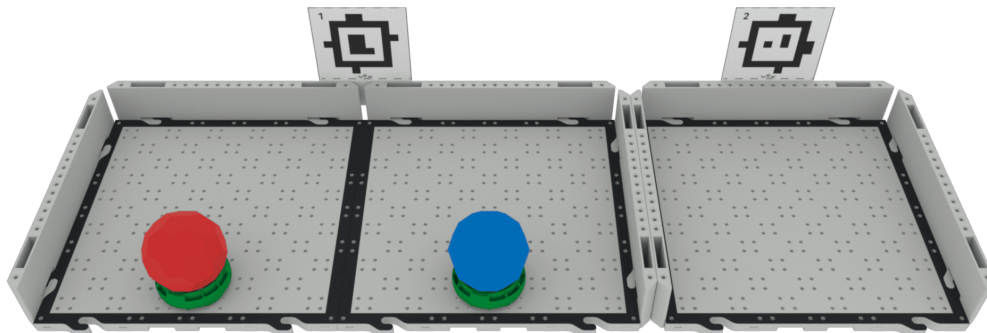
Stage 1 Setup Materials per testing area:

- Buckyballs
 - 2 red, 2 blue
- Rings
 - 2 green
- EXP Field Tiles (3 per testing area)
- EXP Field Walls (7 per testing area)
- 5 inch wide AprilTags - Printable AprilTags are included at the end of this document.
 - Number 1
 - Number 2
 - Landmark April Tags 13 (left boundary) and 26 (right boundary) can be included if desired.

All Materials needed for this Unit can also be found in the [Master Materials List](#).

Each testing area will look like the setup below.

- Two EXP Tiles are connected with walls on three sides to create the collection area. A green Ring is placed at the front edge of each Tile in the collection area. A red Buckyball is placed on the green Ring to the left, and a blue Buckyball is placed on the green Ring to the right. AprilTag 1 is connected to the back of the walls to designate this area.
- One EXP Tile with walls connected on three sides creates the treatment area. AprilTag 2 is connected to the back of the walls to designate this area.
- Areas are described as they are placed from left to right.



Helpful Information

- Students can replace the red Buckyball by hand once the first one has been delivered.
- Students can remove the first red Buckyball from the treatment area once delivered, to make room for the second one.
- The landmark AprilTags can be included as part of the setup in case students want to use them to help to orient the robot as they code. They are optional for this stage.
- Animations of one possible way the robot could move to solve each challenge can be found in the [Teacher Portal](#). You can use these for reference as you facilitate each challenge.

Stage 2: Sort and Sanitize Challenge

The Challenge for this stage is contextualized and introduced at the top of the Stage 2 page, and is summarized in the Challenge Doc. ([Google Doc](#) / [.docx](#) / [.pdf](#))

The Clean Water Mission Challenge Rubric can be accessed here: ([Google Doc](#) / [.docx](#) / [.pdf](#))

Materials Needed for this Unit - Per Group

Have the following materials ready prior to the start of class for each group:

- VEX EXP Kit (1 per group)
- VEX AI Vision Sensor (1 per group)
- Computer (1 per group)
- VEXcode EXP (1 per group)
- Engineering Notebook (1 per student)

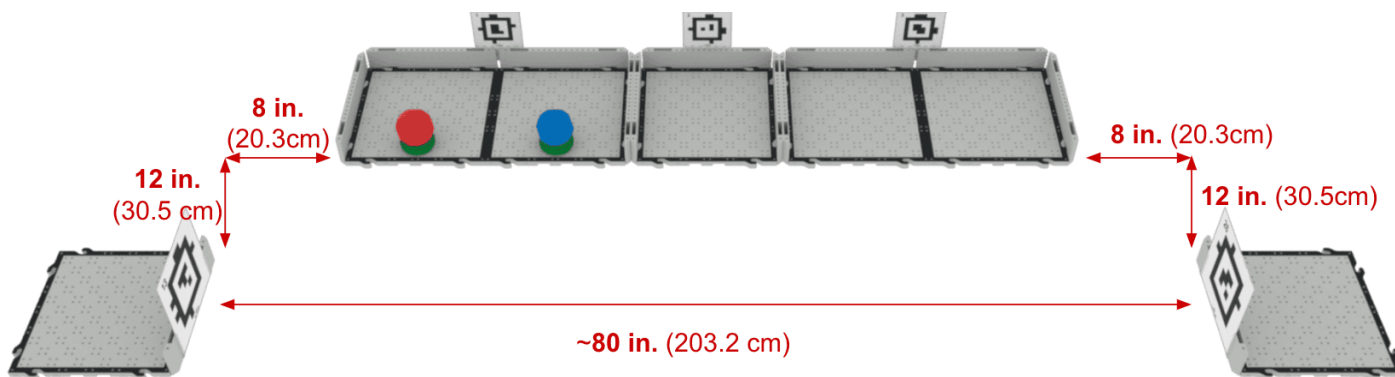
Stage 2 Setup Materials per testing area:

- Buckyballs
 - 2 red
 - 2 blue
- Rings
 - 2 green
- EXP Field Tiles (7 per testing area)
- EXP Field Walls (13 per testing area)
- 5 inch wide AprilTags - Printable AprilTags are included at the end of this document.
 - Numbers 1, 2, and 3
 - 13 (left boundary) and 26 (right boundary)

All Materials needed for this Unit can also be found in the [Master Materials List](#).

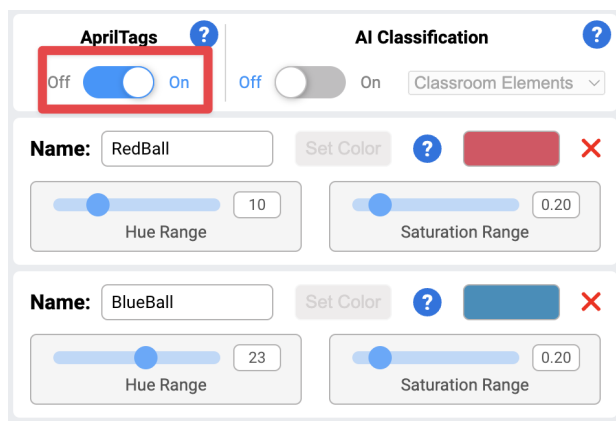
Each testing area will look like the setup below.

- The Stage 1 collection and treatment areas remain intact, with the purification area added to the right.
- To add the purification area, two EXP Tiles are connected with Walls on three sides to the right of the existing areas. AprilTag 3 is connected to the back of the walls to designate this area.
- Areas are described as they are placed from left to right.
- An additional EXP Tile with one wall attached is placed approximately one foot away and 8 inches to the left of the row of water treatment system areas. AprilTag number 13 is attached to designate the left boundary of the treatment system.
- An additional EXP Tile with one wall attached is placed approximately one foot away and 8 inches to the right of the row of water treatment system areas. AprilTag number 26 is attached to designate the right boundary of the treatment system.



Helpful Information

- Students can replace the Buckyballs by hand once the first one has been delivered.
- Students can remove each Buckyball from the treatment and purification areas once delivered, to make room for the next one.
- The landmark AprilTags can be used to orient the robot as students code it to move between areas.
- When coding with AprilTags, be sure that students have set the toggle button in the AI Vision Utility to “on” as shown below.



- Students may add on to their VEXcode project from the previous stage if desired, or start a new project.
- Encourage students to name their projects descriptively (AI Vision Stage 1, e.g.), so they can easily access them. Students will want to reuse sections of code or even entire projects throughout the course of the Unit.
- Students can have multiple stacks of blocks in their projects, and may want to create MyBlocks to help them organize lengthy projects. See [this section of the VEX API](#) for more information.
- Animations of one possible way the robot could move to solve each challenge can be found in the [Teacher Portal](#). You can use these for reference as you facilitate each challenge.

Stage 3: Water Distribution Challenge

The Challenge for this stage is contextualized and introduced at the top of the Stage 3 page, and is summarized in the Challenge Doc. ([Google Doc](#) / [.docx](#) / [.pdf](#))

The Clean Water Mission Challenge Rubric can be accessed here: ([Google Doc](#) / [.docx](#) / [.pdf](#))

Materials Needed for this Unit - Per Group:

Have the following materials ready prior to the start of class for each group:

- EXP Kit (1 per group)
- VEX AI Vision Sensor (1 per group)
- A Computer (1 per group)
- VEXcode EXP (1 per group)
- Engineering Notebook (1 per student)

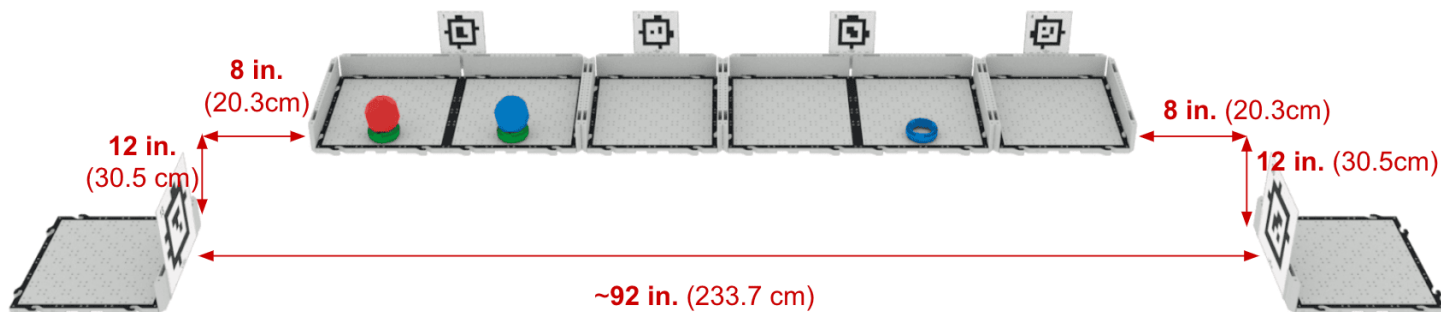
Stage 3 Setup Materials per testing area:

- Buckyballs
 - 2 red
 - 2 blue
- Rings
 - 2 green
 - 2 blue
- EXP Field Tiles (8 per testing area)
- EXP Field Walls (16 per testing area)
- 5 inch wide AprilTags - Printable AprilTags are included at the end of this document.
 - Numbers 1,2,3,4
 - 13 (left boundary) and 26 (right boundary)

All Materials needed for this Unit can also be found in the [Master Materials List](#).

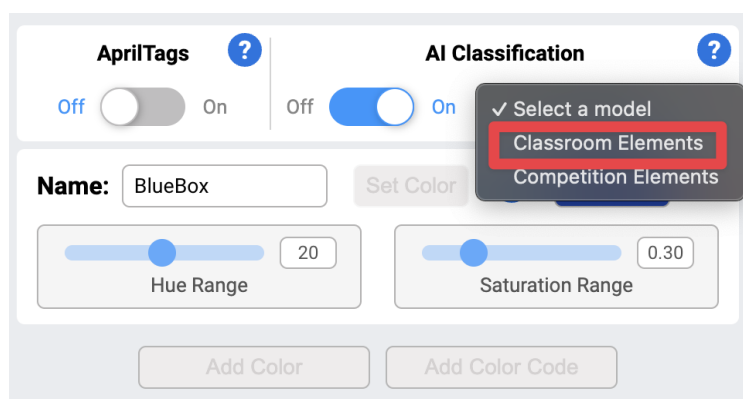
Each testing area will look like the setup below:

- The Stage 2 collection, treatment, and purification areas remain intact, with the distribution area added to the right.
- To add the distribution area, one EXP Tile with Walls connected on three sides is added to the right of the existing areas. AprilTag 4 is connected to the back of the walls to designate this area.
- Areas are described as they are placed from left to right.
- An additional EXP Tile with one wall attached is placed approximately one foot away and 8 inches to the left of the row of water treatment system areas. AprilTag number 13 is attached to designate the left boundary of the treatment system.
- An additional EXP Tile with one wall attached is placed approximately one foot away and 8 inches to the right of the row of water treatment system areas. AprilTag number 26 is attached to designate the right boundary of the treatment system.



Helpful Information

- Students can replace the Buckyballs and blue Rings by hand once the first one has been delivered.
- Students can remove each Buckyball or Ring from their delivery locations once delivered, to make room for the next one.
- When collecting AI Object Classification data using the AI Vision Sensor, be sure students have set the toggle button to 'on' and selected 'Classroom Elements' from the dropdown, as shown in the image below.



- Students can have multiple stacks of blocks in their projects, and may want to create MyBlocks to help them organize lengthy projects. See [this section of the VEX API](#) for more information.
- Animations of one possible way the robot could move to solve each challenge can be found in the [Teacher Portal](#). You can use these for reference as you facilitate each challenge.

Stage 4: Global Clean Water Challenge

The Challenge for this stage is contextualized and introduced at the top of the Stage 4 page, and is summarized in the Challenge Doc. ([Google Doc](#) / [.docx](#) / [.pdf](#))

The Clean Water Mission Challenge Rubric can be accessed here: ([Google Doc](#) / [.docx](#) / [.pdf](#)).

Materials Needed for this Unit - Per Group

Have the following materials ready prior to the start of class for each group:

- EXP Kit (1 per group)
- AI Vision Sensor (1 per group)
- A Computer (1 per group)
- VEXcode EXP (1 per group)
- Engineering Notebook (1 per student)

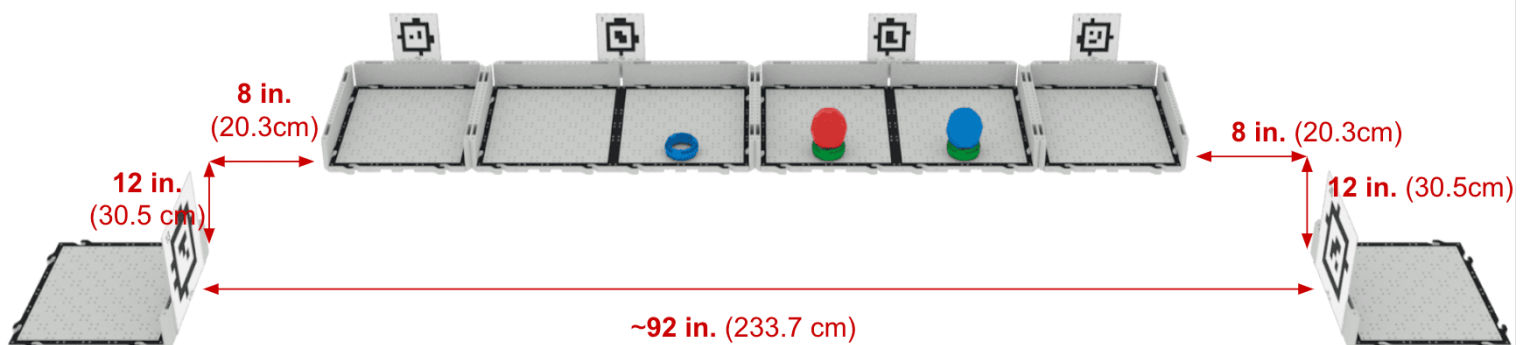
Stage 4 Setup Materials per testing area:

- Buckyballs
 - 2 red
 - 2 blue
- Rings
 - 2 green
 - 2 blue
- EXP Field Tiles (8 per testing area)
- EXP Field Walls (16 per testing area)
- 5 inch wide AprilTags - Printable AprilTags are included at the end of this document.
 - Numbers 1,2,3,4
 - 13 (left boundary) and 26 (right boundary)

All Materials needed for this Unit can also be found in the [Master Materials List](#).

Global Clean Water Challenge Setup:

- In this challenge, the areas of the water treatment system are rearranged. The robot should be able to successfully deliver water to each of the rooms regardless of arrangement. The image below shows one possible setup for the Challenge.

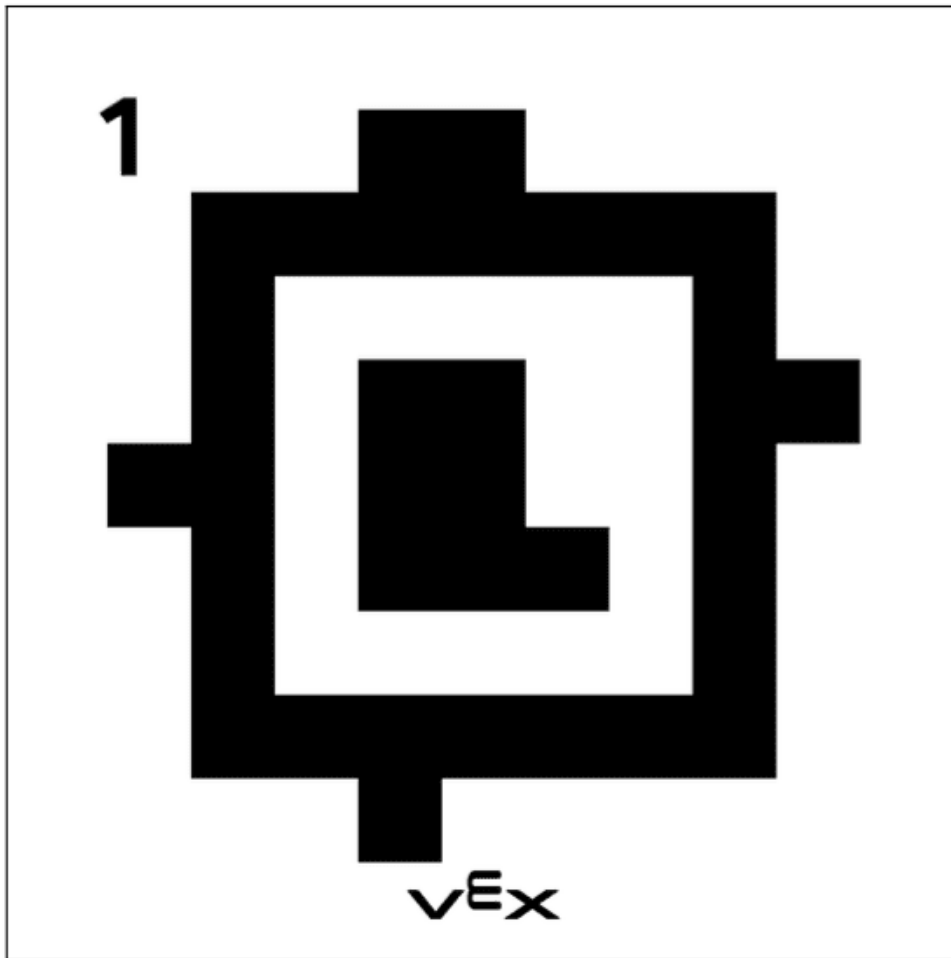


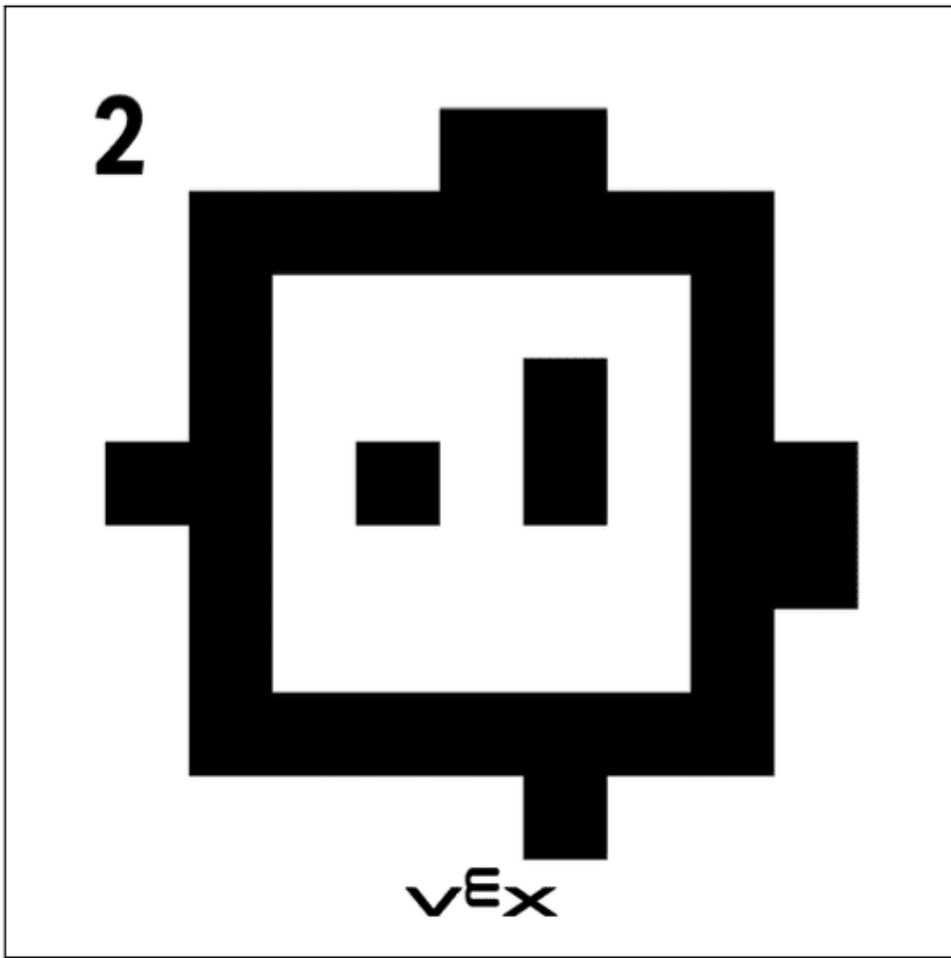
- The areas from Stage 3 remain the same, but are not in the same order left to right.
 - In the version of the setup pictured above, the areas are in this order from left to right: distribution area, purification area, collection area, treatment area.
- The landmark AprilTags to mark the left and right boundaries of the water treatment system remain intact.

Helpful Information

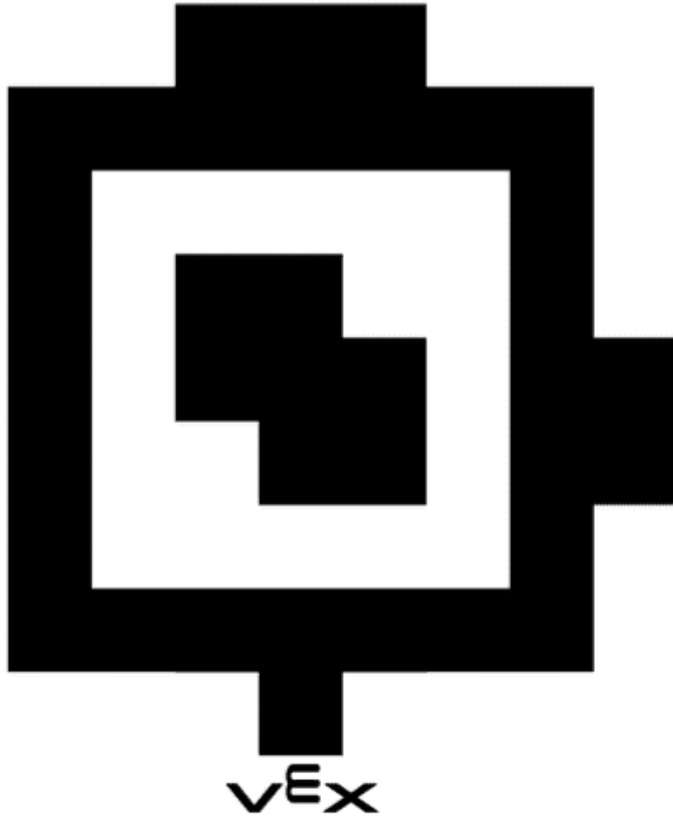
- This is the culmination of the Clean Water Mission Unit.
 - Students should be encouraged to use sections of code and projects from the previous stages of this challenge to solve the Global Clean Water Challenge.
 - Be sure to allow students plenty of time to plan, test and iterate to create an algorithm to solve this advanced level challenge.
- At the conclusion of this challenge, allow students time to reflect on their learning over the course of the entire Unit. Students can document their reflections in their engineering notebooks, and share them with you during their wrap up reflections. You may want to engage in a whole class discussion about their learning and approach to open-ended challenges as well.
- Animations of one possible way the robot could move to solve each challenge can be found in the [Teacher Portal](#). You can use these for reference as you facilitate each challenge.

AprilTags for Printing

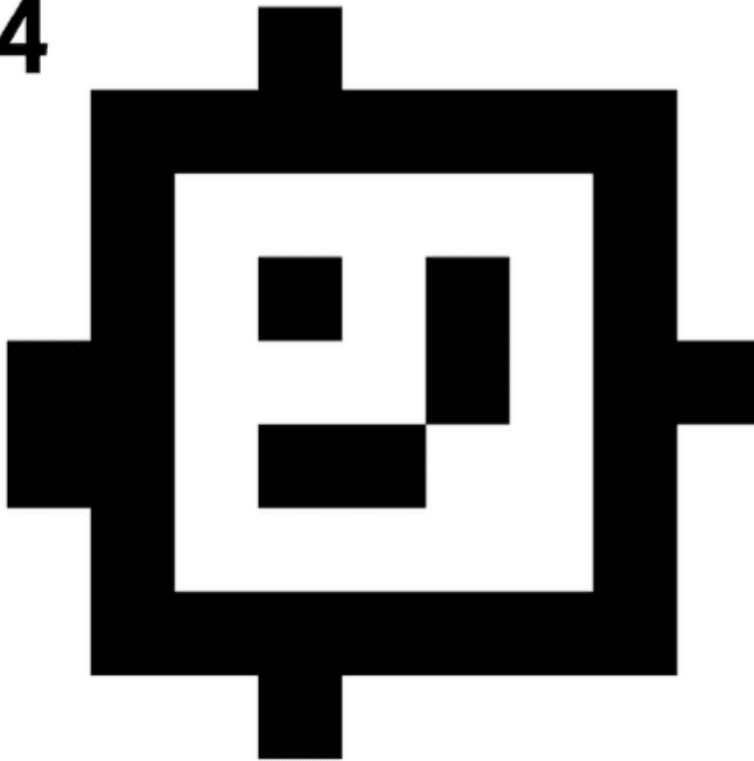




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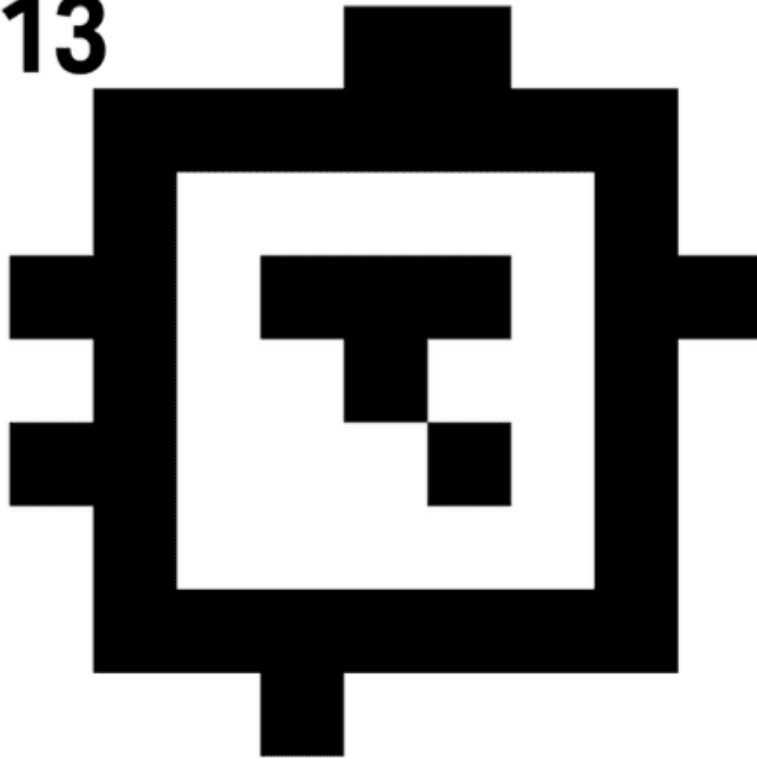


4



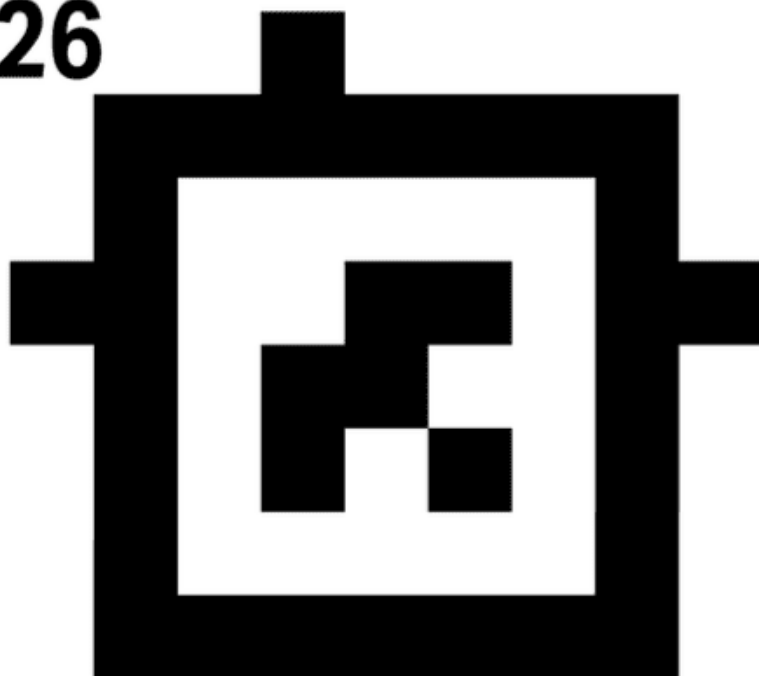
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13



vex

26



vEX