The EV3 STEM CAD Workbook
Exercises and worksheets that complement the Introduction To Programming Curriculum.

Robotics Workbook
Teacher’s Guide

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The STEM CAD EV3 Workbook is designed to supplement the EV3’s Introduction to Programming Curricula and the Expedition Atlantis Math Game. Contact Robomatter at: 412-963-7310 to learn more.
Frequently Asked Questions

Before starting

► Will the STEM CAD EV3 Workbook help me teach to Standards?
   Yes! See Standards, pages 36 - 37.

► What do I need to prepare for class?

► What general topics are covered in the STEM CAD EV3 Workbook?
   See “What is found in each chapter”, pages 7 - 12, and the Scope and Sequence, pages 13 - 26.

► I want to know what’s in each Chapter and Unit, where do I go?

► I have no idea how to teach sketching?
   See Teaching Technical Sketching, page 14 in the Scope and Sequence section.

During class

► How do I teach kids about the importance of Technical Sketching, Technical Drawing, and Computer Aided Drawing?
   See the Introduction to Technical Writing assignment, page 28.
   See the Technical Drawing, the Language of Engineering assignment, page 29.
   See the Introduction to Computer Aided Drawing- MLCad assignment, page 30.

► How do I help students who can’t sketch to become better at it?
   See the “Technical Sketching” example videos and use the Technical Sketching Rubric on page 31.

► What should I teach and when should I teach it?
   See the Scope and Sequence, page 13 - 27.

► What do I do about students who go faster/slower than the others?
   See Differentiated Instruction, page 5.

After class

► How do I prepare my kids for competitions?
   See Chapter 1, Introduction to Engineering in the STEM CAD EV3 workbook.

► Are there quizzes or homework?
   Yes, anything that is not completed in class should be assigned to be completed at home.
Checklist

☐ Identify the activities that you will use
   Technical sketching is a foundational skill for all designers. The STEM CAD EV3 workbook is designed to provide students with simple sketching opportunities that are intended to promote the development of simple skills like dimensioning, drawing interpretation, and other skills designed to promote ideation.

☐ Set up the student workstations
   See page 6, Workstation Setup.

☐ (Recommended) Complete the Introduction to Technical Writing Assignment
   The Introduction to Technical Writing assignment is designed to both demonstrate how to write a set of directions without pictures, and to promote written communications in students.

☐ (Recommended) Complete the Introduction to Technical Sketching exercises
   The Introduction to Technical Sketching exercises are supported with videos that demonstrate proper sketching technique as well as a series of worksheets designed to provide students with practice around the mechanics of sketching.

☐ Become familiar with the lessons
   Read the “In the Classroom” section of the teacher’s guide, pages 7 - 12 to learn about the lessons.

☐ Determine overall pacing for the module
   Identify key dates that you would like to have each project due; make these clear to students in your syllabus or assignment sheets.

☐ Identify and use the assessment rubrics
   Rubrics are used to share expectations for students. Make it clear what you want your students to submit and how you will evaluate it.
Why Use the STEM CAD EV3 Workbook?

► Introduce students to the “Language of Engineering”
  • Technical Sketching
  • Multi-view/Orthographic Projections
  • Pictorial Drawings
  • Interpreting Technical Drawings
► Introduce students to the “Precision of Engineering”
  • Measurement
  • Dimensioning
► Introduce students to the “Mathematics and Mechanics of Engineering”
  • Wheels and Pulleys
  • Gears and Gear Ratios
  • Conversion of Units
► Introduce students to “Tools of Engineering”
  • Engineering Process
  • Time Management
  • Teamwork and Problem Solving

Differentiated Instruction

One of the biggest challenges facing teachers today is meeting the needs of each individual student in their classrooms; that is the core of differentiated instruction. Differentiated instruction asks teachers to approach students at their instructional level, and requires students to show evidence of growth from their instructional level. Differentiated instruction encompasses more than just assessment. It involves all aspects of instruction: classroom delivery, overall learning environment, learning content, and assessment. The STEM CAD EV3 Workbook provides opportunities for students of all abilities:

► The STEM CAD Workbook provides opportunities to teach students at the level that they are currently at, there are no prerequisites for these activities
► Introducing concepts using a scaffolded approach
► Providing opportunities for students to work collaboratively with others, thus providing opportunities for all students, including students having difficulty grasping some concepts
What is the best setup for student workstations?

Students work both independently and collaboratively in small groups. The ideal classroom has enough space in between the computers for small group work.

Set up each workstation with:

a. **MLCad software** installed on each computer
   - Check each computer to see that the MLCad software works
b. Access to the **STEM CAD** workbook
c. Sketching tools
   - Paper
   - Pencils
   - Protractor
   - Meter stick, ruler, or other measuring tools

What are the System Requirements for the **EV3 MLCad software**?

- Operating system: Windows 95 / 98 / ME / NT4.0 / 2000 / XP / Vista / 7 / 8 or Linux
- CPU: Pentium processor (Pentium II or higher recommended)
- Graphics card: VGA graphics card w/ resolution of 800 x 600 (1024 x 768 with 24bit colors or better recommended)
- RAM: 32 MB or higher
- Hard disk space: 512 MB (1 GB or higher recommended)
- Browser for integrated help
What is found in each chapter?

CHAPTER 1: Project Management ............................................. 1.1
This section introduces students to industry-established best practices for brainstorming, working in teams, managing time, conducting design reviews, and using engineering processes. The worksheets contain tips and tricks to help any new team to work together when they are problem-solving. Also, some examples are included that explain how today’s project managers track resources for projects they work on.

CHAPTER 2: Introduction to Sketching ............................... 2.1
Sketching is the language that engineers use; “A picture is worth a thousand words...” This section contains ten sketching worksheets that will give students practice developing basic sketching techniques.

CHAPTER 3: Multi-View Sketching ................................. 3.1
Continuing development in sketching, this section helps to bridge the gap between two dimensional ‘flat’ sketches and their three dimensional representations with the ‘glass box’ example. The worksheets included provide students with an introduction that slowly ramps up with more complex examples. It ends with a Drawing Interpretations section to ensure that students understand multi-view drawings.

CHAPTER 4: Pictorial Sketching ......................................... 4.1
Pictorial sketching worksheets are designed to introduce students to the methods that engineers use when designing things. Students have already seen these representations in other sections, but will now dive deeper into isometric sketching and the thought behind it. There are many examples and exercises in this section that are designed to give students the ability to develop their own pictorial sketches.

CHAPTER 5: Dimensioning and Measurement ..................... 5.1
In this section, students have the ability to practice how to measure and dimension parts applying either English and metric measurement. The chapter includes student worksheets that will walk through techniques for measurement both with a ruler and protractor. It also provides additional measurement examples and dimensioning rules.

CHAPTER 6: Mechanics .................................................. 6.1
The mechanics section reinforces fundamental math skills as students learn about the impact that gears, pulleys, and varying wheel diameters have on their robot solutions. The exercises are designed to give students an opportunity to apply problem-solving skills, convert units, and answer questions about ratios and proportions. Each lesson in the mechanics section is provided with detailed answers to all questions in the Teacher’s Supplement.

CHAPTER 7: Teacher’s Supplement ................................. 7.1
This sections contains answers to all exercises as well as printable material that may be helpful. The printable material consists of isometric graph paper, a ruler and a set of protractors.
Chapter 1 - Brainstorming in teams and managing projects

Can you work well on a team, make decisions and solve problems? A 2015 research project, conducted by The National Association of Colleges and Employers, reported in Forbes Magazine that those are the skills employers most want when they are deciding which new college graduates to hire. The next-most important skill: the ability to communicate verbally with people inside and outside an organization. Employers also want new hires to have technical knowledge related to the job, but that’s not nearly as important as good teamwork, decision-making and communication skills, and the ability to plan and prioritize work. The worksheets in Chapter 1: Project Management were created to help teachers to prepare students for the workplace, by introducing them to some of these skills.

The handouts in this section were designed to help you, the teacher, to teach basic engineering process and project management. Every handout has value; it will be up to you to decide which handouts work for your class. If you are teaching engineering the two handouts in the engineering section will be helpful. Definitions of Engineering can be used to begin a class discussion on what engineers do; this handout can be used as an “introduction to engineering” before students develop their own definition for engineering. The handout Engineering Process shows students a set of steps engineers use when problem solving.

Once students begin a project, they will be divided up into teams. The three handouts Team Building, First Team Meeting, and Robotics Teams are designed to help students begin to learn how to work in teams. Team Building is a handout that can be given as a homework reading assignment to be completed the day before the first team meeting. Students may be required to write a short summary of what each organizer in the handout is saying in their own words. The First Team Meeting handout can be used as talking points for review before students are as they complete major projects. These are common sense rules that need to be reinforced. The Robotics Teams handout is a general organizer that could lead to how teams may want to divide when they begin to design, build, program, test, and troubleshoot their robots.

Students and adults that begin problem solving often begin designing and building before they have actually defined the problem. The handouts Brainstorming Primer and Problem Solving Strategies are designed to be used the same way as Team Building and the First Team Meeting handouts were. Brainstorming Primer can be given as a homework reading assignment where students read the handout and are assigned to write in their own words what the various sections mean. The second handout, Problem Solving Strategies, can be used as talking points for review before students actually begin their brainstorming sessions. Some teachers may find these lessons too simple and will set teams up without proper preparation. But, these two lessons, Working in Teams and Brainstorming are extremely important. Students and adults alike have difficulty with this process. It is better to spend the time upfront teaching how to work together. This will save time and produce better results in the long term.

The Time Management worksheets will give young project managers tools to manage their projects. The Planning Organizer worksheet is designed to help students break the problem into manageable parts. This is the first step before actual assignments are assigned. This is a very general tool to begin to have students look at problems and break them into smaller parts. The Group Matrix and Master Schedule handouts can be used by the project manager or the project leads under the project manager to begin to assign team members responsibilities. What role will each team member play? What task will they be responsible for? What resources will they need to finish their task? The Daily Log is an important tool to document what is being done each day. The Daily Log becomes very important when teams of people are working on the same project, but may be working at different times during the day. The Daily Log allows one team to share notes with another team.

Gantt Charts and PERT Charts handouts were included in the Time Management section to introduce students to two industry tools used by managers. Our experience is that students find the Gantt Chart easier to use. Unfortunately all projects are not linear in nature. Often times, multiple tasks need to be accomplished simultaneously; the PERT Chart allows a project manager to document that. The Competition Schedule handout was developed by a group of teachers in a brainstorming session. It was included because it is a comprehensive tool that students and teachers will find helpful when preparing for a robotics competition.

Design reviews are used by teams to check where they are as they complete major projects. The Design Review handout spells out what a design review is and how teams conduct design reviews to check on group progress.
Chapter 2 - Introduction to Sketching

A picture is worth a thousand words… Engineers need to be able to share ideas quickly. Therefore often times they sketch. The goal of the Introduction to Sketching exercises is to give students confidence so they are able to share ideas using a pencil and paper. The first two worksheets, *Freehand Sketching - Lines and Squares* and *Freehand Sketching - Curves and Circles* are designed to teach students the mechanics of sketching. The next few worksheets will show students how lines and arcs can be used to make up most any object. After the students have become more comfortable with sketching, *Freehand Sketching Grids* will help students to get used to the idea of using the proportions provided by a grid to help maintain scale. The worksheets can be modified to meet teacher’s needs. In all of the sketching exercises the teacher should emphasize the following:

- Keep your sketches in proper proportion. It is often good practice for beginners to start out by drawing a square or rectangle that is proportional to the object that they are sketching.

- Keep your initial lines light; these are called developmental lines. Do not darken your lines until you are confident that what you have drawn is what you would like to keep. The darkened lines are called object lines.

- Grasp the pencil in your hand lightly.

- All parts in a two dimensional picture can be broken into two types of lines: straight and curved. If students are able to draw straight lines and curved lines and keep things in proper proportion, they are well on their way to becoming good sketchers.

- When sketching circles start by sketching a square. Divide the square into quarters, and then sketch the circle one quarter at a time.

The single view sketches worksheets, *Single View Sketching EV3 Parts* and *Single View Sketching EV3 Wheels and Gears*, are designed to give students practice developing their sketching technique. When students begin to gain confidence, you can take away the graph paper and have them work on developing their own strategies to keep things in proper proportion.

The next three sketches in this section, *Sketch EV3 Large Motor Assembly Top View, Side View, and Front View* are more challenging for students. Students will ask why the Front View drawing actually shows the side view. Explain to them that when they study technical drawing they will find that the front view of the object, in the opinion of the designer, shows the most about the object and is sometimes subjective. Keep in mind that these activities may take substantial time to complete and are very difficult..

The last three sketches in this section, *Sketch EV3 Educator Vehicle (REM-Bot) Top View, Side View, and Front View* are more challenging examples for students. They have been labeled “Enrichment Activities” and are intended for use with students that finish materials before the rest of the class.
Chapter 3 - Introduction to Multi-View Sketching

When engineers share ideas they use a “Universal Language” called technical drawing. Technical drawing enables a designer in China to share a drawing with a designer in Denmark and have them both interpret the drawing the same way. In order to share all relevant details about an object, a Multi-View projection is needed. A Multi-View projection is a way of revealing every detail about a three dimensional object with two dimensional views. This can be as few as two views (for a round object) to as many as six views. For our purposes we will be using the typical Top, Front, and Side views. This chapter will help students become more comfortable with Multi-Views.

As in the last chapter, the teacher should emphasize the following:

- Keep your sketches in proper proportion. It is often good practice for beginners to start out by drawing a square or rectangle that is proportional to the object that they are sketching.
- Keep your initial lines light; these are called developmental lines. Do not darken your lines until you are confident that what you have drawn is what you would like to keep. The darkened lines are called object lines.
- Grasp the pencil in your hand lightly.
- All parts in a two dimensional picture can be broken into two types of lines: straight and curved. If students are able to draw straight lines and curved lines and keep things in proper proportion, they are well on their way to becoming good sketchers.
- When sketching circles start by sketching a square. Divide the square into quarters, and then sketch the circle one quarter at a time.

The Glass Box Example is a common multi-view drawing example, used to bridge the understanding of where the views fit together in a three dimensional object. The worksheets Multi-View Front Side or Top? and Multi-View Sketched answer serve as an introduction multi-views and should help display where Top, Front and Side views are located.

The sketching exercises included in the Multi-View Sketches section of this workbook introduce isometric orthographic projections, sometimes called Multi-View projections; they are Multi-View Sketching and Multi-View Sketching EV3® Parts. We attempted to pick drawings that students would find interesting. The drawings in both sections start easy and get increasingly more difficult. As students move to the EV3® Parts section, encourage them to use the real world parts to get a better idea of the angles they’re sketching the parts from. The details in these sketching exercises are not a required part of the sketches. You may instruct the faster students to add details, while other students are given time to complete their sketches.

Students may enjoy the problem solving aspects of the EV3® Standard Drive Base Drawing Interpretations. This handout is designed to reinforce the concept of orthographic projections; how one view relates to another view. Isometric and Oblique Sketching pictorial sketches were included to round out the technical sketching worksheets. Encourage students to sketch an isometric or oblique pictorial cube first, and then break things down proportionally. They have more success sketching pictorial drawings if they use this methodology. For more information on how to teach any of these types of drawings search the Internet or buy a technical drawing textbook. Technical drawing is an important concept for any future engineer to know.
Chapter 4 - Pictorial Sketches

Now that students have become more comfortable with the concepts of multi-views, we will take it one step further. Instead of taking a three dimensional projection and turning into the Top, Front, and Side views, this chapter begins with those three projected views, and teaches students how to turn them into a three dimensional isometric projection.

Since we are sketching in three dimensions, it may be even more important for students to take note of these suggestions. When the objects and projects get more complex, clean sketching becomes more critical. Please emphasize the following:

- Keep your sketches in proper proportion. It is often good practice for beginners to start out by drawing a square or rectangle that is proportional to the object that they are sketching.

- Keep your initial lines light; these are called developmental lines. Do not darken your lines until you are confident that what you have drawn is what you would like to keep. The darkened lines are called object lines.

- Grasp the pencil in your hand lightly.

- All parts in a two dimensional picture can be broken into two types of lines: straight and curved. If students are able to draw straight lines and curved lines and keep things in proper proportion, they are well on their way to becoming good sketchers.

- When sketching circles start by sketching a square. Divide the square into quarters, and then sketch the circle one quarter at a time.

The Isometric Sketching section begins with a walk-through example. This should help students to understand where the Top, Front, and Side views are placed in the three dimensional sketch. This will lead into a few generic objects and then into a few EV3® Parts. When completing the EV3® Parts section, the students should be encouraged to use physical EV3® Parts to aid in the sketches and to get a real world idea of Top, Side, and Front views. You may also continue with other parts and real world objects if more examples are needed. A sample of Isometric paper is included at the end of this chapter for replication.

The final two sketches in this section, Sketch EV3® Standard Drive Base Isometric View Enrichment Activity and Sketch EV3® REMBot Enrichment Activity are meant to be very challenging for students. They are intended to give students, who finish work early, something challenging to work on. Students may have trouble visualizing how to correctly proportion the object they are drawing. They may freely look back on the two dimensional Side, Front, and Top views sketched in the last section of this workbook or a real world robot, if available.
Chapter 5 - Dimensioning and Measurement

These worksheets are designed to help teachers reinforce measurement; an important science and technology concept. There are exercises that use both English and metric measurement. The **Measuring EV3® Standard Drive Base** exercise is intended to be completed using the dimensions provided and basic arithmetic. It is a great worksheet that students should enjoy. Students will begin to understand how dimensions are read and the importance of dimensioning when sharing ideas. We included a worksheet called **Dimensioning Rules** which may be modified for younger children and a **Units of Measurement** included to help students understand the metric and English systems differences. We have also included a **Printable Ruler and Protractor** which can be used if rulers are scarce.

**NOTE:** The default settings for Adobe Acrobat can vary from computer to computer. Be sure to set your default at 100% when printing the worksheets for this chapter.

Chapter 6 - Introduction to Mechanics

This chapter gives the teacher the chance to teach/reinforce fundamental mathematics in context. The worksheets in this chapter require students to apply critical thinking and problem solving skills at the same time.

The worksheets in the Mechanics Section can be used by teachers either as a homework assignment or as a quiz. Each worksheet is designed to check for understanding. The mechanics section is divided into two parts; **Wheels** and **Gears and Pulleys**.

Both sections contain six challenges designed to reinforce students understanding of:

- Conversion of units
- Ratios and proportions
- Basic measurement
- Algebra
- Geometry
- Problem Solving
- Reading and understanding word problems

Each worksheet is accompanied by teacher worksheets which contains notes to the teacher that describe the lesson and all of the answers to questions on the worksheet.

**IMPORTANT NOTE:** Rounding errors might cause students to have similar but slightly different answers.

Chapter 7 - Teacher’s Supplement

This chapter includes solutions and answers to all of the problems and questions asked in the STEM CAD EV3 workbook!
Introduction to Technical Sketching - 8 to 10 days

In this lesson set, students learn the importance of sketching and being able to share ideas via technical sketching. They begin by trying to describe how to build something using only words. The chapter provides many opportunities to learn basic sketching technique, including: keeping sketches proportionally correct, using developmental and object lines to layout an idea, and basic line technique.

1. **Lesson: Introduction to Technical Writing - 3 days**

   Complete Lesson One - *Introduction to Technical Writing* - page 21

   This lesson challenges students to take 6 EV3 pieces and snap them together into a shape. They are then told to write instructions using words on how to build the part. The lesson is challenging, and designed to teach the importance of sketching and drawing.

2. **Introduction to Freehand Sketching - 2 days**

   Begin by having students watch the freehand sketching videos found at the Robomatter MLCad page and then complete the following Freehand Sketching exercises:
   
   - Freehand Sketching - *Lines and Squares* - Workbook page 2.2
   - Freehand Sketching - *Circles and Curves* - Workbook page 2.3
   - Practice Exercises - Workbook 2.4 and 2.5

   *Note: Introduce students to the “Technical Sketching Assessment Rubric” found on page 30 in this teacher’s guide.*

3. **Practice Freehand Sketching - 2 to 3 days**

   Complete the Freehand Sketching exercises (three options) - 2-3 days
   
   - Key, Butterfly, Cars, and Flatware Sketches - Workbook 2.11 through 2.14
   - Tools - Workbook 2.6 through 2.10
   - Single View Sketching EV3 Parts 2.15 through 2.19

   *Note: if you want students to be able to share ideas quickly, then they need to learn to sketch. The workbook contains examples of simple two dimensional tools and EV3 parts to sketch. Examples of the Key, Butterfly, Cars, and Flatware sketching exercises can be found in this teacher’s guide on pages 31 through 34.*

4. **Technical Drawing, the Language of Engineering - 2 Days**

   This lesson builds on the Introduction to Technical Writing Lesson above. Students can now use words and sketches to describe how to recreate their shape. The lesson is described in detail on page 27 in this Teacher’s Guide.

5. **Quiz - 1 day**

   Sketching Quiz - Assign students to complete one of the REMBot sketches found on pages 2.16 through 2.18

   *Preview Introduction to Sketching content next page*
Scope and Sequence

Teaching Technical Sketching 2 days - Technical sketching is a skill; skills can be practiced and learned. Directly below you will find proven tools that provide students with practice on mechanics of drawing straight lines and circles. Before students can learn to draw, then need to learn the mechanics of drawing. Under the worksheets are five videos that demonstrate how to hold the pencil, rotate the paper, and demonstrate that you begin by sketching lightly, and then darken what is correct.

Intro to Sketching Worksheets

Intro to Sketching Videos

Line Technique - Sketching Lines Exercise Demo
This video demonstrates proper line technique to sketch straight lines. The video emphasizes: holding the pencil loosely, keeping lines light, and focusing on keeping the line spacing consistent.

Line Technique - Sketching a Square Demo
This video demonstrates: holding a pencil loosely, keeping lines light, rotating the paper so that you can always use the same consistent motion when sketching a line.

Line Technique - Sketching Squares Exercise Demo
This video demonstrates a practice exercise that students can use to improve their line technique.

Line Technique - Sketching a Circle Demo
This video demonstrates a sure way to sketch arcs and circles. It also demonstrates how people that sketch begin by sketching light lines (known as developmental lines) and then darken the lines when they know that they are correct.

Line Technique - Sketching Circles Exercise Demo
This video demonstrates a practice exercise that students can use to improve their ability to sketch arcs and circles.
Scope and Sequence

Shown below are example images of pages found in the Introduction to Sketching section of the STEM CAD EV3 Workbook.
Multi-View Sketching - 6 days

1. The Glass Box Example - 2 days

   This lesson introduces students to multi-view drawings, also known as orthographic projections.
   - Show students workbook page 3.2 and discuss why, when building plans, it is important to show a multi-view perspective rather than a pictorial drawing of a part.
   - Work as a class to solve workbook pages 3.3 and 3.4 together. Answer questions as needed. The answers to these pages can be found on pages 7.6 and 7.7 in the teacher’s supplement section of the workbook.
   - Review workbook page 3.5 “the Multi-View Cube” and then provide a demonstration to your students how to complete workbook pages 3.6 through 3.8. Example solutions for these drawings can be found on pages 7.8 through 7.10.

2. Multi-View Sketching Practice - 2 days

   This lesson provides independent student practice for students sketching multi-view drawings. Assign students to complete two of the four sketches from pages 3.9 through 3.12 from the workbook. Example solutions for these drawings can be found on pages 7.11 through 7.14 in the teacher’s supplement section of the workbook.

   Note: Use the “Technical Sketching Assessment Rubric” found in this teacher’s guide to assess student’s technical sketching exercises.

3. Multi-View Sketching Quiz - 2 days

   Assign students to complete the Multi-View “Drawing Interpretation” check for understanding quiz found on pages 3.13 and 3.14. You may need to work with students to solve several questions together and then have them complete the quiz independently. The answers to this quiz can be found on page 7.15 in the teacher’s supplement section of the workbook. On day one the students will take the quiz and on day two students will review the results of the quiz.
Scope and Sequence

Shown below are example images of pages found in the *Multi-View Sketching section of the STEM CAD EV3 Workbook.*
Scope and Sequence

Pictorial Sketching - 5-8 days

1. **Introduction to Isometric Pictorial Sketching - 2 to 3 days**
   
   This lesson is designed to teach students about isometric pictorial drawings.
   
   Instruct students to read workbook page 4.2 and then have them begin to solve workbook pages 4.3 through 4.5, a step-by-step problem. Work as a class to complete workbook pages 4.6 through 4.9.
   
   Assign students to complete two of the four sketches from pages 4.6 through 4.9 from the workbook. Example solutions for these drawings can be found on pages 7.17 through 7.20 in the teacher’s supplement section of the workbook.

2. **Isometric Sketching Practice - 2 to 3 days**
   
   This lesson provides independent practice for students sketching isometric pictorial drawings.
   
   Demonstrate to students how to sketch the EV3 parts found on pages 4.10 through 4.13. Example solutions for these drawings can be found on pages 7.21 through 7.24 in the teacher’s supplement section of the workbook.

3. **Isometric Sketching Quiz - 1 to 2 days**
   
   Assign students to complete one of the two Isometric Sketches from 4.14 or 4.16.
   
   *Note: Use the “Technical Sketching Assessment Rubric” found in this teacher’s guide to assess student’s technical sketching exercises.*
Scope and Sequence

Shown below are example images of pages found in the Pictorial Sketching section of the STEM CAD EV3 Workbook.
Scope and Sequence

Introduction to MLCad - 3-5 days

By now students have a basic understanding of sketching and are ready to learn other ways to build and share ideas. MLCad software is intuitive and easy to use and most students pick it up quickly. Use the instructional videos shown below to introduce MLCad.

This lesson has the students learning MLCad and completing a project at the same time. The STEM CAD Workbook Bundle includes 5 short instructional videos; each video targets a simple learning goal:

- Opening a Model
- Zooming and Panning
- Selection and Working with Parts
- Positioning Parts
- and, Rotating Parts

Student will quickly learn to use the software by completing: Introduction to Computer Aided Drawing - MLCad lesson.

MLCad Instructional Videos - the videos are accessible for free at: www.robomatter.com/mlcad

1. In this lesson, students will learn how to create a new model, add parts and save it.

2. In this lesson, students will learn about basic part and model zooming and panning.

3. In this lesson, students will learn about the selection of parts and what you can do with them.

4. In this video, students will learn how to position parts using the Grid.

5. In this video, students will learn how to rotate parts.
Access the Getting Started Library

1. Scroll down to the Getting Started category.
2. Expand the library of parts.
3. Drag the parts into MLCad.
4. Begin to assemble the parts.
Scope and Sequence

Mechanics/MLCad - 5 days

The Robomatter build of MLCad includes 46 working examples of simple machines, gears, pulleys, and compound gear mechanisms that can be used to demonstrate how things move mechanically. Follow the directions below to find how to access these builds.

Access to Simple Machine Builds

1. Scroll down to the Simple Machines category.
2. Expand the category.
3. Drag any “assembled model” into any of the MLCad viewing planes to display the model.
4. These models are also contained in the “Simple Machines” directory in the MLCad folder.
Scope and Sequence

Dimensioning and Measurement - 5 days

1. **Introduction to Measurement - 1 day**
   
   Review measurement with students, either metric or English, see pages 5.2 or 5.3.
   
   Assign students to complete the Measurement Practice assignment, page 5.4.
   
   The answer sheet for the Measurement Practice assignment can be found on pages 7.29 and 7.30 in the teacher’s supplement section of the workbook.

2. **Measurement with a Protractor - 1 day**
   
   Review the protractor with students, see page 5.5 in the workbook.
   
   *Note: For classrooms without protractors or meter sticks there are printable rulers and protractors on page 7.34 in the teacher’s supplement section of the workbook.*
   
   Assign students to complete the Measurement EV3 Parts assignment, page 5.6.
   
   The answer sheet for the Measurement EV3 Parts assignment can be found on pages 7.31 and 7.32 in the teacher’s supplement section of the workbook.

3. **Measuring EV3 Standard Drive Base - 1 day**
   
   For students to complete this assignment they will need to have a standard EV3 robot to measure. Students can work in pairs if needed. Assign students to complete worksheet page 5.7.
   
   *Note: For classrooms without protractors or meter sticks there are printable rulers and protractors on page 7.34 in the teacher’s supplement section of the workbook.*
   
   The answer sheet for the Measuring EV3 Standard Drive Base assignment can be found on pages 7.33 in the teacher’s supplement section of the workbook.

4. **Dimensioning - 2 days**
   
   Begin by explaining the importance of clearly dimensioning the size and location of significant features of a part if you are developing plans for a new part.
   
   Have students review page 5.8, Dimensioning Rules.
   
   Assign students to measure and dimension several of the sketches that they completed in the multi-view and isometric drawing chapters.
Introduction to Mechanics

This mechanics section of the workbook focuses on providing the student with practice completing the mathematics behind movement. This set of worksheets can be used by the teacher for homework assignments or as simple “check for understanding” quizzes.

1. Wheels Diameter/Distance Traveled
   - Diameter/Distance Traveled handout - page 6.2
   Note: there are teacher notes in the teacher supplement section on pages 7.37 through page 7.39.
   - Diameter/Distance Traveled worksheet - page 6.3 Answer sheet - pages 7.40, 7.41.
   - Diameter/Distance Traveled word problems - page 6.4 Answer sheet page 7.42.

2. Wheels Radius/Distance Traveled
   - Radius/Distance Traveled handout - page 6.5
   Note: there are teacher notes in the teacher supplement section on pages 7.43 through page 7.45.
   - Radius/Distance Traveled worksheet - page 6.6 Answer sheet - page 7.46.
   - Radius/Distance Traveled word problems 1 - page 6.7 Answer sheet pages 7.47 through 7.50.
   - Radius/Distance Traveled word problems 2 - page 6.8 Answer sheet pages 7.51 through 7.54.

Continued next page
Scope and Sequence

Mechanics (continued)

3. Wheels Diameter/Conversion of Units
   - Wheels Diameter/Conversion of Units worksheet 1 - page 6.9
     Note: there are teacher notes and worked solutions on the Conversion of Units handout in the teacher supplement section on pages 7.55 through page 7.59.
   - Wheels Diameter/Conversion of Units worksheet 2 - page 6.10
     Note: there are teacher notes and worked solutions on the Conversion of Units handout in the teacher supplement section on pages 7.60 through page 7.63.

4. Gears - Introduction to Gear Ratios
   - Introduction to Gear Ratios worksheet - page 6.11
     Note: there are teacher notes and worked solutions for the Introduction to Gears Ratios handout in the teacher supplement section on pages 7.64 through page 7.66.
   - Gear Ratios/Pulleys worksheet - page 6.12
     Note: there are teacher notes and worked solutions for the Gear Ratios/Pulleys handout in the teacher supplement section on pages 7.67 through page 7.69.
   - Gear Ratios/Word Problems- page 6.13
     Note: there are teacher notes and worked solutions for the Gear Ratios/Pulleys handout in the teacher supplement section on pages 7.70 through page 7.73.

5. Gears - Introduction to Gear Ratios (continued)
     Note: there are teacher notes and worked solutions for the Gear Ratios/Speed handout in the teacher supplement section on pages 7.74 through page 7.77.
   - Gear Ratios and Speed Problem Solving - page 6.15
     Note: there are teacher notes and worked solutions for the Gear Ratios and Speed Problem Solving handout in the teacher supplemental section page 7.78 through page 7.82.
   - Gears Pulleys and Speed/Problem Solving - page 6.16
     Note: there are teacher notes and worked solutions for the Gears Pulleys and Speed/Problem Solving handout in the teacher supplemental section page 7.83 through page 7.87.

Note: See page 21 in this teacher’s guide and you will find that there are 46 different example designs of MLCad simple machines and gears for students to experiment and learn with.
Scope and Sequence

Shown below are example images of pages found in the Mechanics section of the STEM CAD EV3 Workbook.
Introduction to Technical Writing

The purpose of the lesson is to impress upon students the need to be able to share their ideas using technical drawings. This lesson aligns with the English and Language Arts College and Career Readiness standards as well as the Engineering Design standards.

Directions

1. Have students work in pairs on this assignment.

2. Provide students with the parts pictured above and give them 30 seconds to snap the pieces into a shape. Tell your students that the shape doesn’t matter.

Note: you can use any parts found in the EV3 kit, but if you use these 6 parts shown above, you will find that they are included in a category of parts named “Getting Started” in the Robomatter MLCad directory. In one of the follow up lessons students will be asked to use MLCad to develop a set of instructions and all of the parts will be found in the same library.

3. Assign your students to write a set of text only directions (no pictures) that describes how to build the shape that they just snapped together.

Note: Tell the class that they will be exchanging their set of directions with another group and the second group of students will be assigned to build their shape following their step-by-step written directions.

4. Provide students with two periods to write this set of directions.

5. On day three have students exchange their set of directions with another group in the class and attempt to build each other’s model.

6. Discuss the difficulties student had with this assignment.

7. Introduce students to Technical Sketching Unit
Directions

1. Have students work in pairs on this assignment.

2. Provide students with the parts pictured above and give them 30 seconds to snap the pieces into a shape. Tell your students that the shape doesn’t matter.

   Note: you can use any parts found in the EV3 kit, but if you use these 6 parts shown above, you will find that they are included in a library of parts named “getting started” in the Robomatter MLCad directory. In one of the follow up lessons students will be asked to use MLCad to develop a set of instructions and all of the parts will be found in the same library.

3. Assign your students to develop a set of directions using technical sketching and words that describes how to build the shape that they just snapped together.

   Note: Tell the class that they will be exchanging their set of directions with another group of students and the second group of students will be assigned to build their shape following their step-by-step written directions.

4. Provide students with two periods to complete this set of directions.

5. On day three have students exchange their set of directions with another group in the class and attempt to build each other’s model.

6. Have the second team of students evaluate and provide feedback on the set of instructions.
Introduction to Computer Aided Drawing - MLCad

This lesson introduces students to MLCad and how to create digital instructions. It aligns with the English and Language Arts College and Career Readiness standards as well as the Engineering Design standards.

Directions

1. Have students work in pairs on this assignment.

2. Provide students with the parts pictured above and then give them 30 seconds to snap the parts into a shape. Tell your students that the shape doesn’t matter.

   Note: you can use any parts found in the EV3 kit, but if you use these 6 parts shown above, you will find that they are included in a library of parts named “getting started” in the Robomatter MLCad directory. In one of the follow-up lessons students will be asked to use MLCad to develop a set of instructions and all of the parts will be found in the same library.

3. Assign your students to develop a set of directions using MLCad software to describe how to build the shape that they just snapped together.

4. See page 20 in the Scope and Sequence section of this Teacher’s Guide to learn how to access the “Getting Started” category in MLCad.

   Note: Tell the class that they will be exchanging their set of directions with another group and the second group of students will be assigned to build their shape following their step-by-step written directions.

5. Provide students with two periods to complete this set of directions.

6. On day three have students exchange their set of directions with another group in the class and attempt to build each other’s model.

7. Have the second team of students evaluate and provide feedback on the set of instructions.
## Technical Sketching Assessment Rubric

<table>
<thead>
<tr>
<th>Category</th>
<th>Sketching Only Scoring - Answer each statement below with a 1 if the answer is “YES” and a 0 if the answer is “NO”. 5 - A 4 - B 3 - C. The student should complete the evaluation before the teacher.</th>
<th>Student</th>
<th>Teacher</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Proportionally Correct</td>
<td>Is the object that you are sketching proportionally correct?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Developmental Lines</td>
<td>Did you use developmental lines that are light and fade into the background of the sketch?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Object Lines</td>
<td>Did you use object lines that are dark but neat?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Sketching Circles</td>
<td>When you sketched circles and arcs did you begin by sketching a square and then divide the square into quarters and sketch the parts of the circle or arc one section at a time?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Neat</td>
<td>Is your sketch neat?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Total

### Additional Criterion
Include these criterion if your drawings include them.

<table>
<thead>
<tr>
<th>6 Multi-View Sketches 1</th>
<th>Are your views (top view, front view, side view) in the correct position on the paper?</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>7 Multi-View Sketches 2</td>
<td>Do your views align correctly?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Dimensioning 1</td>
<td>Did you use “extension lines” and “dimension lines” to dimension your sketch?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 Dimensioning 2</td>
<td>Is you sketch dimensioned accurately?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Pictorial Sketches</td>
<td>Is the pictorial sketch correct?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Total

**Teacher Notes:**
Keys provide an inexpensive, though imperfect, method of access control to physical properties like buildings, vehicles and cupboards or cabinets. As such, keys are an essential feature of modern living, and are common around the world. It is common for people to carry a set of keys that they need for their daily activities around with them, often linked by a keyring adorned by trinkets usually known as a keychain\(^1\).

Your Job:
1. Sketch the key at the left in the box below.
2. Use your newly acquired sketching technique to develop a new type of key.
3. Write a description of what you think the old key opened as well as what your new key is designed to open.

\(^1\) Wikipedia Key(Lock)

### Sketching Assessment Rubric

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use developmental lines</td>
<td>1 pt</td>
</tr>
<tr>
<td>Use object lines</td>
<td>1 pt</td>
</tr>
<tr>
<td>Sketch proper proportion</td>
<td>1 pt</td>
</tr>
<tr>
<td>Sketching assignment complete</td>
<td>2 pts</td>
</tr>
<tr>
<td>Sketch neat</td>
<td>2 pts</td>
</tr>
</tbody>
</table>

7 - A  6 - B  5 - C  4 - D
Technical Sketching - Discover a Butterfly!

There are approximately 20,000 species of butterflies in the world! About 725 species have occurred in North America north of Mexico, with about 575 of these occurring regularly in the lower 48 states of the United States, and with about 275 species occurring regularly in Canada.\(^1\)

Butterfly wings are symmetrical.

Your job:
Design three different butterfly wings.

Use the sketch evaluation rubric below to evaluate your sketches.

You will need an additional sheet of paper.
Submit all three sketches to your teacher for evaluation.

\(^1\)Butterfly Questions and Answers - North American Butterfly Association
www.naba.org/qanda.html

<table>
<thead>
<tr>
<th>Sketching Assessment Rubric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use developmental lines</td>
</tr>
<tr>
<td>Use object lines</td>
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<td>Sketch proper proportion</td>
</tr>
<tr>
<td>Sketching assignment complete</td>
</tr>
<tr>
<td>Sketch neat</td>
</tr>
</tbody>
</table>

7 - A  6 - B  5 - C  4 - D
Technical Sketching - Design Your Perfect Car

Design a Car Requirements:

Design is an iterative process; rarely is your first idea the best one. Use the pictures below as a guide to determine the scale of your car. Develop a series of five sketches of your dream car. Turn in all five sketches for evaluation. The sketches should show the evolution of your design.

Sketching Assessment Rubric

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use developmental lines</td>
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<tr>
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</tr>
<tr>
<td>Sketching assignment complete</td>
<td>2 pts</td>
</tr>
<tr>
<td>Sketch neat</td>
<td>2 pts</td>
</tr>
</tbody>
</table>

7 - A    6 - B    5 - C   4 - D
Technical Sketching - Design a Flatware Set (Knife, Fork, and Spoon)

Flatware Set Design Requirements:

1. Needs to be proportioned similar to what is pictured directly below

2. Needs to look like it comes from the same family

Sketching Assessment Rubric

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use developmental lines</td>
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<td>Use object lines</td>
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<tr>
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</tr>
<tr>
<td>Sketching assignment complete</td>
<td>2 pts</td>
</tr>
<tr>
<td>Sketch neat</td>
<td>2 pts</td>
</tr>
</tbody>
</table>

7 - A 6 - B 5 - C 4 - D
## Common Core English Language Arts

<table>
<thead>
<tr>
<th>Standard (CCR Anchor Standards for Writing)</th>
<th>STEM CAD Robotics Workbook</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CCRA.W.4</strong> Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.</td>
<td>Students are asked to write technical instructions and supporting information for plans that they develop.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Standard (CCR Anchor Standards for Speaking)</th>
<th>STEM CAD Robotics Workbook</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CCRA.SL.4</strong> Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.</td>
<td>Students demonstrate these skills when they present their technical sketches and supporting information during design reviews and other student presentations.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Standard (CCR English and Language Arts)</th>
<th>STEM CAD Robotics Workbook</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CCRA.RST.9</strong> Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to the student’s grade and texts.</td>
<td>As students learn about technical sketching, drawing, dimensioning, and mechanics there are many new symbols, key terms, and domain specific phrases for them to learn and understand.</td>
</tr>
</tbody>
</table>

| **CCSS.ELA.Literacy.4** Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. | Students are required to write to support their technical sketches with clear coherent descriptors. |

## Next Generation Science Standards (NGSS)

<table>
<thead>
<tr>
<th>Standard</th>
<th>STEM CAD Robotics Workbook Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MS-ETS1-2.</strong> Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.</td>
<td>When students begin developing engineering plans they will be required to consider both hardware and software designs according to pre specified design criteria.</td>
</tr>
</tbody>
</table>

| **MS-ETS1-4.** Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. | When solving more difficult and complex design challenges, students are guided toward iterative testing and refinement processes. In engineering design problems student continue to iterate and refine based on testing. |

| **HS-ETS1-2.** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. | Problem Solving methodology for robotic design problems directs students to break down large problems into smaller solvable ones, and build solutions up accordingly; the design challenges provide students with opportunities to practice, each based on a real-world design problems. |

| **HS-ETS1-3.** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. | Well designed robotic engineering design problems require students considerations around cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. |
## Computer Science and Math Standards Addressed

### CSTA K-12 Computer Science Standards

<table>
<thead>
<tr>
<th>CSTA K-12 Computer Science Standards</th>
<th>STEM CAD Robotics Workbook Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CT: Computational Thinking</strong></td>
<td></td>
</tr>
<tr>
<td>L1:3.CT-02 Use writing tools and drawing tools to illustrate thoughts, ideas, and stories in a step-by-step manner.</td>
<td>Students are required to accurately describe ideas via a step-by-step manner.</td>
</tr>
<tr>
<td>CT.L3A-09 Discuss the value of abstraction to manage problem complexity.</td>
<td>When students develop a set of plans they often have to change the scale of the drawing enabling the teacher to talk about abstraction.</td>
</tr>
<tr>
<td>L1:6.CT-01 Understand and use the basic steps in algorithmic problem-solving</td>
<td>Technical sketching breaks things into proportionally correct lines, arcs, and circles and then builds them up into pictures.</td>
</tr>
<tr>
<td><strong>CL: Collaboration</strong></td>
<td></td>
</tr>
<tr>
<td>L1:3.CL-01 Gather information and communicate electronically with others with support from teachers, family members, or student partners.</td>
<td>When students are working with the CAD software they work in teams to gather information and then design plans. In the STEM CAD Robotics workbook students are required to describe a set of plans using words, then words and sketches, and then using CAD. At the end of that experience they are ready to describe how computing enhances traditional forms of design.</td>
</tr>
<tr>
<td>CL.L3A-01 Work in a team to design and develop a software artifact.</td>
<td></td>
</tr>
<tr>
<td>CL.L3A-03 Describe how computing enhances traditional forms and enables new forms of experience, expression, communication, and collaboration.</td>
<td></td>
</tr>
<tr>
<td><strong>CCP: Computing Practice and Programming</strong></td>
<td></td>
</tr>
<tr>
<td>CPP.L2-03 Design, develop, publish, and present products.</td>
<td>Students are required to develop CAD drawings.</td>
</tr>
<tr>
<td>CPP.L3A-10 Explore a variety of careers to which computing is central.</td>
<td>When students study robotics and engineering design they are also learning the impact of computing.</td>
</tr>
</tbody>
</table>

### Common Core Mathematics Content

<table>
<thead>
<tr>
<th>Standard (CCSS.Math.Content)</th>
<th>STEM CAD Robotics Workbook Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCSS.Math.Q.A.1 Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities</td>
<td>Students use ratio language to describe and make use of the relationship between quantities such as wheel rotations and distance traveled, and gears and gear ratios.</td>
</tr>
<tr>
<td><strong>Modeling</strong> Modeling links classroom mathematics and statistics to everyday life, work, and decision-making.</td>
<td>Technical drawing required students to develop accurate models with mathematically correct dimensions and notes.</td>
</tr>
<tr>
<td>CCSS.Math.Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.</td>
<td>When developing a set of technical sketches students need to choose the proper units to describe the size, shape, and quantity of what they’ve designed. These units then are used in other data sets to calculate cost, weight, etc.</td>
</tr>
<tr>
<td>7.RP.A.3 Use proportional relationships to solve multi-step ratio and percent problems.</td>
<td>Comparisons between rate-derived quantities are common during robot navigation tasks.</td>
</tr>
</tbody>
</table>