ENGINEERING DESIGN ASSESSMENT GUIDE

Hummingbird Robotics Kit

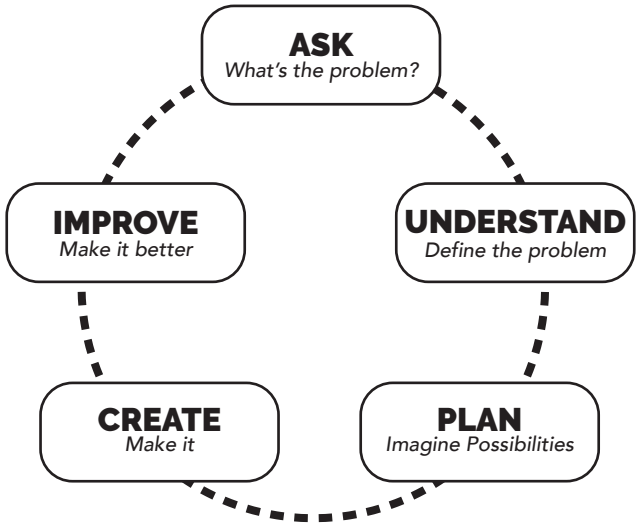
Engineering Design (ED) is a mindset and a process for problem-solving. The ED mindset encourages students to remain open to growth and improvement. The ED process guides students to define a problem, work toward a solution, and iteratively improve designs.

HOW TO USE THIS GUIDE

We hope that teachers will use this resource to:

1. **Understand** the process & mindset of ED;
2. **Identify** ED skills in students;
3. **Inform** ED curriculum & instruction.

THE ENGINEERING DESIGN PROCESS*



*Find a full sheet poster of the Engineering Design Process in our **Rapid Prototyping Activity.**

INCLUDED IN THIS GUIDE

ED GLOSSARY

This glossary defines ED skills, breaks them down into observable behaviors, and gives examples of ED in action with the Hummingbird Robotics Kit. Skills include Problem-Solving, Abstraction, and Algorithmic Thinking.

ED ASSESSMENT

Use this to record evidence of your students engaging in ED for portfolios, conferences, & conversations, and to inform ED curriculum & instruction.

ENGINEERING DESIGN GLOSSARY

SKILL 1: DEFINING THE PROBLEM (DP)	
DP1	**DEFINING THE PROBLEM**
	Definition: Identify criteria for success, constraints, and resource limits for a given problem.
	Example: A student is given an open-ended task to make a robot that encourages their peers to recycle cans. The student can determine how they will measure their robot's success at the task. They recognize the capabilities of materials they have available to them, and consider the time constraints.

SKILL 2: INTENTIONAL DESIGN (ID)	
ID1	**DELIBERATE PLANNING**
	Definition: Develop a complete plan for constructing and programming the intended robot based on the criteria and constraints. Then consider how to follow this plan before beginning construction and programming.
	Example: The student will sketch out designs, prototype ideas, make lists, and/or take notes—all before actually starting to build their robot.
ID2	**FOLLOWING A PLAN**
	Definition: Work to follow a design for creating a robot despite challenges, rather than changing plans haphazardly while building.
	Example: A student starts with a plan to build a rabbit that stands on its rear legs, but then discovers that the rabbit falls over when the servos move. A student who does not stick to the plan may decide, "Now I'm building a rabbit that is lying down" without having a desire to understand whether they really can get the rabbit to stay standing up. A student who follows the plan will consider the cause of the problem and address it by modifying their robot so that the final rabbit matches their planned standing design.

ENGINEERING DESIGN GLOSSARY

SKILL 3: INNOVATING (IN)	
IN1	**GENERATING MULTIPLE SOLUTIONS**
	Definition: Brainstorm multiple possible solutions for each challenge or need instead of just beginning to create the first solution that comes to mind.
	Example: The student might sketch three different ways of attaching a cardboard arm to a servo. This skill can also be applied when facing a new problem discovered during the creation of a robot. When an initial design is ineffective, the student considers multiple improvements before proceeding.
IN2	**SOLUTION EVALUATION**
	Definition: Carefully consider the strengths and weaknesses of multiple potential solutions and describe the reason for making a choice. Use success criteria, and project & resource constraints to select the best solution.
	Example: The student considers two ways to have their robot express emotions: The student could use servos to control the shape of the robot's mouth or they could use tri-color LEDs to make the eyes a color symbolic of the emotion. The student considers that the mouth movements would be too challenging to implement in the remaining project time, while the tri-color eyes will be able to be completed quickly and will still meet the emotion expression criteria, so they choose to use the tri-color LEDs.
IN3	**"OUTSIDE THE BOX" THINKING**
	Definition: Come up with possibly risky, but novel solutions to problems. These solutions might incorporate innovative uses of materials, creative mechanisms, or a solution unlike any examples shown in class.
	Example: The student is constructing a robot that needs to hold a very large sign. The student develops a solution with a helium balloon connected to the sign, allowing the robot to lift the sign with very little force. This is very unconventional thinking and shows "out of the box" design ability.

ENGINEERING DESIGN GLOSSARY

	SKILL 4: REFINING AND TESTING (RT)
RT1	**TRADE-OFFS CONSIDERATION**
	Definition: Recognize when important goals of the robot are at risk of not being accomplished due to resource limitations. Reduce or eliminate low priority features to reach high priority goals.
	Example: The student is making a storytelling humanoid robot, and they would like to have it walk across the table. After some design work, the student realizes that the walking goal is much harder to achieve than the primary storytelling goal, and so decides to spend their remaining time making a better stationary storytelling robot. (Notice that this thoughtful process and decision is different from a student who gives up on the walking goal because they found it difficult without weighing the impact of that decision).
RT2	**SYSTEMATIC DIAGNOSIS**
	Definition: Utilize a methodical process of elimination to determine the source of a problem.
	Example: A student with a robot that falls over when the arms move will carefully consider why it is falling and perform a series of tests to determine the issue. The student determines that the robot shifts its weight too far forward in certain poses and makes a wedge to put under the robot to shift the center of gravity so that it stops falling over. (Note: Students who do NOT use diagnosis may change multiple variables at once, try to fix problems through arbitrary modifications, or try to work around the problem by modifying success criteria).
RT3	**THOROUGH TESTING**
	Definition: Carefully test each part of the robot or program, in addition to the whole system, and compare test results to the success criteria.
	Example: A student is building a ball-throwing robot. While building they test whether the robot arm can hold the ball at all and make refinements until it is able to do so. Later, when testing the completed robot, the student repeatedly measures how far the ball is thrown with multiple trials to confirm that the robot reliably meets their final criteria for success.

ENGINEERING DESIGN GLOSSARY

SKILL 5: PROTOTYPING (PR)	
PR1	**DESIGN FOR CONSTRUCTION**
	Definition: During design and construction, carefully consider how each part will be constructed. Consider the strengths and weaknesses of available materials to avoid potential issues. Also, consider the tools available to construct the robot and will plan for how those tools will be used.
	Example: The student is building a robotic drawbridge model and recognizes that the cardboard for the bridge bends easily. In their design, the student includes a brace underneath the bridge surface to correct that material weakness. The student also designs the bridge structure such that there are no tight spaces where the glue gun cannot reach, and designs doors into the robot so that it is easy to reach the Hummingbird board to wire the robotic components.
PR2	**MAKING IT REAL**
	Definition: Take an idea and create a physical model or prototype which accurately reflects the original idea. The model is carefully crafted, constructed with attention to detail, and successfully meets the initial design criteria.
	Example: A student envisions the construction of robotic model of a tree. The student approaches this task with great attention to detail, first selecting a specific tree species and researching the proper leaf shape of that species. The student then selects the appropriate materials for replicating those features given the resources available, and carefully constructs the tree. In the end, they are satisfied that the robotic tree model successfully matched the design idea as they envisioned it.

SKILL 6: COMMUNICATING DESIGN (CD)	
CD1	**CLEAR COMMUNICATION OF DESIGNS**
	Definition: Clearly communicate design ideas to teammates, teachers, and others.
	Example: A student has an idea for an elaborate string-pulley mechanism to move a component on their robot, and the student is able to explain the mechanism through sketches, diagrams, and words to accurately and precisely convey the idea to the student's teammates.

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CODE	DESCRIPTION OF SKILL	OBSERVATIONS
DP1	**Defining the Problem:** Does the student identify criteria for success, constraints, and resource limits for a given problem?	
ID1	**Deliberate Planning:** Does the student develop a complete plan before she begins construction?	
ID3	**Following a Plan:** Does the student make a plan and follow it despite challenges, rather than changing plans haphazardly while building?	
IN1	**Generating Multiple Solutions:** Does the student generate multiple design solutions before implementation?	
IN2	**Solution Evaluation:** Does the student carefully consider the strengths and weaknesses of potential solutions against project constraints and success criteria before selecting a solution?	
IN3	**"Outside the Box" Thinking:** Does the student generate risky, innovative, or novel solutions to problems?	
RT1	**Trade-Offs Considerations:** Does the student prioritize goals and reduce features of lower importance in order to achieve more critical goals?	
RT2	**Systematic Diagnosis:** Does the student utilize a methodical process of elimination to determine the source of a problem?	
RT3	**Thorough Testing:** Does the student carefully test the functionality of each component of the robot and program against the goal?	

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CODE	DESCRIPTION OF SKILL	OBSERVATIONS
PR1	**Design for Construction:** Does the student carefully plan how each component will be constructed, taking strengths and weaknesses of materials into consideration?	
PR2	**Making It Real:** Does the student take an idea and create a carefully crafted and elegantly executed physical model which accurately reflects the original idea?	
CD1	**Clear Communication of Ideas:** Does the student clearly communicate her design ideas to teammates, teachers, and others?	

To put Engineering Design into action, use our **Rapid Prototyping Activity!**

Adapted from the "Arts and Bots Talent Definitions" from
Cross, J., Hamner, E., Zito, L., & Nourbakhsh, I. (2016, October). Engineering and computational thinking talent in middle school students: a framework for defining and recognizing student affinities. In Frontiers in Education Conference (FIE), 2016 IEEE (pp. 1-9). doi: 10.1109/FIE.2016.7757720