**Gear Up Design Journal Overview and Facilitation Guide:**

**Introduction:**

We are Gatorbotics, a high school robotics team from Castilleja School in Palo Alto, California. As a girls team operating in the male dominated field of engineering, we fully understand the importance of diversifying the rapidly growing world of STEM. As a historically strong robotics program, we feel it is our responsibility to share our love for STEM with as many younger students as possible. We launched our Gear Up! movement in 2019 to create an accessible, low-cost robotics curriculum that we then taught to students who are involved with our community partner organizations. While "gearing up" refers to increasing speed in engineering, it also means to prepare for one's future. Our team believes that having a fundamental understanding of computer science and mechanical engineering is critical, especially with the advent of new technology in the decades to come. Beyond just engineering tools, we believe taking students through the entire design process provides them with foundational life skills such as interviewing and being interviewed, giving and receiving feedback, problem solving, presentational/public speaking skills, and empathy. Simply put, our curriculum gives students basic engineering tools and life skills in a self-contained, low resource/cost structure which empowers them to design solutions for challenges they identify in their own communities.

Website: gatorbotics.org

**Program Overview:**

Our curriculum is summarized in our publicly available Design Journals. The structure of the Design Journal project is simple: students interview a partner, identify a challenge their partner faces, brainstorm solutions for the challenge they identified, build a prototype of one design, and finally present their solution. The journal serves as an interactive workbook throughout the duration of the project, with instructions explaining each step and space for student work. The original program was designed to take around 10-12 hours (10 sessions of 1 hour each); however, it can easily be altered depending on time and resource constraints (see the facilitator's guide for more details regarding program specifics).

**Facilitator's guide:**

Each student should have their own Design Journal; they can write their names on the line provided (where it says "________'s Design Journal") and often enjoy decorating the cover. The students should work through the same journal over the course of the project.

The journals were designed to be mostly self-contained; facilitators can choose how much to explain or introduce to students separate from the journals. We have included notes and recommendations for each section of the journal below, but it is ultimately up to the facilitator's discretion what to present and how much the students explore on their own.

**Picking a Journal:**

There are four different design journals available. The first journal covers the interview stage, design + prototyping, electronics, CAD, and presenting. The second journal covers everything the first does except CAD. The third journal covers everything the second journal does, except motors and motion. Finally, the fourth journal covers the third journal, except LEDs and electricity. All four journals are valuable to students. Facilitators should pick the journal that best aligns with their time constraints and materials available. It is worth noting that the expected times are loose estimates, older students or smaller groups will likely move quicker, and the time provided for prototyping can vary widely depending on student speed and interest.

| Time (all loose estimates which can vary widely) | Materials | Journal Name |
| --- | --- | --- |
| 10 - 12 hours | ● Design Journals<br>● Pencils<br>● Prototyping materials<br>○ Cardboard<br>○ Duct tape<br>○ Recyclable materials<br>○ Craft supplies, etc (see prototyping page notes)<br>● Electronics Materials<br>○ Small LEDs (link or similar)<br>○ Copper tape (link or similar)<br>○ Cell batteries (link or similar)<br>● Access to Ipads, computers, or similar device for CAD<br>● Optional<br>○ Small DC motors (link or similar) | Gear Up! Design Journal 1 |
| 8 - 10 hours | ● Design Journals<br>● Pencils<br>● Prototyping materials<br>○ Cardboard<br>○ Duct tape<br>○ Recyclable materials<br>○ Craft supplies, etc (see prototyping page notes)<br>● Electronics Materials<br>○ Small LEDs (link or similar)<br>○ Copper tape (link or similar)<br>○ Cell batteries (link or similar)<br>● Optional<br>○ Small DC motors (link or similar) | Gear Up! Design Journal 2 |
| 7 - 9 hours | ● Design Journals<br>● Pencils<br>● Prototyping materials<br>○ Cardboard<br>○ Duct tape<br>○ Recyclable materials<br>○ Craft supplies, etc (see prototyping page notes)<br>● Electronics Materials<br>○ Small LEDs (link or similar) | Gear Up! Design Journal 3 |

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| | ○ Copper tape (link or similar)<br>○ Cell batteries (link or similar) | |
| 6 - 8 hours | ● Design Journals<br>● Pencils<br>● Prototyping materials<br>○ Cardboard<br>○ Duct tape<br>○ Recyclable materials<br>○ Craft supplies, etc (see prototyping page notes) | Gear Up! Design Journal 4 |

**Journal guide:**

We have included notes and recommendations for each section of the journal below. It is not required to follow the guide, facilitators should present however they wish; however we do believe reading over the notes may be helpful. The guide includes notes for every page of the original journal. For facilitators running shortened programs, you can skip the irrelevant pages.

| Page Number | Title | Notes |
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| 1 | Cover page | Students should write their names and can decorate the front with markers, stickers, pens, pencils, etc. if time allows. |
| 2 | The Game Plan | This page is a great way to introduce students to the project; explain that they will be designing and prototyping their own robots to solve a challenge. |
| 3 | Step 1: Understand | Often the hardest part of this project for students is to transition from wanting to build a really cool robot with little to no function or practical application to designing a robot for a **specific purpose.** This is the time to explain to students the importance of understanding what the challenge is *before* designing a solution, as opposed to presenting a solution to a problem that may not exist.<br><br>It's important to ensure students understand that we can make *no assumptions* about what problems exist, we need to actually ask people about their lives in order to understand what challenges they face. Ask students to brainstorm questions they could ask to understand someone's life and challenges.<br><br>Example questions to offer:<br>● What is your favorite/least favorite part of the day?<br>● When are you the happiest?<br>● When do you get stressed or upset? |
| 4, 5 | Interviewing! | Students can either find a partner in class to interview and design |

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<tr><td></td><td></td><td>for, or they can interview someone at home for homework. Either way, they should ask at least 4 questions and follow up questions to get a sense of their partner’s daily life and any challenges they may face.</td></tr>
<tr><td>6</td><td>Let’s Synthesize!</td><td>Students should reflect on their interviews and identify one thing their interviewee loves and one challenge that they face. It may be a little difficult for some students to identify a challenge, in which case you may have to provide some examples. The challenge does not have to be too serious, but it should be relevant to the interviewee’s life.<br><br>Example challenges:<ul><li>Having to do laundry or other chores</li><li>Being unable to transport/travel easily or efficiently</li><li>Difficulty completing daily tasks</li></ul>Students should also try and figure out why the challenge is important to the interviewee. If they are struggling with this, ask them to consider how their lives may be different if they didn’t face this challenge.<br><br>Example:<ul><li>One challenge Sam faces is having to do laundry (or other chores). This is important to her because it takes her away from homework and spending time with family.</li></ul>Finally, finding out who else may be affected by this challenge pushes students to consider wider perspectives. This question is often the most challenging for them. If they are struggling, you can ask them to consider who else may face similar challenges (example 1) or who else is affected by this one person’s challenge (example 2).<br><br>Examples:<ul><li>Sam’s friends may also have the same problem of laundry/other chores taking time away from important things and people.</li><li>Because Sam spends time doing laundry, she gets to spend less time with her family, which makes them sad.</li></ul></td></tr>
<tr><td>7</td><td>Step 2: Brainstorm</td><td>Here’s a good place to introduce the concept of brainstorming, or coming up with as many ideas as possible. Ask students to come up with solutions they could build to the challenge they identified earlier and sketch them in the boxes provided. If “solution” is too vague for them to understand, you could use the words “robot” or “machine” to describe what they will be drawing.</td></tr>
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| | | Remind the students that their sketches do not have to be perfect or complete, and they should just draw whatever comes to mind. It can be helpful to time them, giving them about 2-3 minutes per sketch, to prevent students from spending all of their time on one idea. Ideally they come up with at least 5 distinguishable ideas. Also encourage them to label their sketches so they remember what each one is/does. |
| 8 | Feedback is fun! | Students should pattern up and explain their three favorite ideas to their partner. Their partner should then give them specific feedback which they can record in their design journal.<br><br>It's helpful to explain to students why feedback is important, and also help them understand what good feedback looks like. Challenge them to go beyond "I like it!" or "that's cool!" and provide specific recommendations for improving the designs.<br><br>Example specific feedback:<br>● It'd be cool if your robot was on wheels to follow you around.<br>● What if, in addition to cleaning the floors, your robot could climb walls and clean windows as well? |
| 9 | Design away! | Encourage students to incorporate the feedback they received and choose a final design. Their final sketch can be different from their original design; they can even combine parts of their favorite initial sketches into one design.<br><br>Students should also name their final design (names can be fun or descriptive, as long as the student is happy). |
| 10 | What's your vision? | After designing, it is helpful for students to be reminded of who they are designing for and why. It's easy to lose sight of the ultimate beneficiary, so having students write a need statement helps bring their original interviewee and their challenge back into focus. |
| 11 | Step 3: Prototype! | This is typically lots of fun for the students; they love seeing their ideas come to life! A few things to remind them of before building:<br>1) Introduce the idea of prototypes! It's helpful to think of them like "practice builds" that are smaller, simpler, and lower cost than the actual product. Introduce the benefits of prototyping as well: being able to test out the robots before building them avoids costly mistakes.<br>2) They should PLAN before they build. Ask them to list the features that they want and how they will accomplish them in the design journal. This prevents students from getting ahead of themselves and wasting time on unnecessary aspects. |

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| | | 3) They should build small so that everyone can use the available materials.<br><br>It's helpful to provide them with a variety of materials, especially cardboard!<br><br>Material suggestions:<br>● Cardboard (must have!)<br>○ Students will likely make the majority of their robot out of cardboard<br>● Duct tape<br>○ Lots of duct tape will be helpful as it will likely be the most popular adhesive<br>○ Other adhesive suggestions: hot glue, double sided tape, or glue sticks.<br>● Brads or cardboard connectors<br>○ These are great for connecting wheels to the base of robots. If you punch them in the center of the wheel and through the robot, the wheel will be able to spin!<br>● Popsicle sticks<br>● Assorted recyclable materials<br>○ Toilet paper or paper towel rolls, empty yogurt containers, egg cartons, etc.<br>● String<br>● Straws<br>● Scissors<br>○ Scissors are very important! Students will likely use them to cut cardboard, tape, string, and many other materials. Do not forget the scissors!<br>● Cardboard cutters<br>○ Cardboard cutters are helpful to cut curves in cardboard, but are not necessary if they are not accessible. Exacto knives would also work similarly. |
| 12, 13 | Doodle Page | Extra space for sketching designs, planning, or just drawing for fun! |
| 14 | Prototype Reflections | Introducing the idea of reflecting on your prototype is helpful at this stage. Ask them to identify one thing that went well with their prototype and one thing that could've gone better with their prototype. If they are struggling to answer the last questions regarding what they would change about their prototype, it may be helpful to reframe as "what would you like to add to your prototype?" or "what does the next version look like?"<br><br>Note: Students do not need to be "done" with their prototype for reflections to be valuable. |

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| 15 | Intro to Electronics | Introducing electronics is very fun because students can understand how to transition from a cardboard design to a robot which can move on its own.<br><br>Depending on the age of the students, you will want to vary how deep you go into understanding electronics. For students new to electronics, you can talk about “loops” (circuits) where energy can flow from a battery (energy source) to a lightbulb (the load) and back to the battery, allowing the lightbulb to turn on. You will likely also want to discuss positive and negative charges. |
| 16,17 | Light up your world | It’s easy to transition right from discussing simple circuits to exploring LEDs (light emitting diodes). Explain how the positive side of the battery should connect to the longer leg of the LED and the negative side of the battery should connect to the shorter leg of the LED. Charge will then run through the circuit and turn on the LED. Students can also discuss simple on/off switches by connecting and disconnecting conductors in a circuit.<br><br>Have students sketch where they would put an LED on their robot. It’s also important for them to recognize that beyond just being fun, lights should serve a purpose, even if the purpose is just to signal when the machine is on. Ask students to add in the rest of the circuit to their sketch. Where would the batteries go and how would they wire it? Where would the switch be?<br><br>If you have access to LEDs, copper tape, and batteries, I highly suggest you let students add the LED onto their prototype. They love watching their robot come to life! Materials for these simple circuits are typically inexpensive, averaging less than a dollar per person. See “Picking a journal” section for more information regarding materials and examples |
| 18,19 | Designing for motion | Connecting onto the intro to electricity, you can explain how motors get connected into a circuit just like lightbulbs.<br><br>Another important feature to discuss is directional movement. Motors can only spin, they can’t move forward and backwards, but what if you want your robot to be able to drive around like a car? Introduce the idea of rotational movement (motors) vs linear movement (cars) and how we transfer between the two using wheels. It can be fun to have students act this out by having them spin in place (rotation movement) and roll on the floor (linear movement) if you have the space.<br><br>On the following page have students draw arrows in all of the directions they want their robots to move. Also include smaller parts like arms or other mechanisms if they move as well. In the second box ask them to draw the design with the motors everywhere they want movement. They should include a battery |

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| | | and wires in their drawing, making sure to connect the circuit.<br><br>If you have extra time and resources, students can explore connecting small DC motors like these, although that is not necessary. |
| 20 | Let's get digital! | Computer Aided Design, also called CAD, has become one of the most useful tools for engineers in the past few years. CAD software allows engineers to build and prototype their designs digitally. More information about CAD can be found here.<br><br>Introducing CAD and letting students explore can be very fun, and it can give them a chance to practice using a real-world engineering tool. TinkerCAD is a free, simplified, easy to use CAD software. If you have access to laptops, students can use the web browser format, or if students have access to iPads or tablets, there is a free TinkerCAD app available.<br><br>If students have access to either form of TinkerCAD, giving them time to learn how to use the program is important. The following introductory videos and tutorials can be helpful:<br>● TinkerCAD intro video<br>● TinkerCAD Snowman tutorial (students can follow along)<br>● TinkerCAD Jet tutorial (students can follow along)<br>Allowing students to design one project by following a tutorial gives them better control over the software and they tend to be more successful when designing their own creations.<br><br>After students have gotten comfortable with TinkerCAD basics, they can CAD their own robots. It can be very exciting for them to see their own design in a digital format. |

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<td>Step 4: Share!</td>
<td>One of the most important parts of this process is teaching students how to meaningfully share their ideas. Ideally, they have a chance to prepare and present a serious presentation of their process to a group. The presentation teaches students how to effectively communicate their complicated designs, while also giving them a chance to practice public speaking.<br><br>First, it’s important to explain to students why presenting their solutions is important. Remind them that they designed a robot to help someone, and it is difficult to help someone when they do not know a solution exists to their challenge. Ask students to list people who may benefit from their design in their journals to help them remember why their robot is important.<br><br>Next, they should focus on designing a presentation. A few important things to emphasize to students before they begin preparing presentations:<br>● They should focus on telling a story: Who did they design for? What was their challenge? How did they solve the challenge?<br>● They should explain their design in detail, describing all of the functions<br>● Images and visual aids are hugely helpful for engaging your audience. Students should show their prototypes, CAD (if applicable), early sketches, etc.<br><br>Presentations can occur in different forms. If students have access to computers or other similar technology, they could design a slide deck to present with, including bullet points and pictures. If students have the time and materials, they could create a poster with information about their robot and design process. The simplest presentation could just be students standing in front of the group with their prototypes explaining what they have accomplished. All three presentation forms are valuable, and students should be given time to prepare and practice for each one.<br><br>The last robotics session could involve all students presenting their robots to the class using the presentation worksheet in the journal. Encourage other students to ask questions, too!</td>
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