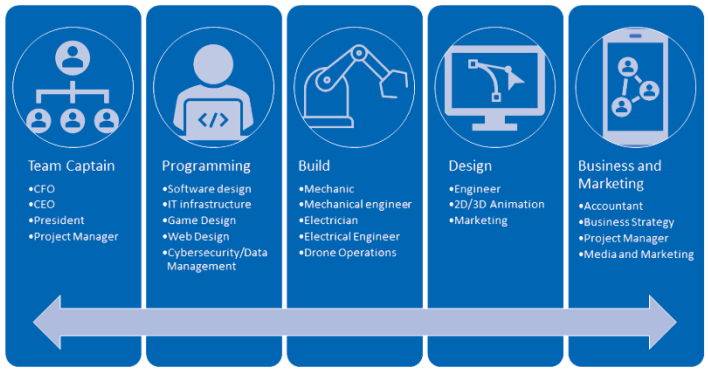
FIRST® Tech Challenge Work-Based Learning or Independent Learning Toolkit



FIRST® is More Than Robots®. "We are not using kids to build robots. We are using robots to build kids." *FIRST* Founder Dean Kamen

The mission of *FIRST* is to inspire young people to be science and technology leaders and innovators, by engaging them in exciting mentor-based programs that build science, technology, engineering, and math (STEM) skills, inspire innovation, and foster well-rounded life capabilities including self-confidence, communication, and leadership.

Many *FIRST* ® Tech Challenge team members have various roles that help the team progress and improve. Utilizing a system where students can progress in their skills while helping their team can increase team engagement and help students find their future career path.

Using this Toolkit, you can help your *FIRST* ® Tech Challenge students achieve their goals by:

- Building competencies with introductory skills to advanced skills that work towards jobs and industry certifications
- Integrating work-based learning through job roles on a team where skill development results in increased technical skills and teamwork creating more impact for your team
- Using industry technology and experts that provide experiences to students of projects they see in future industries.
- Providing pathways for students to explore their career interests by defining their own learning goals and steps to accomplish those goals.

This guide is a progression of skill learning in the different team roles you might find on a *FIRST*® Tech Challenge team. Many of these roles can help students gain work-based learning skills along with pursuing industry certifications. Some skills may be replicated in multiple job roles and students may end up completing skills in multiple different roles. The tools for student progression of skills are a menu of options and not necessarily a prescriptive program.

In each area, you will find resources and ideas for students to apply their learning to develop skills utilizing the *FIRST* resources and some third-party resources. They can assist teachers, coaches, and mentors to guide students to continue skill development, whether they are building a robot for competition or working with a mentor to gain industry skills.

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FIRST® Core Values and CTE Career-Ready Practices

The *FIRST* Core Values emphasize friendly sportsmanship, respect for the contributions of others, teamwork, learning, and community involvement and are part of our commitment to fostering, cultivating, and preserving a culture of equity, diversity, and inclusion.
The *FIRST* Community expresses the *FIRST* philosophies of *Gracious Professionalism*® and *Coopertition*® through our Core Values:

- **Discovery:** *We explore new skills and ideas.*
- **Innovation:** *We use creativity and persistence to solve problems.*
- **Impact:** *We apply what we learn to improve our world.*
- **Inclusion:** *We respect each other and embrace our differences.*
- **Teamwork:** *We are stronger when we work together.*
- **Fun:** *We enjoy and celebrate what we do!*

If we compare the Career Technical Education (CTE) Career-Ready Practices as defined by Advance CTE, many of their Career-Ready Practices apply to these Core Values of *FIRST*:

CRP-1 Showing responsibility through *Gracious Professionalism*
CRP-2 Applying interpersonal communication skills
CRP-3 Using inclusion during teamwork
CRP-4 Demonstrating creativity and innovation
CRP-5 Considering impact of decisions
CRP-6 Critical thinking and perseverance
CRP-7 Modeling integrity, leadership, and time management
CRP-8 Using technology to enhance productivity
CRP- 9 Considering personal health and well-being
CRP-10 Applying academic and technical skills

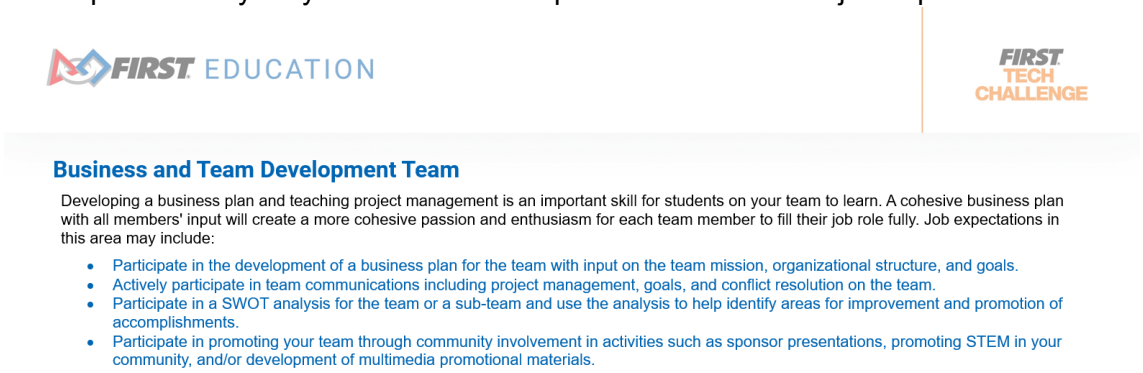
Students develop Career-Ready Practices by applying *FIRST*'s Core Values on their team and how they identify themselves as contributors within a workplace environment. The job roles available to team members span the following Career Clusters aligned to the Common Career Technical Core Clusters:

a. Business Management and Administration,
b. Manufacturing,
c. Science, Technology, Engineering & Mathematics,
d. Marketing
e. Informational Technology.

How to Use This Toolkit

Effective work-based learning opportunities involve alignment of classroom and workplace learning, application of academic, technical, and employability skills in a work setting, and support from classroom or workplace mentors. This guide contains tools to help a teacher or a student use their *FIRST* experience as a work-based learning credit. Credit availability should be determined by the school they are hoping to acquire credit through and requirements for each district can vary. After the process for credit is defined:

1. Students should review the job role clusters and identify which ones they would like to develop additional skills in.
2. Identify the job expectations they would like to focus on. Use the following example. A student might be focused on business and team development. They may choose the bullet points in blue as their job expectations.


FIRST EDUCATION
FIRST TECH CHALLENGE

Business and Team Development Team

Developing a business plan and teaching project management is an important skill for students on your team to learn. A cohesive business plan with all members' input will create a more cohesive passion and enthusiasm for each team member to fill their job role fully. Job expectations in this area may include:

- Participate in the development of a business plan for the team with input on the team mission, organizational structure, and goals.
- Actively participate in team communications including project management, goals, and conflict resolution on the team.
- Participate in a SWOT analysis for the team or a sub-team and use the analysis to help identify areas for improvement and promotion of accomplishments.
- Participate in promoting your team through community involvement in activities such as sponsor presentations, promoting STEM in your community, and/or development of multimedia promotional materials.

3. Identify the Career Ready Practices based upon the Common Career Technical Core they would focus on in their job role.
4. Mentors or teachers can use the possible learning activities within this guide or describe their own.
5. Fill out the training agreement found on page 34 of this guide.
6. Mentors evaluate their performance and evidence (Observed or Portfolio) on meeting the criteria using the following rating criteria:
    a. 4- **Highly Skilled**- student can teach others about the task
    b. 3 – **Skilled:** student can perform the standard independently as a team lead
    c. 2 – **Moderately skilled:** student can perform task with assistance from mentors or team captain
    d. 1 – **Introduced**: student was taught the skill from a team lead or mentor
    e. N – **No exposure**: student has no experience or knowledge of this task
    f. O – **Observed**
    g. P – **Portfolio**
7. Students complete a reflection and build a portfolio of their accomplishments in their job role.

Business and Team Development

Developing a business plan and teaching project management is an important skill for students on your team to learn. A cohesive business plan with all members' input will create a more cohesive passion and enthusiasm for each team member to fill their job role fully. Job expectations in this area may include:

- Participate in the development of a business plan for the team with input on the team mission, organizational structure, and goals.
- Actively participate in team communications including project management, goals, and conflict resolution on the team.
- Participate in a SWOT analysis for the team or a sub-team and use the analysis to help identify areas for improvement and promotion of accomplishments.
- Participate in promoting your team through community involvement in activities such as sponsor presentations, promoting STEM in your community, and/or development of multimedia promotional materials.

Mentor Performance Rating

4 – **Highly Skilled**- student can teach others about the task
3 – **Skilled:** student can perform the standard independently as a team lead
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Career Cluster

Business Management and Administration

Industry Certifications

Tableau Desktop Specialist Certification
Google Analytics Individual Qualification

Standard	Description	Mentor Performance Rating	Business and Team Development Possible Learning Opportunity
BM-MGT 7.3	Develop business plans to meet company needs.		Team Business Plan Team Organization Describe the nature and types of business organizations to build an understanding of the scope of organizations. If your team does not have a business plan, create an initial draft of that plan. These are your initial thoughts. Then use the remaining resources in this section to continue to improve that plan and create goals for improvement.
BM-MGT 7.4	Plan for future company growth to guide company operations.		
BM-MGT 7.5	Design organizational structure to facilitate business activities.		
BM-MGT 8.1	Develop and implement strategic plan.		
BM-MGT 8.2	Analyze strategic plans.		
BM-HR 5.13	Contribute to organizational development to change the beliefs, attitudes, values, and structure of organizations so that they can better adapt to new technologies, markets and challenges.		
BM-HR 7.1	Implement strategic planning processes to guide human resources management decision-making.		

Standard	Description	Mentor Performance Rating	Business and Team Development Possible Learning Opportunity
BM-HR 7.2	Evaluate organization's strategic planning and policy-making processes to guide decision-making.		
BM-BIM 1.1	Apply knowledge of business contracts to establish business relationships.		Fundraising Toolkit Budget Understand tools, strategies, and systems used to maintain, monitor, control, and plan the use of financial resources. Use the fundraising toolkit to develop a team budget and sponsor recruitment to ensure financial sustainability of your team. Create a budget and write sponsorship letters to acquire needed funding.
BM-ADM 2.5	Select document type and layout to produce business letters.		
BM-ADM 2.6	Select appropriate writing method to produce a variety of reports.		
BM-BIM 2.3	Implement suitable internal accounting controls to ensure the proper recording of financial transactions		
BM-MGT 5.1	Manage business risks to protect a business's finances.		
BM-MGT 5.2	Manage financial resources to ensure solvency		
BM-HR 2.1	Communicate with staff to clarify workplace expectations and benefits.		Mentor Manual Explore from the experts on best practices and details of effective team management. Use the video to help develop a goal for team management considering team building, communication, and conflict management.
BM-HR 3.1	Model behaviors and actions to effectively motivate and lead people.		
BM-HR 3.2	Model behaviors and actions to effectively motivate and lead change.		
BM-HR 3.3	Model behaviors and actions to effectively motivate and promote the use of teamwork in the workplace.		
BM 4.2	Utilize technology to facilitate customer relationship management and workplace communication		The Power of The *FIRST* Community Award Descriptions Explore the resources to develop strategies for your team to connect and motivate others to learn more about STEM and *FIRST*. Conduct a team brainstorming session to create your own plan for how you might make an impact in your community and the *FIRST* Community. How might you increase documentation and create a presentation about your team?
BM 5.1	Explain the nature and scope of knowledge management practices within a business.		
BM 5.2	Use knowledge management strategies to improve the performance and competitive advantage of an organization.		
BM 6.1	Explain the nature and scope of quality management practices within a business.		
BM 6.2	Identify management principles utilize for continuous quality improvement.		
BM-ADM 2.1	Perform scheduling functions to facilitate on-time, prompt completion of work activities.		Award Descriptions Game and Season Explore the links to learn more about how you can apply and position your team for awards. Use the Award descriptions as well as the information about awards located in Game Manual 1.
BM-ADM 2.2	Manage business records to maintain needed documentation.		
BM-ADM 2.3	Prepare documentation of business activities to communicate with internal/external clients.		
BM-ADM 2.4	Utilize information technology tools to manage and perform work responsibilities.		
BM-ADM 2.6	Select appropriate writing method to produce a variety of reports.		

Standard	Description	Mentor Performance Rating	Business and Team Development Possible Learning Opportunity
			Conduct a team brainstorming session to develop goals for how you might improve practices to make your team more eligible for awards.
BM-MGT 7.4	Plan for future company growth to guide company operations.		Recruitment Explore the Recruitment tab on the website. Develop recruitment flyers and recruitment materials for your team.
BM-HR 5.2	Develop programs to assist in meeting needs of separated and transitional employees.		
BM-HR 5.4	Plan talent-acquisition activities to guide human resources management decision-making.		
BM-BIM 2.2	Manage risk to protect a business's well-being.		Tableau for Education Become a Tableau expert in no time and on your own schedule. Have students use Tableau for data entry techniques and apply them on your team and gain career skills. There are additional resources on how Tableau is used in *FIRST* Robotics Competition for scouting. These could also be applicable to *FIRST* Tech Challenge.
BM-BIM 3.1	Enhance usability of computer system operations.		
BM-BIM 3.2	Use database software to create databases that facilitate business decision-making.		
BM-BIM 3.3	Use data entry techniques to enter information in databases		
BM-BIM 3.4	Use commands to retrieve data and create reports from databases.		
BM-BIM 3.5	Apply data mining methods to acquire pertinent information for business decision-making.		
BM-BIM 3.7	Use technology to support business strategies and operations.		

Build Team Resources

Chassis and Drive System

Use these learning resources for building, design, and fabrication of the drive system. Utilize the guides to help you build a chassis then learn how to customize the chassis for your own criteria. Job expectations in this area may include:

- Follow proper safety procedures for tool use and fabrication.
- Assemble a chassis using guides provided or design your own with other vendor supplies.
- Apply tips and best practices to ensure proper tolerance and friction is minimized.
- Modify the design of a chassis to fit the game strategy.
- Create custom parts or a frame for the chassis using industry-standard fabrication processes including additive manufacturing, drilling, and cutting.
- Analyze how modifications to a chassis and robot manipulators affect the drive system.
- Analyze different types of drive systems and chassis requirements for each type.
- Design and build a custom drive system to achieve design criteria constraints.
- Repeat the design process for different types of drive systems.

Mentor Performance Rating

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Career Cluster

Manufacturing
Science, Technology, Engineering & Mathematics

Industry Certifications

OSHA Safety Certification

Standard	Description	Mentor Performance Rating	Chassis and Drive System Possible Learning Opportunity
ST 3.1	Apply appropriate safety and health practices when developing plans, projects, processes or solving complex problems.		UL Safety Learning Portal Safety Manual Learn important details about staying safe while working on and building your robot. *Safety Manual Training, Fire Extinguisher and Safety Awareness, Hand and Power Tool Safety Awareness, Hazard Communication – Safety Data Sheets, Personal Protective Equipment (PPE) Awareness, Recognizing Electrical Hazards Awareness, Lockout/Tagout Awareness, Hearing Conservation Awareness*
ST 3.2	Use appropriate safety techniques, equipment, and processes in planning and /or project applications.		
ST 3.3	Identify potential and existing hazards to plans, projects, or processes where safety, health, and environmental issues may be affected.		
ST-ET 1.1	Apply the core concepts of technology and recognize the relationships with STEM systems (e.g., systems, resources, criteria and constraints, optimization and trade-off, and controls).		Game and Season Robot Building Resources Each year you are introduced to a *FIRST* Tech Challenge Game. Building your robot to the game gives you unique criteria and constraints for a robot build. Developing the skills in building a robot can be accomplished by using build guides that help you achieve the season's challenge. Use the links above to choose a build guide that helps you meet the year's challenge to build a robot.
ST-ET 3.1	Use knowledge, techniques, skills and modern tools necessary for engineering practice.		
ST-ET 6.6	Apply and create appropriate models, concepts, and processes for an assigned situation, and apply the results to solving the problem.		
ST-SM 1.3	Use the skills and abilities in science and mathematics to integrate solutions related to technical or engineering activities using the content and concepts related to the situations.		
ST-SM 2.1	Demonstrate the ability to recognize cause and effect when faced with assigned projects or issues.		
ST 2.5	Apply a technological, scientific, or mathematical concept (use of algorithms) when communicating with others on issues, plans, processes, problems, or concepts.		Drivetrain Considerations Motor Considerations XYZ Design Brief As you improve your robot design, you will want to consider the technical aspects behind your design such as the maneuverability of the drivetrain and how your motors will perform. Use the resources above from REV to research distinct types of drivetrains and the performance of your motors in your drivetrain.
ST-ET 3.1	Use knowledge, techniques, skills, and modern tools necessary for engineering practice.		
ST-ET 3.4	Illustrate the ability to characterize a plan and identify the necessary engineering tools that will produce a technical solution when given a problem statement.		
ST-ET 5.2	Demonstrate the ability to evaluate a design or product and improve the design using testing, modeling, and research.		
ST-ET 6.1	Apply the use of algebraic, geometric, and trigonometric relationships, characteristics, and properties to solve problems.		

Standard	Description	Mentor Performance Rating	Chassis and Drive System Possible Learning Opportunity
ST-ET 5.1	Apply the design process using appropriate modeling and prototyping, testing, verification, and implementation techniques.		Legal and Illegal Parts All designs have design constraints. Utilize the resource above to ensure that you meet the design constraints of legal and illegal parts for your robot.
ST-ET 5.2	Demonstrate the ability to evaluate a design or product and improve the design using testing, modeling, and research.		
ST-ET 4.3	Describe design constraints, criteria, and trade-offs in regard to variety of conditions (e.g., technology, cost, safety, society, environment, time, human resources, manufacturability).		
MN 6.1	Demonstrate the planning and layout processes (e.g., designing, print reading, measuring) used in manufacturing.		3D Printing for *FIRST* Tech Challenge Design Software Look to add connectors, guards, or custom chassis parts that can occur with 3D Printing and CAD design.
MN 6.2	Summarize how materials can be processed using tools and machines.		
MN 6.3	Describe various types of assembling processes (e.g., mechanical fastening, mechanical force, joining, fusion bonding, adhesive bonding) used in manufacturing.		
MN 6.1	Demonstrate the planning and layout processes (e.g., designing, print reading, measuring) used in manufacturing.		CAD for Robotics and Manufacturing Learn about designing for 3D printing, laser cutting and manufacturing with this lesson from Onshape.
MN 6.2	Summarize how materials can be processed using tools and machines.		

Designing Manipulators

Designing manipulators requires understanding of how to best interact with game objects and fabricating the needed items to achieve that interaction. Job expectations in this area may include:

- Demonstrate quick prototyping techniques and data collection to make design decisions.
- Explore different types of manipulators used in robotics and weigh the pros and cons of each type of manipulator and its application to a game strategy.
- Safely perform industry standard fabrication processes including additive manufacturing, milling, drilling, cutting, and welding.
- Apply the fundamental physics of simple machines, gear ratios, sprockets, and belt design to design manipulators to achieve a game strategy.
- Analyze motor specifications and performance data to choose the best actuator for a design criterion including motors and pneumatics.
- Analyze an actuator's required electrical inputs and outputs and communicate performance needs to the programming team.
- Use analytical geometry and advanced physics concepts to refine and improve the design of a manipulator.

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Career Cluster
Manufacturing
Science, Technology, Engineering & Mathematics

Industry Certifications
SME Certified in Robotics Fundamentals
SME-Certified Manufacturing Associate

Standard	Description	Mentor Performance Rating	Designing Manipulators Possible Learning Opportunity
ST-ET 3.4	Illustrate the ability to characterize a plan and identify the necessary engineering tools that will produce a technical solution when given a problem statement.		Prototyping Intakes Lifts Delivery Shooter
ST-ET 4.2	Explain the elements and steps of the design process and tools or techniques that can be used for each step.		

Standard	Description	Mentor Performance Rating	Designing Manipulators Possible Learning Opportunity
ST-ET 5.1	Apply the design process using appropriate modeling and prototyping, testing, verification and implementation techniques.		Explore options for prototyping using the resources from REV Robotics. Notice how they start out with different designs and then test them. Use the ideas to create your own prototypes to achieve a goal from the current season or previous seasons.
ST-ET 5.2	Demonstrate the ability to evaluate a design or product and improve the design using testing, modeling and research.		
ST-ET 5.3	Demonstrate the ability to record and organize information and test data during design evaluation.		
ST-ET 6.1	Apply the use of algebraic, geometric, and trigonometric relationships, characteristics, and properties to solve problems.		*FIRST* @ Home Free and Flexible STEM Activities Sessions 4, 5, 6,10, 11, and 12 are a series of lessons where students build an escape room using principles of electricity, simple machines, gear ratios, and encryption which can all be transferred to building a robot. Have students complete the lessons and build manipulators for the escape room that could also be used on a robot.
ST-ET 6.2	Apply the process and concepts for science literacy relative to engineering and technology.		
ST-ET 6.3	Exhibit the ability to select, apply and convert systems of measurement to solve problems		
ST-ET 6.4	Apply basic laws and principles relevant to engineering and technology.		
ST-ET 6.6	Apply and create appropriate models, concepts, and processes for an assigned situation, and apply the results to solving the problem.		
ST 2.2	Use modeling, simulation, or visual reproduction to effectively analyze, create, and/or communicate to others regarding plans, projects, problems, issues, or processes.		REV Motors Planetary Gear System Understand how to choose suitable motors for your robot based on application, motor qualities, and specifications. You'll then learn the fundamentals for getting the most out of your selected motors by choosing the proper reductions and configurations. Have students use the REV site to understand the planetary gear system, then have them use the motor performance data to choose the suitable motor for a manipulator design.
ST 2.5	Apply a technological, scientific, or mathematical concept (use of algorithms) when communicating with others on issues, plans, processes, problems, or concepts.		
ST-ET 1.2	Develop the active use of information technology applications.		
ST-ET 1.3	Use computer applications to solve problems by creating and using algorithms, and through simulation and modeling techniques.		
ST-ET 3.2	Describe the elements of good engineering practice (e.g., understanding customer needs, planning requirements analysis, using appropriate engineering tools, prototyping, testing, evaluating and verifying).		
MN-MIR 4.1	Coordinate preparation for the installation, customization, or upgrading of equipment.		REV Duo Technical Resources Use the resources to understand how to transmit and transform motion.
MN-MIR 4.2	Obtain machine information from vendors related to proper installation, customization, or upgrade.		

Standard	Description	Mentor Performance Rating	Designing Manipulators Possible Learning Opportunity
MN-MIR 4.6	Test the equipment to ensure proper function after installation, customization, or upgrading.		As students learn about different methods for transmitting and transforming motion, have them prototype their own method with different materials that could be found at home or in the robotics lab.
MN-PPD 2.4	Set up and program equipment for new processes.		
MN-PPD 2.5	Schedule and test new processes.		
ST-ET 6.1	Apply the use of algebraic, geometric, and trigonometric relationships, characteristics and properties to solve problems.		MIT Simple Machine Geometry Use this MIT lesson on kinematics to design mechanisms. Have students use the simple machine geometry lesson to understand how to plan best spacing and execution of designing different manipulators.
ST-ET 6.2	Apply the process and concepts for science literacy relative to engineering and technology.		
ST-ET 6.3	Exhibit the ability to select, apply and convert systems of measurement to solve problems.		
ST-ET 6.4	Apply basic laws and principles relevant to engineering and technology.		
ST-ET 6.5	Explain relevant physical properties of materials used in engineering and technology.		
ST 2.2	Use modeling, simulation, or visual reproduction to effectively analyze, create, and/or communicate to others regarding plans, projects, problems, issues, or processes.		Robot Mechanisms by Siemens Explore the lessons designing mechanisms in CAD using SolidEdge on 4 Bar Mechanisms, Crank and Sliders, Scotch Yoke, Cam Mechanisms, and other types of advanced mechanisms with resources created by Siemens. Have students use the principles in the CAD tutorials to understand how different types of mechanisms are created.
ST 2.5	Apply a technological, scientific, or mathematical concept (use of algorithms) when communicating with others on issues, plans, processes, problems, or concepts.		
ST-ET 1.3	Use computer applications to solve problems by creating and using algorithms, and through simulation and modeling techniques.		
ST-ET 2.2	Read and create basic computer-aided engineering drawings.		
ST-ET 3.1	Use knowledge, techniques, skills and modern tools necessary for engineering practice.		
MN 6.1	Demonstrate the planning and layout processes (e.g., designing, print reading, measuring) used in manufacturing.		Game Manual O Manufacturing and Machining CAD for Robotics and Manufacturing Learn about designing for 3D printing, laser cutting, and manufacturing with these resources.
MN 6.2	Summarize how materials can be processed using tools and machines.		
MN 6.3	Describe various types of assembling processes (e.g., mechanical fastening, mechanical force, joining, fusion bonding, adhesive bonding) used in manufacturing.		

Electrical

Use these resources to develop electrical skills while building your *FIRST* Tech Challenge robot. Wiring the robot includes ensuring correct transmission of the electrical current as well as reducing communication loss through good wiring techniques. Job expectations in this area may include:

- Use the *FIRST* Tech Challenge Control system with industry connectors to complete the electrical path for the drive system, motors and sensors.
- Understand and ensure polarity transfer of electrical wire connections including PWM, 4-Pin JSTPH, and XT30 Power.
- Understand and design an electrical system that mitigates electrical discharge.
- Properly crimp, solder, and insulate connections to ensure electrical current transfer with the proper polarity.
- Understand needed electrical current input and output of sensors, motors, and servos.
- Analyze an electrical schematic from a manufacturer to identify how the electrical current is transferred in the circuit and properly identify common schematic symbols.
- Apply fundamentals of electronics including ohms, amps, resistors, and fuses.

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Career Cluster

Science, Technology, Engineering & Mathematics

Industry Certifications

SME Certified in Robotics Fundamentals
SME-Certified Manufacturing Associate
FESTO Industry 4.0

Standard	Description	Mentor Performance Rating	Electrical Possible Learning Opportunity
MN-MIR 3.4	Develop corrective action plan to fix the problem.		Benchtop Wiring Test Control System Videos Electrical foundations cover basic wiring and electrical tasks commonly performed by technicians on robotics systems. Develop skills to understand the wiring and configuration of motors, servos, and sensors.
ST-ET 6.4	Apply basic laws and principles relevant to engineering and technology.		
ST-ET 6.5	Explain relevant physical properties of materials used in engineering and technology.		
ST-SM 1.3	Use the skills and abilities in science and mathematics to integrate solutions related to technical or engineering activities using the content and concepts related to the situations.		
MN-MIR 3.1	Gather equipment information and history that can assist in identifying and diagnosing problems.		Wiring Best Practices Robot Wiring Video

Standard	Description	Mentor Performance Rating	Electrical Possible Learning Opportunity
MN-MIR 3.2	Isolate system and component failure following diagnostic procedures.		Robot Reliability Checklist Understand the importance of reducing vibration and shock on connections, increasing redundance, port savers, wire management, and strain relief. Have students analyze the current robot and determine if there are any areas where wiring best practices could be improved.
MN-MIR 3.3	Identify root cause of problem using diagnostic procedures.		
MN-MIR 3.4	Develop corrective action plan to fix the problem.		
MN-MIR 3.5	Execute corrective action plan.		
ST-ET 5.2:	Demonstrate the ability to evaluate a design or product and improve the design using testing, modeling and research.		Managing Electrostatic Discharge Effects Electrostatic discharge can cause communication failures on *FIRST* Tech Challenge Robots. Learn more about electrostatic discharge and ways to mitigate it. Analyze your robot design and improve electrostatic discharge mitigation. Design new parts with a 3D printer to improve wire management.
ST-ET 6.2	Apply the process and concepts for science literacy relative to engineering and technology		
ST-ET 6.4	Apply basic laws and principles relevant to engineering and technology.		
ST-ET 6.5	Explain relevant physical properties of materials used in engineering and technology.		
ST-ET 6.4	Apply basic laws and principles relevant to engineering and technology.		Motor Basis REV Understand brushless motor applications including power, torque, and performance. Have students apply data from the website and create a chart that allows them to better understand their motors and how to achieve the best performance of their motors.
ST-ET 6.5	Explain relevant physical properties of materials used in engineering and technology.		
ST 2.2	Use modeling, simulation, or visual reproduction to effectively analyze, create, and/or communicate to others regarding plans, projects, problems, issues, or processes.		
ST 2.5	Apply a technological, scientific, or mathematical concept (use of algorithms) when communicating with others on issues, plans, processes, problems, or concepts.		
ST-ET 1.3	Use computer applications to solve problems by creating and using algorithms, and through simulation and modeling techniques.		

Business and Marketing

Business and marketing tools can help you promote your team. Use the tools below to help your team develop a business and marketing plan and the materials needed to achieve that plan. Students can use other industry resources to further develop their skills in producing the materials. Job expectations in this area may include:

- Lead a SWOT analysis and use it to create a plan for communication, budgeting, and team goals.
- Based on the SWOT analysis, develop a communication plan for communicating with the sponsor's needs and benefits.
- Develop materials to communicate your team mission, organizational structure, and goals to team members and your community.
- Understand, apply, and develop team materials to communicate the best practices of what to do and not do during a sponsor presentation and maintain sponsor relations.
- Develop a communications plan for improving relationships with your *FIRST* community, current sponsors, mentors, future sponsors, and STEM advocacy in your community.
- Participate in the development of promotional materials using industry tools (graphic design, audio, video, and website development) to be used for award promotion from a sub-team (Promote Award, Scouting and Strategy, Media Publications, or Website)
- Use data analytics tools to develop materials to help communicate the team's goals for outreach, impact, and an action plan.
- Organize and develop presentation materials including scripts, letters, handouts, and media tools.

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Career Cluster

Marketing

Industry Certifications

Apple Certified Pro-Final Cut Level 1

Standard	Description	Mentor Performance Rating	Business and Marketing Activity	Possible Learning
MK 2.4	Determine needed resources for a new marketing project or business venture.		Fundraising Toolkit; Fundraising	Learn about Fundraising 101, Community Analysis, Team Documentation, Organizing Presentations, Maintaining Sponsor Relations, Fundraising Best Practices. As you work with each section, customize and develop a complete marketing and communications plan for your team.
MK 4.8	Explain marketing research activities to develop or revise marketing plan.			
MK 8.2	Generate product ideas to contribute to ongoing business success.			
MK 9.1	Acquire a foundational knowledge of promotion to understand its nature and scope.			
MK 10.4	Utilize marketing information to develop a marketing plan.			
MK 9.4	Discuss the use of public relations activities to communicate with targeted audiences.			
MK-COM 5.4	Explain the use of social media in marketing communications to obtain customer attention and/or to gain customer insight.		Using Social Media	Develop marketing materials using social media and incorporate digital literacy skills and copyright awareness in your materials.
MK-COM 1.5	Manage internal and external business relationships in marketing communications.			
MK-COM 3.5	Utilize information-technology tools to manage and perform marketing communications responsibilities.			
MK-COM 5.3	Use direct marketing strategies to attract attention and build brand.			
MK 9.6	Manage promotional activities to maximize return on promotional efforts.		Marketing Resources	Explore the marketing resources tab on the website. Consider the *FIRST* branding standards as well as your team brand as you develop your team logos and branding guide for your own team.
MK-COM 4.4	Position products/services to acquire desired business image.			
MK-COM 5.14	Utilize publicity to inform stakeholders of business activities.			
MK-COM 5.16	Employ sales promotions activities to inform or remind customers of business/product			
MK 9.4	Discuss the use of public relations activities to communicate with targeted audiences.		Team Awards	Explore the resources above to learn more about how you can apply and position your team for awards. Develop needed marketing materials for the awards, such as graphic design, audio, video, and website development.
MK 9.5	Explain the use of trade shows/expositions to communicate with targeted audiences.			
MK-COM 5.15	Utilize publicity/public-relations activities to create goodwill with stakeholders.			
MK-COM 5.2	Utilize word-of-mouth strategies to build brand and to promote products.			
MK-COM 3.5	Utilize information-technology tools to manage and perform marketing communications responsibilities.		Promote and Compass Awards	

MK 9.6	Manage promotional activities to maximize return on promotional efforts.		Use video production and marketing techniques to develop a Promote or Compass Award that can be used to promote your team.
MK-COM 4.4	Position products/services to acquire desired business image.		
MK 9.4	Discuss the use of public relations activities to communicate with targeted audiences.		
IT-WD 3.1	Prepare functional specifications.		Web Design and Communication Explore design and productivity courses through sources such as Apple or Adobe. Use the skills in the course to develop or produce a product for your team (Video, Website, or Published Document)
IT-WD 3.2	Prepare visual design specifications.		
IT-WD 3.3	Create final project plan.		
IT-WD 5.3	Employ basic motion graphic programming knowledge.		
IT-WD 5.4	Use basic web development skills.		

Control System and Programming

Programming through the control system on the robot is a fundamental part of competing successfully with your robot. It can take time and you might use different languages. The language you choose may depend on your mentor's experience and the career pathway you are considering as a student. Job expectations in this area may include:

- Understand and apply networking principles to establish robot configuration and communications between the driver's station and Control Hub.
- Utilize programming libraries, review libraries, source code, or game tools in the program.
- Develop different algorithms utilizing sensors for a robot in autonomous mode including encoders, IMU, and PID control.
- Utilize machine learning tools to develop data sets and enable the robot to perform functions based on those data sets.
- Understand how to measure bandwidth usage and conduct performance monitoring on the network.
- Transition from a graphics-based language like the Blocks Programming Tool to a text-based language like Java.
- Pursue courses in a specific program language to understand the language structure including concepts such as structure, handling variables, functions and files, debugging, data types, operators, objects and inheritance, control flow, arrays, strings, references, overloading, and exceptions.
- Create a training manual for your team on how you might utilize concepts such as structure, handling variables, functions and files, debugging, data types, operators, objects and inheritance, control flow, arrays, strings, references, overloading, and exceptions.

Mentor Performance Rating

4 – **Highly Skilled**- student can teach others about the task
3 – **Skilled:** student can perform the standard independently as a team lead
2 – **Moderately skilled:** student can perform task with assistance from mentors or team captain
1 – **Introduced:** student was taught the skill from a team lead or mentor
N – **No exposure:** student has no experience or knowledge of this task

Career Cluster

Information Technology

Industry Certifications

CompTIAITF+
CompTIAA+
CompTIANetwork
CompTIASecurity

Standard	Description	Mentor Performance Rating	Control System and Programming Possible Learning Activity
IT-SUP 2.1	Perform configuration management activities.		Blocks Programming Guide Control System Introduction
IT-SUP 2.2	Evaluate application software packages.		

Standard	Description	Mentor Performance Rating	Control System and Programming Possible Learning Activity
IT-SUP 3.1	Identify the purpose of computer components (e.g. current and new technologies as they arrive).		Use the resources above to configure and program your control system utilizing the integrated development environment with the *Blocks Programming Tool.*
IT-SUP 3.2	Demonstrate knowledge to build or install computer system.		
IT-SUP 3.3	Demonstrate ability to couple troubleshooting skills with hardware knowledge to solve client problems.		
IT-PRG 4.1	Employ tools in developing software applications.		Blocks Video Tutorials Computational Thinking Video Playlist Use the tutorials and playlist above using the *Blocks Programming Tool* to program a motor, servo, color sensor, or the IMU to advance your programming skills.
IT-PRG 4.3	Apply language-specific programming tools/techniques.		
IT-PRG 6.1	Explain programming language concepts.		
IT-PRG 6.3	Demonstrate proficiency in developing an application using an appropriate programming language.		
IT-SUP 3.1	Identify the purpose of computer components (e.g. current and new technologies as they arrive).		Computer Vision Overview Utilize the tools for machine learning to develop algorithms using Tensorflow utilizing built-in data sets. Expand your capabilities by building custom data sets with the Machine Learning Toolchain.
IT-PRG 4.1	Employ tools in developing software applications.		
IT-PRG 4.3	Apply language-specific programming tools/techniques.		
IT-PRG 3.2	Assess the potential importance and impact of new IT technologies and emerging classes of software.		
IT-SUP 3.1	Identify the purpose of computer components (e.g. current and new technologies as they arrive).		IMU Video; IMU Docs; IMU Initialization; IMU Move to Position; IMU Counter-clockwise IMU Clockwise; IMU Finish Maze With this series of resources, you can utilize sensors such as a gyroscope and accelerometer to improve navigation on your robot. The links above will help you learn more about the sensor to develop a program for your robot to complete a maze using the Blocks Programming Tool.
IT-PRG 4.1	Employ tools in developing software applications.		
IT-PRG 4.3	Apply language-specific programming tools/techniques.		
IT-PRG 3.2	Assess the potential importance and impact of new IT technologies and emerging classes of software.		
IT-PRG 5.2	Explain computing/networking hardware and software architecture.		Control System Troubleshooting Guide Understand your robot control systems' wireless connectivity and the factors that affect the ability of the wireless network to communicate effectively. Choose the best wireless network for your robot using a Wi-Fi channel analyzer.
IT-NET 3.1	Demonstrate knowledge of the basics of network architecture.		
IT-NET 3.2	Demonstrate knowledge of basic network classifications and topologies.		
IT-NET 3.5	Characterize network connectivity basis and transmission line applications.		
IT-PRG 6.1	Explain programming language concepts.		myBlocks; OnBot Java; OnBot Java Docs; External Libraries; Use the links above to learn how to create custom myBlocks in OnBot Java. Then utilize the OnBot Java tutorials and External
IT-PRG 6.4	Explain basic software systems implementation.		
IT-PRG 7.1	Develop a software test plan.		

Standard	Description	Mentor Performance Rating	Control System and Programming Possible Learning Activity
			libraries to build your own code classes utilizing object-oriented programming methods.
IT-PRG 4.1	Employ tools in developing software applications.		Github Tutorials Utilize the Github Tutorials to understand how to use repositories and version controls of the software development cycle.
IT-PRG 4.3	Apply language-specific programming tools/techniques.		
IT-PRG 3.2	Assess the potential importance and impact of new IT technologies and emerging classes of software.		
IT-PRG 5.2	Explain computing/networking hardware and software architecture.		
IT-PRG 6.1	Explain programming language concepts.		Code Academy; CS Awesome ;Jetbrains Use these sites to learn the fundamentals of Java. Choose four concepts you would like to develop and apply within your OnBot Java. Build your learning to take the AP Java CSA exam or other industry certifications.
IT-PRG 6.2	Summarize program development methodology.		
IT-PRG 6.3	Demonstrate proficiency in developing an application using an appropriate programming language.		
IT-PRG 6.4	Explain basic software systems implementation.		
IT-PRG 6.5	Develop software requirements/specifications.		
IT-PRG 6.6	Resolve problems with integration.		
IT-PRG 7.2	Perform testing and validation.		PID Control; Game Manual 0; Uses the resources above to learn more advanced techniques for programming your robot such as control loops, advanced state machines, and odometry.
IT-PRG 2.2	Define scope of work for the programming project.		
IT-PRG 3.2	Assess the potential importance and impact of new IT technologies and emerging classes of software.		
IT-PRG 7.1	Develop a software test plan.		
IT-PRG 7.2	Perform testing and validation.		

Design and Engineering

Designing and engineering a robot requires understanding mechanical engineering principles and using modeling programs to test ideas and determine the details of a final design. Use the available CAD programs from *FIRST* to advance your design skills. Each software program has tutorials to learn specific skills, so you can use the program that your school may have or a mentor is familiar with. Job expectations in this area may include:

- Understand what CAD is and how spatial reasoning is used to create 3D parts from geometry.
- Use sketches and features to construct and model geometric shapes including squares, rectangles, circles, and triangles. Then, convert them into geometric forms including cubes, spheres, cylinders, cones, rectangular prisms, and pyramids.
- Perform sketching elements including creation, dimensions, selection and creation, editing, and project edges.
- Create drawing views, base, projected, selection, and detail. Include annotations, dimensions, and a bill of materials.
- Model parts through actions including fillets, chamfers, complex holes, revolves, pattern features, construction planes, and axes.
- Use CAM software to create G-Code to manufacture a part through additive or subtractive manufacturing.
- Create and manage top-level assembly and subassemblies.
- Create a component from a body.
- Make assemblies with inferences, rigid groups.
- Conduct motion studies with parts.
- Apply mechanical and electrical engineering principles to a design. Perform motion analysis within parts and use data to make design decisions.

Mentor Performance Rating

3 – **Skilled:** student can perform the standard independently as a team lead
2 – **Moderately skilled:** student can perform task with assistance from mentors or team captain
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N – **No exposure**, student has no experience or knowledge of this task

Career Cluster

Science, Technology, Engineering & Mathematics

Industry Certifications

Autodesk Certified Associate
OnShape Certified Associate
Certified Solidworks Associate
3DExperience Solidworks Associate

Standard	Description	Mentor Performance Rating	Design and Engineering Possible Learning Activity
ST-ET 1.1	Apply the core concepts of technology and recognize the relationships with STEM systems (e.g., systems, resources, criteria and constraints, optimization and trade-off, and controls).		Design 101 Understand the fundamentals of design around a game strategy as well as how to develop manipulators through prototyping. Identify the tips and tricks you would like your team to adopt to improve game strategy. Record these in a training manual for future team members.
ST 2.5	Apply a technological, scientific, or mathematical concept (use of algorithms) when communicating with others on issues, plans, processes, problems, or concepts.		
ST-ET 1.1	Apply the core concepts of technology and recognize the relationships with STEM systems (e.g., systems, resources, criteria and constraints, optimization and trade-off, and controls).		
ST-ET 1.1	Apply the core concepts of technology and recognize the relationships with STEM systems (e.g., systems, resources, criteria and constraints, optimization and trade-off, and controls).		SolidProfessor Use the drop down to take the *available Engineering Graphics and Spatial Visualization courses*. Once those courses are complete, take the courses in *Dimensioning and Tolerancing*. Design specific parts on the robot that focus on detailed dimensions and tolerancing.
ST 2.3	Apply a currently applicable computer programming language to a process, project, plan or issue as assigned.		
ST 2.5	Apply a technological, scientific, or mathematical concept (use of algorithms) when communicating with others on issues, plans, processes, problems, or concepts.		
ST-ET 1.1	Apply the core concepts of technology and recognize the relationships with STEM systems (e.g., systems, resources, criteria and constraints, optimization and trade-off, and controls).		
ST-ET 1.1	Apply the core concepts of technology and recognize the relationships with STEM systems (e.g., systems, resources, criteria and constraints, optimization and trade-off, and controls).		Autodesk Have students take the *Introduction to Design for Manufacturing* course. Additional courses may also be found on SolidProfessor. Continue to take courses on the path to achieve the Autodesk Certified Associate for Mechanical Design. Use these skills to design parts for the manufacturing team to use on the robot.
ST 2.3	Apply a currently applicable computer programming language to a process, project, plan or issue as assigned.		
ST 2.5	Apply a technological, scientific, or mathematical concept (use of algorithms) when communicating with others on issues, plans, processes, problems, or concepts.		
ST-ET 1.1	Apply the core concepts of technology and recognize the relationships with STEM systems (e.g., systems, resources, criteria and constraints, optimization and trade-off, and controls).		
ST-ET 1.1	Apply the core concepts of technology and recognize the relationships with STEM systems (e.g., systems, resources, criteria and constraints, optimization and trade-off, and controls).		OnShape Use student resources to learn the basics of Onshape. As you learn to design parts and assemblies, apply them to our

Standard	Description	Mentor Performance Rating	Design and Engineering Possible Learning Activity
ST 2.3	Apply a currently applicable computer programming language to a process, project, plan or issue as assigned.		robot. Gain advanced skills and content through SolidProfessor to obtain a Certified Onshape Associate Certification.
ST 2.5	Apply a technological, scientific, or mathematical concept (use of algorithms) when communicating with others on issues, plans, processes, problems, or concepts.		
ST-ET 1.1	Apply the core concepts of technology and recognize the relationships with STEM systems (e.g., systems, resources, criteria and constraints, optimization and trade-off, and controls).		
ST-ET 1.1	Apply the core concepts of technology and recognize the relationships with STEM systems (e.g., systems, resources, criteria and constraints, optimization and trade-off, and controls).		
ST-ET 1.1	Apply the core concepts of technology and recognize the relationships with STEM systems (e.g., systems, resources, criteria and constraints, optimization and trade-off, and controls).		Solidworks and 3DS experience use the learning resources in the 3DS experience. Apply them to your robot as you learn to design parts and assemblies. Continue improving your skills and consider taking the Certified Solidworks Associate in Mechanical Design Certification.
ST 2.3	Apply a currently applicable computer programming language to a process, project, plan or issue as assigned.		
ST 2.5	Apply a technological, scientific, or mathematical concept (use of algorithms) when communicating with others on issues, plans, processes, problems, or concepts.		
ST-ET 1.1	Apply the core concepts of technology and recognize the relationships with STEM systems (e.g., systems, resources, criteria and constraints, optimization and trade-off, and controls).		

Student Work-Based Learning Training Plan

Student Name	Grade Level	Experience Level
Student Career Cluster Pathway	**Job Role**	**Mentor**
Student Goals for Learning: **Technical Skills to be Learned:**		

Core Values and Career Ready Practices	Learning Pathways
CRP-1 Showing responsibility through *Gracious Professionalism*® CRP-2 Applying interpersonal communication skills CRP-3 Using inclusion during teamwork CRP-4 Demonstrating creativity and innovation. CRP-5 Considering impact of decisions CRP-6 Critical thinking and perseverance CRP-7 Modeling integrity, leadership, and time management CRP-8 Using technology to enhance productivity. CRP- 9 Considering personal health and well-being CRP-10 Applying academic and technical skills	**Industry Certifications to Achieve (2nd or 3rd year)**