MENTOR GUIDE

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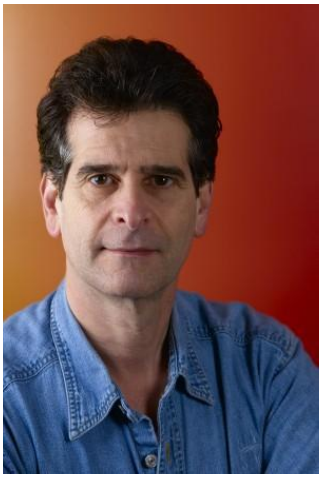
About FIRST®

FIRST®: (For Inspiration and Recognition of Science and Technology) was founded by inventor Dean Kamen to inspire young people's interest and participation in science and technology.

As a volunteer-driven organisation, *FIRST®* is built on partnerships with individuals, as well as businesses, educational institutions and government. To help make the *FIRST®* mission a reality, some of the world's most respected companies provide funding, mentorship, time and equipment. Mentors include over 90,000 committed Volunteers who are integral to introducing almost 250,000 young people to the joy of problem *solving* through engineering.

FIRST® Tech Challenge UK & Ireland is on a mission to inspire the next generation of science and technology leaders. Captivated by the enthusiasm and technical abilities of students, we are determined to bring the *FIRST®* ethos to the UK & Ireland through the provision of accessible, mentor-based STEM educational programmes grounded in robotics.



"*We want to change the culture by celebrating the mind. We need to show kids that it's more fun to design and create a video game than it is to play one.*" - **Dean Kamen, *FIRST®* Founder**.

FIRST® founder Dean Kamen is President of DEKA Research & Development Corporation, a dynamic company focused on the development of revolutionary new technologies with a wide range of applications. As an inventor, physicist and entrepreneur, Dean has dedicated his life to developing technologies that help people lead better lives. Dean's proudest accomplishment is *FIRST®*.

Welcome Message

Teams and Mentors,

Welcome to the *FIRST®* family!

As a former participant of the *FIRST®* programmes, I've experienced the power of *FIRST®* and how it can shape the future of its participants. As somebody who has spent the past decade mentoring students across the *FIRST®* programmes, I'm thrilled that we are launching *FIRST®* Tech Challenge in the UK & Ireland for the 2018-19 academic year. As a student, I was fortunate to be part of the programme when it was all but non-existent. There is nothing more exciting than thousands of students getting the same opportunity I was fortunate to have over a decade ago.

To ensure that all participating teams have a great experience this year and beyond, I've pulled together some amazing individuals who've been working with me to create resources to support all teams through their journeys. They are experienced *FIRST®* participants with over two decades of combined experience behind them.

On behalf of Jordi, Tanner, Kaito, Lucian & myself, we wish you all a fun-filled inspiring season and we hope that the resources we've provided will be of assistance when needed.

Muktar Ali
Chief Operating Officer
FIRST® Tech Challenge UK & Ireland

About FIRST® Tech Challenge

What is the FIRST® Tech Challenge?

FIRST® Tech Challenge is a student-centred activity that focuses on giving students a unique and stimulating experience. Each year, teams participate in a new game that requires them to design, build, test and programme autonomous and driver-operated robots that must perform a series of tasks.

The playing field for the game consists of the *FIRST®* Tech Challenge Game Pieces set up on a foam-mat surface, surrounded by a metal and Lexan field frame.

Note: Details about setting up a playing field can be found on the official *FIRST®* website after the yearly game challenge kick-off.

Each tournament features alliances, which are comprised of two teams, competing against one another on the playing field. Teams work to overcome obstacles and meet challenges, while learning from and interacting with their peers and adult mentors.

Students develop a greater appreciation of science and technology and how they might use that knowledge to impact the world around them in a positive manner. They also cultivate life skills such as:

- Planning, brainstorming and creative problem-solving
- Research and technical skills
- Collaboration and teamwork
- Appreciation of differences and respect for the ideas and contributions of others

To learn more about FTC®, visit www.firsttechchallengeuk.org.

FIRST® Tech Challenge (FTC®) Core Values

Volunteers are integral to the *FIRST®* community. The *FIRST®* Tech Challenge relies on Volunteers to run the programme at many levels, mentoring an individual team to managing smooth events, and FTC® would not exist without them.

FIRST® asks everyone who participates in FTC® to uphold the following values:

- We act with integrity.
- We are a team.
- We do the work to get the job done with guidance from our coaches and mentors.
- We respect each other in the best spirit of teamwork.
- We honour the spirit of friendly competition.
- What we learn is more important than what we win.
- We behave with courtesy and compassion for others at all times.
- We share our experiences with others.

- We display Gracious Professionalism® in everything we do.
- We have fun.
- We encourage others to adopt these values.

Gracious Professionalism®

FIRST® uses this term to describe the programme's intent. This is one of the most important concepts that can be taught to a young person who is learning to get along in the work world. At *FIRST®* team members help other team members, but they also help other teams.

Gracious Professionalism® is not clearly defined for a reason. It can and should mean different things to everyone.

Some possible meanings of Gracious Professionalism® include:

- Gracious attitudes and behaviours are win-win.
- Gracious folks respect others and let that respect show in their actions.
- Professionals possess special knowledge and are trusted by society to use that knowledge responsibly.
- Gracious professionals make a valued contribution in a manner pleasing to others and to themselves.

In the context of *FIRST®*, this means that all teams and participants should:

- Learn to be strong competitors, but also treat one another with respect and kindness in the process.
- Avoid leaving anyone feeling as if they are excluded or unappreciated. Knowledge, pride and empathy should be comfortably and genuinely blended.

In the end, Gracious Professionalism® is part of pursuing a meaningful life. When professionals use knowledge in a gracious manner and individuals act with integrity and sensitivity, everyone wins and society benefits.

"The FIRST spirit encourages doing high-quality, well-informed work in a manner that leaves everyone feeling valued. Gracious Professionalism seems to be a good descriptor for part of the ethos of FIRST. It is part of what makes FIRST different and wonderful." - **Dr. Woodie Flowers, National Advisor for *FIRST®***

It is a good idea to spend time going over this concept with the team and to reinforce it regularly. Provide the team with real-life examples of Gracious Professionalism® in practice, such as when a team loans valuable materials or expertise to another team that they will later face as an opponent in competition. Routinely highlight opportunities to display Gracious Professionalism® at events and encourage team members to suggest ways in which they can demonstrate this quality themselves and through outreach activities.

Community Outreach

A vital component of FTC® is helping to build the *FIRST®* community by introducing more young people to the experience, and by celebrating science, technology and engineering. Outreach events include activities to encourage students and mentors to join existing robotics teams or to start new teams, as well as to raise awareness of robotics in education in general. While it may seem counterintuitive for teams to try to create new competitors, the bigger picture is that *FIRST®* is not really about the competition, but about inspiring students. The more teams there are, the more students there are who might be inspired.

Giving back to the *FIRST®* community also means supporting other *FIRST®* participants by finding ways to help and support new teams, and by working with other teams to develop new skills and abilities.

FIRST® stresses community involvement in several ways, including recognition via awards, such as the Inspire and Connect awards.

Suggestions for Community Outreach

- *Get parents involved*. Parents are their children's greatest supporters. They are incredibly valuable as volunteers, cheerleaders and advocates for the benefits of *FIRST®*. Give parents the opportunity to learn more about what their children are doing and to develop their own enthusiasm and appreciation for science, technology and engineering.
- *Assist in the development of new* FIRST® *teams*. Act as a resource for a new mentor or for a community member who is interested in getting involved with *FIRST®*.
- *Lead a workshop for a local partner*. Help other teams in the local community develop their skills and abilities by supporting them as they learn a new programming language or work with a new mechanism. Share the experience and knowledge that has been gained through previous years of participation.
- *Hold an open practice, build day, or scrimmage*.
- *Do a demonstration at a local event or community centre*. During outreach events, make sure that there are regular opportunities for team members to briefly describe the robot and what robotics means to them.
- *Promote* FIRST® *in the community through positive word of mouth and local media*, where appropriate. Create flyers to hand out at events or create a press release about upcoming events and distribute it to local newspapers or websites.
- *Recruit new mentors and players*.

The Mentor

What is a Mentor?

Mentoring is an important part of the *FIRST®* programme and contributes, in a large part, to the programme's success. If done correctly, this learning process builds and expands team members' self-confidence, as well as their knowledge. If the process has a strong foundation and works properly, adult team members come away with as much as students do.

Note: Every adult on a *FIRST®* team is a mentor due to leading through guidance and example. It is important to remember students need guidance, structure, encouragement and, most of all, a fun experience!

A Mentor…

- Requires no special skills, but should have patience, dedication and a willingness to learn alongside the team.
- Is any person who works with the team in his or her area of expertise, for at least one team meeting.
- Helps provide valuable one-on-one interaction and serves as a resource in his or her specialty.
- Directs the process the team follows to solve the yearly game challenge, without providing the solution him or herself.
- Is a confidant, supporter, coach, teacher, motivator and facilitator.

Note: Teams require **at least one adult mentor**, who is **18 years or older**.

Mentors and students are equal. The relationship is a partnership. Each person works collaboratively towards a mutual and beneficial goal. To succeed, both the mentors and all team members must commit to this.

Mentors should also be willing to acquire some basic knowledge of the programming environment and robot building. Many teams enlist the support of a technology teacher or technical mentor for additional assistance. *FIRST®* strongly encourages teams to invite people with backgrounds in engineering and programming to share their knowledge and experience with teams.

A Mentor's role includes…

- Inspiring students in science and technology.
- Actively sharing knowledge and experience with the teams to help foster intellectual growth.
- Motivating and engaging students in meaningful activities.
- Balancing effective work habits with FUN!
- Allowing students to do as much of the work as possible.
- Providing students with opportunities to make choices, both good and bad.
- Encouraging students to take risks and be inventive.
- Allowing and encouraging independent thought.

- Creating, encouraging and facilitating open, honest communication within the team.
- Fostering a reciprocal environment of trust and respect for every team member and his or her ideas.
- Encouraging accountability within the team.
- Facilitating team activities and discussion.
- Developing roles within the team.
- Coordinating help.
- Maintaining equipment.
- Communicating with sponsor organisations.
- Purchasing supplies.
- Registering for competition.
- Planning and scheduling meetings, visits and trips.
- Acting as a liaison between team members, mentors, parents and volunteers.
- Informing students and parents about what is expected of them in terms of their commitment to the team, each step of the way.
- Collecting consent and release forms for *FIRST®* UK.

Rewards of Mentoring

- Adults share simple concepts of team-building and cooperation they have learned through job experiences, as well as their knowledge of specific, and perhaps complicated engineering tasks.
- Mentors grow and learn new perspectives from the young minds brainstorming and working under their tutelage.
- Through teaching others, mentors develop a greater understanding of their own area of expertise.
- Team members learn technical and organisational skills well enough to be assigned some mentoring roles.
- Young mentors gain valuable work experience by training, coordinating and facilitating in a collaborative team environment.
- Mentors strengthen their connections with the community in which they mentor.
- Participation in *FIRST®* is an overall amazing experience, and a lot of fun!

Possible Mentor Contributions

- **Engineers** can teach the team the necessary skills for the robot's design, while demonstrating the engineering design process.
- **Programmers** can teach the team about programming principles and help the teams to troubleshoot programmes.
- **Sixth Form College or University students** can help teams work through programming or design challenges, share strategising methods, and serve as role models.
- **Marketing experts** can teach students about marketing their team to others, including other teams, sponsors or local communities.

- **Graphic artists** can provide advice on team logos and t-shirts.
- **General volunteers** are valuable to help with scheduling meetings, providing transportation and snacks, assisting with fundraising, or providing carpentry assistance for field construction.

Advice for Mentors

Mentoring an FTC® team can be one of the most rewarding experiences in a person's life. Like any great reward, it involves a commitment of time and energy. However, it should not be taken too seriously! It should be enjoyed.

The goal of FTC® is to help students have fun with robots while they become comfortable with technology. Whether or not the team is successful at a competition, team members win just by participating.

It is important for every adult to remember that there are responsibilities that come with the adult/student relationship. Young people look up to people they trust and respect, and will look to mentors as role models. A mentors' actions will be closely watched and their behaviour will be perceived as appropriate.

Prior to meeting with students, have a meeting with all mentors to set expectations. This can give adults an opportunity to ask questions they may not want to ask in front of the students, openly discuss topics such as diversity, and discuss ideas and potential problems or concerns about working with young people. If a school district has an individual who works with school or business partnerships, they should be invited to this meeting to help answer questions.

Twelve Basic Guidelines for Mentors

1. Be a mixture of best friend, honest guide and coolest teacher.
2. Avoid the temptation to do the work or to deprive team members of the chance to discover the right answer on their own. Mentors should guide a team without directing it. This creates the best learning and growth experiences for team members.
3. A mentor's behaviour and attitude can and will influence how a team chooses to respond to the environment around them throughout the season and at events. Demonstrate and encourage Gracious Professionalism® at all times.
4. Foster discussions between all team members and groups. Discussions are critical for effective brainstorming and strategy development.
5. Patience is a necessity. Practice it, especially with the most trying of students.
6. Never use sarcasm while teaching or helping someone. A good mentor never resorts to sarcasm and anger to hasten the process of learning.
7. Mentoring is a two-way street. It is as much a job for a teacher as it is for a learner. Practice both with equal humility.
8. Never let students indulge in fruitless activities during learning hours. Find something to teach in all activities and try to make every activity an educational experience.
9. Infuse enthusiasm in every activity and part of the challenge. To spur creativity, mix humour and a passion for learning and discovery.
10. Get involved in technical and non-technical experiences. Be supportive to students in both regards.
11. Be the team's best cheerleader, enthusiast, leader and friend. Happy teams win many accolades and learn the most.
12. Forging relationships and gaining friends are far more valuable experiences than participating on an unhappy team and gaining meaningless trophies.

Mentor Time Management

As a mentor, additional time will be needed each week, beyond team meetings, to prepare and coordinate the tasks listed above.

Effective Mentor Time Management:

- Create a realistic meeting schedule. Consider personal and professional commitments, major holidays and school events.
- Keep a team calendar posted in the work area. Note key dates, deadlines and meetings.
- Entries in the team's Engineering Notebook should coincide with these dates.
- Have the team contribute to the selection of deadlines for certain parts of the project, so that they will feel ownership over the process and support mentors in ensuring all deadlines are met.
- Do not accept procrastination. Be firm about deadlines and do not accept "we have plenty of time" as an excuse for not getting things done. Refer to the calendar and regularly remind team members of deadlines.
- Ask for help. Work with other mentors, parent volunteers, mentors in training and team members to accomplish team goals, track progress and meet requirements on time.

The Team

Forming an FTC® Team is a great experience as that team will almost become like a second family. The maximum number of students in a team is 15, however a team could be formed of just 10 students without any issue. Every team is different and there is no "ideal" number of students on a team. Ultimately, the size of a team is based upon the mentor's preference and the interest of the students.

Age Range

An FTC® team is made up of pre-university students, aged 12 to 18. FTC® is optimised for students in year 9. Students cannot be older than Sixth Form College if they are a participating team member. University students and others who have completed Sixth Form are welcome to participate in the roles of mentor or coach.

Depending on the age and maturity level of the team, there may be social and developmental differences with mixed-age teams. This can work as an advantage, but mentors should be prepared to deal with team members from a variety of levels.

Time Commitment

Time commitment for mentors and team members will vary with experience and a team's dynamics. It is important to discuss duties, time commitment, meeting times and dates up front. If students cannot make a reasonable number of meetings, mentors need to consider this. The level of commitment should be generally the same among all team members.

Time Commitment Guidelines

- *FIRST®* recommends starting with one or two meetings per week during the team-building stage.
- During the design and build phase, meetings should take place more frequently, as indicated by the team's needs.

- Sessions lasting 2-3 hours are generally the most productive.
- On an 8-10 week schedule, plan to have the team meet for at least 10 sessions.

Team Roles

No matter how large the team is, each member should get a role in the team. Having the students get personalised roles will motivate not just robotics-interested students, but also students in the school that are keen to focus on finance, graphic design or communications. There are required roles set out by programme guidelines, essential roles that need to be filled from the very beginning, and additional roles that will enhance the team's output. We recommend that teams review the roles and each participant reflects on which roles they are (1) most qualified for, and (2) most interested in. After that, the team can have a discussion and select who is best suited for each position. If the team cannot agree, an anonymous election may be best.

Project Manager Coordinates all aspects of the team and lead group discussions with the finished product in mind	The Project Manager is the highest student leadership position. They coordinate all aspects of the team and lead group discussions with the finished product in mind. While a rewarding and exciting position, it is also challenging and important: they need to put in extra efforts to be one step ahead of the team.
Communication Officer Coordinates community outreach for the team, including the assembly and presentation of the Inspire Award.	The Communication Officer coordinates community outreach for the team, including the assembly and presentation of the Inspire Award, which is the product of their outreach initiatives. They organise events and programmes which promote STEM in local communities and/or raise funds for the team.
Financial Officer Develops and maintains a team budget, and ensures the team's expenses do not exceed allocations.	The Financial Officer develops and maintains a team budget, and with the Inventory Specialist ensures the team's expenses do not exceed allocations. They research and propose fundraisers and other solutions to funding future seasons, and gather travel options for competition events.
Drivetrain Engineer Leads other members of the team in building the drivetrain.	The Drivetrain Engineer will ensure it is maintained and repaired and will assist in creating the superstructure to fit other components to the robot. They report to the Project Manager to update them on progress.
Manipulator Engineers Each target one challenge in the game, and organise other team members to create a solution	The Manipulator Engineers each target one challenge in the game and organise other team members to create a solution. Enforcing good recording and working practices, they will oversee the refinement and iteration of the design, using one another to ensure their designs function well together.

Software Engineer Responsible for the development and maintenance of the code needed to operate the robot.	The Software Engineer acts as a programmer and is responsible for the development and maintenance of the code needed to operate the robot. They primarily organise programmes made by different groups due to the simplicity of the FTC® coding language. If needed, they can help the Media Coordinator with IT support.
Health and Safety Captain Safety FIRST! This member develops and promotes safe practices and habits in all phases of the season.	The Health and Safety Captain develops and promotes safe practices and habits in all phases of the season. They create educational materials to promote safety and coordinate with the Communication Officer to spread these materials. They are also responsible for developing a safe culture for the team.
Document Controller Records and gathers evidence of progress and learning for the Engineering Notebook (EN).	The Engineering Notebook (EN) is a resource that demonstrates the team's journey throughout the season, presented at competition. The Document Controller will record and gather evidence of progress and learning for the EN. The EN is required in order to be eligible for most awards.
Graphic Designer Produces sponsor decals for the robot, designs team apparel, and works on publicity materials.	The Graphic Designer produces sponsor decals for the robot, designs team apparel, and works on publicity materials under the team budget. They are also responsible for creating and maintaining the team's visual identity by upholding the identity standards and creating templates.
Media Coordinator Creates, maintains and supports the team's online presence and creates digital team media.	The Media Coordinator creates, maintains and supports the team's online presence and creates digital team media. This includes a team website, Facebook page, Twitter and/or photo-sharing sites. In doing so, they also cultivate a team identity based on goals and spirit of *FIRST®*.
Strategy Officer Decides on the best possible strategy for the robot using a thorough game analysis.	The Strategy Officer decides on the best possible strategy for the robot using a thorough game analysis. They will also be deciding on strategy during competition using gathered information about other teams and robots.
Electrical Engineer Responsible for developing and maintaining all the electronics needed to operate the robot.	The Electrical Engineer is responsible for developing and maintaining all the electronics needed to operate the robot, working in tandem with the Software Engineer. They have

	a thorough knowledge of the electrical components of the robot, and make the wiring functionally and aesthetically pleasing.
Design Officer A well-designed robot is the foundation for success during the season.	The Design Officer uses CAD to develop the robot design electronically. They must have previous experience with CAD, or similar design software, as they keep pace with the Engineering team during design development. Their assembled models prevent designs from interfering with one another when they are assembled.
Inventory Specialist Orders, receives and counts materials and products for the team, developing a thorough knowledge of the uses of their inventory.	The Inventory Specialist orders, receives and counts materials and products for the team, developing a thorough knowledge of the uses of their inventory. They create a dynamic parts organisation system, keep the existing inventory organised, and ensure that the inventory records are accurate at all times.
Spirit Coordinator A nominated member at competition who will lead chanting and other group activities.	The Spirit Coordinator is a nominated member at competition who will lead chanting and other group activities. This member will only be needed on competition days.

Team Dynamic

FIRST® Teams

There is more than just camaraderie on many *FIRST®* teams. Many teams become extended families, with strong, lasting relationships. Students and adults absorb knowledge from each other and grow through team-building and learning processes from which everyone benefits.

It is important to ensure that the team dynamic remains **positive, supportive, engaging** and, above all, **fun**. Throughout the experience, team members will face long hours and days working on the robot and awards submissions. Whenever possible and appropriate, keep the atmosphere friendly and add laughter.

FIRST® Tech Challenge teams and their mentors come from a variety of backgrounds. New teams should not expect to be like every other team. Each team will have a different set of skills, experiences and ways of doing things. Take time to get to know each other and find an approach and style that suits the team and its goals.

Teams are encouraged to develop and promote team identity. It is a great way to help *FIRST®* judges, announcers and audiences to recognise a particular team at a competition. It is also a way to help teams create a "buzz" about what they are doing in their own communities.

Encourage team identity by adding the team logo to robots, t-shirts or hats. Create a team cheer, banner or website, and hand out fliers or other giveaways that will make the team memorable.

Creating a Positive Team Dynamic

There is a lot at stake during each of the competition stages so developing an environment of trust and respect between all team members is a priority, and is part of the mentor's role. Mentors set the tone for the team dynamic through their own demeanour, actions and words. Everyone on the team needs to know all team members are valued and they are honest, respectful and dependable. Stress this point at the very first meeting and encourage this attitude among the team members throughout the season. Remember, every team should work towards a balance of work effectiveness and FUN!

The true goals of FTC® have very little to do with winning medals or trophies. If a team can look back at the end of the season and say even one of the following, they have succeeded.

- We learned how useful and fun math and science can be.
- We did something we did not think we could do.
- We respected and considered ideas from everyone on the team.
- We helped our community.
- We figured out how to manage time, deal with setbacks and/or communicate ideas.
- We had fun!

Remember to take breaks for snacks, games and getting to know each other. Breaks should be timed to maintain productivity, but students should be granted some freedom in how they spend that time.

Keys to Creating a Positive Team Dynamic

1. Team Building

- Many teams have team-building events and other activities so new team members can get to know each other in a fun and relaxed environment. These activities can help make team members more comfortable and can build the foundation of a good working relationship.
- Team-building exercises allow members to communicate feelings in a positive and healthy way, and encourage Gracious Professionalism® as they work together toward a common goal.
- Letting students have fun together allows them to develop communication skills and respect, leading to smoother progress when work resumes.
- Encourage laughter. Laughter builds camaraderie and diffuses tension.
- Host a team-building night to showcase talents and hobbies. Have students and mentors be prepared to share information about themselves in an informal atmosphere. Possible activities include a karaoke night or talent show, a pizza party or spaghetti dinner, or a simple games night.

2. Mutual Trust and Respect

- Relationships between all team members, including the relationship between team members and mentors, should be based on common goals and should build on mutual trust and respect throughout the season.
- It is important for mentors to be approachable and available to students.
- Communication is the key to building trust and respect on a team.
- All team members should follow through with commitments made to the team. This includes mentors as well as students.
- Respect all ideas. Make sure everyone treats all brainstorming and ideas with respect. Allow people to disagree with or challenge an idea, but do not allow them to judge an individual.
- A mutual foundation of trust and respect is critical for a supportive learning environment. Everyone's voice should be heard and all ideas should be listened to with a patient and open mind. Part of a mentor's role is to listen to team members and to keep lines of communication open. While every idea or suggestion may not be usable, expressing a clear concept or idea is a great learning experience, and may serve as inspiration for other, more effective ideas.

3. Equality of Labour

- Students should feel that they are part of the thinking, contributing and doing process for the team. They should feel they are equal with their peers and that their efforts are of equal worth.
- Equal contributions of time and resources among team members should be considered when tasks and roles are assigned to team members.
- All efforts of team members and mentors should be appreciated and recognised.

4. Communication

- Set clear goals for the season and include expectations for group success at functioning together as a team.
- All team members should understand what is expected of them and how their responsibilities have been assigned.
- Let the students know they will have a large part in building the team's robot once they have learned and practiced the necessary skills.
- Everyone should know their ideas are important and will receive consideration. Mention this often as the season progresses.
- Keep the group focused. It is the facilitator's job to keep the team discussions focused on the topic.
- Always be an alert and active listener.
- Include everyone. Bring quiet team members into the discussion and work to prevent those who feel comfortable with communication from monopolising the conversation.
- Unite the group. If there is a problem within the team, allow the team to communicate its frustration, decide on a course of action, and then help them move forward.
- Do not take sides. Keep conversations to facts, not emotions. Do not let things get personal.

- Paraphrase what has been heard from the others, or get someone else to do it. This keeps communication open because another listener may be able to correct or explain something that has been misunderstood.
- Build on ideas. Encourage people to build on ideas that have already been presented.
- Record ideas. Document brainstorming ideas and decisions for future team reference.
- Avoid rehashing. Do not reopen discussions that have already been closed or decisions that have been made unless absolutely necessary. Team members should agree up front not to rehash unless all members of the team agree to do so.
- Be aware of verbal and non-verbal cues. It may be necessary for a mentor to step in and help students work through communication difficulties. Validating a team member's feelings will encourage them to discuss problems when they arise. Sometimes acknowledgement or positive feedback may be all the response a team member needs.

5. Facilitate

- Clarify the task without doing the work. Define it as a simple task or a complex set of jobs that will take weeks to complete. Make sure the team understands how the task fits in with their goals and objectives, as well as what is expected of each individual. Provide a realistic deadline for the task's completion.
- Be aware of one person's potential impact on the group. Facilitators do not need to be experts in the topic being discussed, but if they are, they must be careful not to lead the discussion to a preconceived outcome.
- Get to know the group, its members, their goals and their differences. This helps mentors anticipate conflict and turn the experience into productive learning.
- Prevent group paralysis by watching for problems in achieving consensus, allowing adequate time for discussion, and being prepared to step in if the group cannot make a decision. Knowing when to push the decision on the group, or to make it, is a skill good mentors develop over time.

6. Keep Students Engaged

- To maintain group enthusiasm, encourage new team members to share observations about their experience at meetings or events. This will help to bring new members out of their shells and inject the team with a new perspective and fresh ideas. It can also lead to lively, engaging discussion with more experienced members who can share their experiences and build on the ideas put forth by new members.
- Play robot games during team meetings and allow all team members to participate in different roles. Small challenges and games that involve driving, picking up or moving objects with the robot can serve as try-outs for the Drive Team, or provide a fun way for all team members to develop a greater understanding of how the robot works. Experimentation with different roles and strategies will benefit the individual and the team as new approaches are tested and new abilities and interests are discovered.

- Get creative by involving the team in marketing and team identity tasks. Allow all team members to participate in the development of a team name and logo or naming the robot for this year's challenge. Create decorations for the pit or props and costumes for events.

Build Season

The build season is carried on from the day of Kick-off to the UK & Ireland Championship. In this section, only robot-related material is discussed, no outreach or finance. All time scheduling in the build season is assuming each team will meet once a week. If the team decides to meet more than once a week, then elongate the time spent on each Milestone and Flowchart. Make sure to keep your Team Milestones calendar up to date and add new Milestones as you see fit.

Kick-off Day

The *FIRST*® Tech Challenge build season begins on kick-off day, and it is marked by the release of the second part of the game manual and the game animation. The first session will begin by splitting up the students in small groups that will focus on specific aspects of the game manual. Divide the students into three groups, **The Robot** (25%), **The Tournament** (25%), and **The Game** (50%). Each group will present in front of the team once they're familiar with the rules, so make sure they write down key observations! Every subgroup should familiarise themselves with the rules in the manual, and make sure that everyone has downloaded the game field map!

For **The Robot**, the students should ask themselves these questions; *How big can it be? How heavy can it be? How far can it extend? What's banned? Can we shoot stuff? How many motors can we have?* They shouldn't talk about Alliance Flags, Numbering, etc. these aren't important until competition prep.

For **The Tournament**, they should keep in mind these questions; *how does ranking work? What is an alliance? How are alliances selected? How are elimination matches played? Are there tiebreaks?* Students shouldn't discuss the Overall Structure or Awards. This section will later affect what the team decides on their priority list, as the sole goal is to play for the rank and Alliance Selection.

The Game is a big chunk of the game manual, and the students should read through it carefully and thoroughly read all the definitions. They should consider the Match Structure; autonomous, teleop, and endgame lengths. They should be clear on what is the objective, it's advised they write a simple summary with specific vocabulary of each game piece. The students should be familiar with the general setup of the game; the location of game pieces and the robots on the field at the start. Students should have an overview of the points, for example for autonomous, teleop, and end-game, ask these questions; *what can you score? How much are they worth? How is the scoring different between auto and teleop? Are there any non-point scoring mechanisms?* Just like any other sport, FTC® has penalties, and they can be game changing, so make sure students are familiar with these. They should learn about the technicalities such as yellow card progression, out-of-match effect, *how many points deducted for different penalties?* Someone has to drive these robots, and that drive team has rules as well! They should familiarise themselves with the different roles, the pin rules, the end-of-game point assessments, *what counts as manipulation?* Different tolerances. The last part of The Game is the game-specific section, which is about the autonomous limitations, the possession limits of each game piece, the blocking rules, and finally the scoring methods of each game piece (limits).

The students should spend an hour reading through all these rules and then meet as a team and present in front of class everything they've learned. One student should "lead" this meeting, either the project manager or if your team has one, the strategy officer. Each group should present the things they felt were most important about their section and then the rest of the team can ask them questions if they're unclear about some rules. The last thing that should occur in this session should be watching the reveal video one last time so students leave with a good picture of the challenge this year.

On the second session, the team should have gone over all game specifications already, now, they should focus on Scoring Analysis. Students should consider *how long it takes to do each objective? How far you need to go? the difficulty of game piece manipulation, how long would it take to intake or eject? Is there any vertical change (lifting or other) necessary?* A good way for students to be familiar with the game is for them to play *stubots*. This exercise is quite self-explanatory, and it's when the students will act as robots on a "game field" and do the actions a robot would do. *Stubots* is always valuable for being able to visualise how the game will flow. It also gives a basis of comparison, humans are much better at some things than robots. Make sure students aren't coming up with ideas on how to make certain manipulators, as of now, they're solely familiarising themselves with the game.

Once the students know the rules, they are familiar with how scoring works, and know how to be "the best robot," they should write a priority list on the poster provided. A priority list is something that the team will look up to for the whole season, it's something that dictates what they focus on the most. Clearly, the most important thing in the competition is for the robot to move, so the drivetrain is the number one priority. For the rest of the list, it is up to the students to decide. For example, the second priority could be the intake mechanism, how the robot acquires game pieces from the field, it could also be a launcher mechanism for the robot to score goals because that gets the team the most points. Whatever they end up choosing, that list will have to be followed for the rest of the season.

Developing Ideas

Before the students embark on developing ideas, they should make sure they're familiar with the rules of this year's competition.

In the third session of the season, before any ideas are thought of for the manipulators, the students should focus on the number one priority, the drivetrain. Make the students reference the "Drivetrain" Flowchart for how to choose the adequate drive train. Whatever the students decide on, make sure that the decision the students make is final and that everyone is happy with it.

Remember, although this may seem like something quick, it should take a whole session to decide on what drivetrain is best for this year's competition.

On the second session of the Milestone, so fourth session of the season, the students will start thinking of ideas for different mechanisms to pick up game elements, shoot game elements, etc. Make sure the students aren't thinking too much about "how" to build something as it can be counterproductive and may stifle creativity, instead make sure they **think "what" the robot has to do**. It's recommended that students think outside the box with their designs. Also, make sure students don't over complicate their ideas as teams will often be more successful by choosing a simple design within their capabilities and executing it very well than by choosing a complex design that they are not capable of executing!

In this brainstorming session, focus on the quantity of ideas generated instead of the quality of ideas generated. Many ideas are generated in the hope that a few good ideas will develop. Students are encouraged NOT to make any judgment on the ideas proposed, only to compile a large list of ideas. The students should "play" *stubots* again, but this time pay specific detail on what the robot has to do, like pick up a game piece or launch a game piece in order for them to get a good idea of what type of intake mechanism or manipulation mechanism is required for the robot.

After a couple hours, the students should have compiled a long list of ideas for different mechanisms. Before moving onto prototyping, they should know which ideas are the most important ones, which ones would be good to have, and which ones aren't that important but would be nice. A good way to do this is by ranking the ideas into three sections, **R for Required**, ideas that MUST be included, **P for Preferred**, ideas that are important but the robot won't fail without it, and **W for Wish**, ideas that aren't that important but would be nice if possible.

FIRST® Prototyping

From the previous session, the students should have a list of what they felt was most important and what wasn't so important. As this Flowchart is very important, the students should spend three sessions on it.

In the first session most of the student's ideas will come to life; they will LEARN how their ideas are introduced. A group of two or three students will begin building a rough prototype of the drivetrain that was decided two sessions ago. They should work on the drivetrain in concurrence with the rest of the team working on prototypes. By the second or third session, this group should power the drive train and test it as best as possible. The rest of the team should split into groups of two or three to come up with different the different manipulator ideas that were thought of last session, there should at least be two mechanisms for each manipulator.

Each group should watch the different playlists so they can think of "HOW" to accomplish the "WHAT." When it comes to coming up with designs, it is good to think outside the box as well as using pre-made designs. Before they start making anything, they should all sketch their designs so that the group has a good idea of what they are making. Remind the students that not everything needs to be prototyped, just the things they want to make work! Push the students to not settle for mediocre concepts, but to strive to find the *right* solution.

After they've sketched their ideas out and have a good idea of what they want to make, the subgroups will start making these designs out of Cardboard ("Cardboard Aided Design"). Make sure that the team is aware that this prototyping session is only the first one, meaning that the prototypes are designed to be crude as long as they are functional enough to be educational to the team. Improvements and innovations early in the process will yield better results later in the process. Remember that on concurrence with manipulator prototyping, there will be a group of two or three students who will be working on the drivetrain.

Once it looks like almost all subgroups have finished their cardboard prototyping, the students for each subgroup should meet to discuss their prototype, so all the launcher sub groups should meet, all the intake sub groups should meet, and the manipulation sub groups should meet. If this hasn't happened halfway through the second session of this Flowchart, then the students need to pick up their pace. This session is good for each subgroup to talk among themselves about the pros and the cons of their prototype. Students should ask each other questions like *how their prototype works? How it ties in with the game? How important is it for the robot to have it? How can it be changed?*

Once the team has met in their subgroups, which should be half way through the second session of this flowchart, they should be split into their prototype groups again and their prototypes should be made of metal. This will be harder on the students as not everyone has worked with metal before, however there are multiple sources online and sources provided that will help them make what they're trying to portray. It's very important that students test and record their prototypes when they are done. At the end of their prototyping sessions, which should take several meetings, they will present their ideas but rather than subjectively back up their idea, they will objectively back it up. This includes either taking videos of their prototyping working in different conditions, or recording a shooter mechanism shoot 50 times and stating only 40 shots went in, etc.

Decision Making

By this Flowchart, the team should be on their eighth session of the season, unless they met more than once a week. This Flowchart will only take one session and it is where the team will end up choosing a final design for each one of their manipulators. This step is where the students will use the lessons learned from their prototyping and determine which concept is "best" and go forward with it. Before the students present in front of the team, they should get together for a little bit to talk through their presentation. When they start presenting, make sure everyone is listening and someone, either a member of that subgroup or someone else from the team is writing down key points about their presentation. Like when ideas were flushed out in the *FIRST®* prototyping session, after each subgroup presents, let the team ask questions about the prototype, this time the questions should be more objective than in the previous session, like *where in the robot would this intake be placed? Can the elevator carry more than one game piece? Is it more accurate if you add another set of wheels to the flywheel?*

After they've all presented, it's time to choose final designs for each manipulator. As this is one of the most important decisions in the season, the team should really talk this out and take their time. Compare how each concept fulfils the specifications and see if one is significantly better than the others. Look back to the priority list made, how is one design better than the others in terms of ranking points? A good way to rank certain designs is by making a **Weighted Objective Table** (WOT). A WOT is used to compare several different parts of a mechanism by ranking them based on a list of criteria. Here's an example of how a WOT would look like for two different launcher ideas:

Comparison Criteria	**Weight**	**Flywheel**		**Catapult**	
		Score	**Weighted Score**	**Score**	**Weighted Score**
Speed	9	5	45	2	18
Accuracy	7	2	14	5	35
Space	5	2	10	2	10
Complexity	4	3	12	3	12
Total:	25	13	81	14	75

As you can see above, the table on the left isn't specifically focusing on one launcher but just general qualities and how important each quality is ranked out of ten, i.e. the speed of the launcher is very important whereas how much space it takes on the robot isn't as much. Each launcher is then given a certain score out of five for each criterion, for example the flywheel shoots projectiles very fast and takes up very little space, however it is not very accurate. Then these scores get multiplied by the weight on the left-hand table, to get the weighted score. All the weighted scores are then added up for a total, and as seen from above, the Flywheel has a higher ranking, which would mean that it's the better design. This example is not official, each team will have different WOTs depending on what criteria they may come up with depending on their strategy.

Once a WOT has been made for each prototype, then the team will finalise on the three ideas per manipulator. If the team can get to a conclusion solely by talking it out, then that is perfect, however most of the times, the team will struggle to pick the "best" design, so it is suggested they vote as they did before in the *FIRST®* Prototyping session. They can do this either by having a "heads down – hand up" vote, a method where students don't feel intimidated by choosing something due to what the majority think, or they could just have a normal vote where they raise their hands when a design is read out.

Final Group Prototyping

The team should now be at a place where they have a general idea of how the final robot will look like. They should know what drivetrain they are doing and what manipulators they are making for each task. If the team appointed a Design Officer, then this officer should incorporate some of the ideas onto CAD or a design software on their computer. It will be difficult to do so as there shouldn't be any final measurements, however it is a good idea to have at least a general idea on the computer of the final design. Again, it isn't obligatory to do this, just a suggestion.

The team should be split into four groups, or if the team decided to do just two manipulators instead of three, then split group into three different groups; a drivetrain group, and the rest manipulators. Each group should have a member that is not fully committed to build, but is either a Communication Officer, a Financial Officer, or other roles that don't require building. In these groups, each individual design should be thought of again and changes to the design should be thought of regarding the feedback given by the team in the previous session. Before more iteration occurs, **all the sub-teams have to have an integration meeting**, where they discuss where everything goes on the robot, and makes sure that no mechanisms collide with each other. For example, this could mean that the intake manipulator has to change its support system to allow the manipulation mechanism to fit in well. This is very important and should be done thoroughly, and if possible should be supported by CAD models and assemblies. If this doesn't occur, each individual subgroup will make their final designs, and will find it almost impossible to put it all together in one robot, which will mean they will have to change their designs all over again.

In each subgroup, the students should iterate their design and test it as much as possible, the more tests the merrier. There are some other optional pieces that may be generated during this session, like CAD Models, Assembly Drawings, Bill of Materials, Maintenance Guides, and more. This session is also the process when design calculations are completed such as optimisations of gearing, material strength, weight and more.

After each subgroup has met and perfected their design, the team should come together again to present for one last time. The drivetrain group should show the robot moving around, driving over obstacles, etc. The manipulator groups should show the team their manipulator working in different scenarios. Then, the team should talk about how each design can be improved by giving suggestions and talking about the pros and cons of each mechanism.

Final Design

At this stage, the team should have a finished drivetrain, and close to final designs of the manipulators for each different task. However, the *FIRST®* final decision will most likely not be the best, so after completing everything, the students should ask themselves these questions and see how the prototype can improve in the following ways; *how can we make it more robust? How can we make it smaller? How can we make it simpler? How can we make it more efficient? How can we make this easier to construct? What other functionality would be easy to add? Why was it done this way? Did we think of doing it a different way? Why did we rule out other alternatives? Does it fulfil our requirements and specs? How can we make it function better? How can we make it weigh less? How can we make it faster?* The students should keep asking themselves these questions until they get to a point where they think they can't make their prototype any better.

Once the students have reached that stage where they can't get their prototype to be any better, it's time to make it real. Before building the final robot, the team should have **one final integration meeting**, making sure that everything fits in place and nothing has to be changed for something else to fit. After the students are sure their designs won't overlap with each other, then they can modify the existing prototypes to the final design or build final designs from ground up. Once each group has gotten the final design, the team can begin putting the different manipulators together, attaching the intake, shooter, etc. to the drivetrain. Once the robot is finally assembled, take a nice good look at the robot and congratulate the students on getting this far!

Now it's time to test everything together. If the team hasn't chosen a drive team yet; a driver, an operator, and a coach, make sure the team appoints one. The drive team can be chosen through an application process where the students apply and write a paragraph explaining why they want that role, and the driver can be chosen by having "driver try-outs", where students who want to become drivers have to drive around a certain obstacle course and whoever does it better, becomes the driver. Once the drive team has been chosen, start testing everything the robot needs to do; drive around the game field, pick up the game pieces, shoot the game pieces, etc. Basically, test every possible scenario the robot could ever find itself in the competition. Keep having these driver tests and iterations to the designs of the manipulators until the UK & Ireland Championship event starts!

Drivetrain

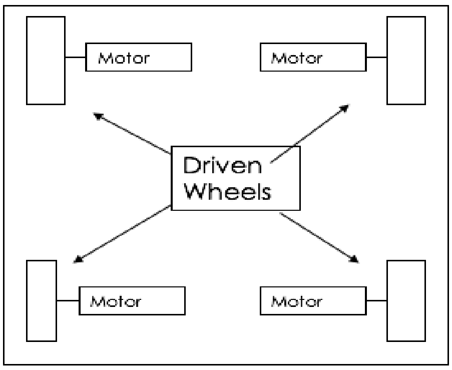
One of the most important tasks the students will have to accomplish will be to build a drivetrain for their robot. There are multiple potential options available out there already, some of which are more complicated to build and require more commitment, and some that can be assembled very quickly. This section will go more in depth with the drivetrain flowchart provided by us.

How to power the wheels

There are several ways to run and power the wheels, either by running motors straight onto all wheels, or by powering only one wheel on either side and connecting all wheels either by gears or chains. Below are the details of different ways to power:

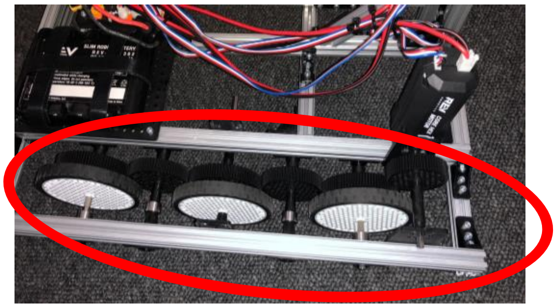
Attaching motors to wheels

This option has very few pros and a lot of cons. The good aspects of this method are that it is simple and takes up little space. As seen on the image, there isn't much engineering involved in attaching wheels onto motors. The cons of this method are it puts the robot weight onto the shaft of the motor, which can potentially lead to bending of the shaft or breaking of the motor. Also, with the REV kit provided, six motors are given to a team, and if a team chooses to make a drivetrain where each wheel is powered by a motor, those six motors will run out quickly, and motors are needed for the different types of manipulators. This method could be used either when making a four-wheel drive train, or when choosing to make an Omni wheel drivetrain, these will be discussed later.



Attaching gears to wheels

Instead of connecting a wheel for each motor, there's another good solution which is to have one motor run a set of gears that run the wheels on each side. As seen on the image, one side is powered by a motor (blue circle), and the gears power the back wheels (red circle). The good features of doing this are that gears can be utilised to transfer power, so it's good when it comes to the robot pushing other robots out of the way or when pushing heavy obstacles out of the way. On top of that, the gears do not put pressure on the motor shafts. Some issues with having gears are that in the long run, gears can strip, leading to grinding of gears and sometimes skipping teeth, which can lead to no power to be transferred.



Attaching sprockets to wheels using chain

Similar to attaching gears, another way to power the wheels are by connecting them with chain using sprockets that are attached to the wheel. As seen on the image, the middle wheel is powered by one motor, and the rest is all connected with on sprockets using chain. The good characteristics of this method are that the sprockets are generally the most effective in transferring power because they don't run into the problems that gears and direct power do. On top of that, this method can also allow the motor to be placed at a greater distance away from the wheel, allowing for more liberty of how the drive train can be designed. There are some cons, like if the chain isn't properly linked, the links could snap, causing only the wheels to be powered by the motors to run.

Different types of Drivetrains

After being familiar with how to power and connect wheels, it is important to know which drivetrain is best to choose for different occasions. This subsection will be closely tied in with the flowchart provided on drivetrains. When choosing the best drivetrain, the team should consider if they want to become a defensive robot, offensive and move around quickly, etc. Below are the different possible options. Keep in mind, there are more drive trains out there, so feel free to explore the web and find some new methods!

Tank drive

Tank drives are usually the easiest to build and programme out of the drivetrains given in this section. There are several different types of tank drives, the most basic one (not recommended) is a four-wheel tank drive, where the two front or back wheels are powered, and two back or front wheels aren't. The non-powered wheels are not even connected by gears or chain to the powered wheels, they only move when the robot is in motion. This drive train is very simple to build and easy to programme, however it doesn't have much traction, if one motor fails then one whole side will be unpowered, and there is no easy manoeuvrability.

Another similar tank drive is a four-wheel drive, where either all four wheels have their own motor to power them, or if two wheels are powered and through chain or gears the other two are powered. What's good about this drivetrain is that it has more power to push robots and obstacles around, it can still move even if one motor fails, and has better steering as it has a longer wheelbase. Some cons about this drivetrain are that it is not as manoeuvrable as holonomic drivetrains and can be more difficult to adjust and turn.

This drivetrain could keep increasing its number of wheels, which would increase its manoeuvrability. A team could have a six-wheel drive train, which is recommended as it is very easy to power all six wheels with only two motors, either by chain or gears, it allows the robot to be very powerful as well as allowing it to easily manoeuvre around the field. Eight-wheel drive is also an option and it has high manoeuvrability and high push power, however now, the gears and the chains would get a little bit too complicated as one motor powering four wheels could over power run the motor causing it to break.

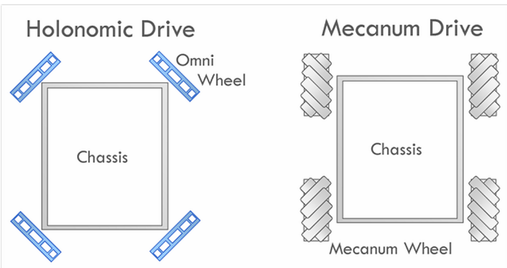
There are two different variations of the tank drive, which can only properly be used when having a six-wheel drive. An option would be to have all the wheels at the same height, which is the easiest option, however there is also West Coast drive, which has the middle wheel lowered by one fourth of an inch in comparison to other wheels, allowing for a smoother turning and a small turning radius, however it requires more work to be built.

Holonomic drivetrain

For Holonomic drivetrain, the team has to buy wheels as the ones provided with the KoP (Kit of Parts) are the REV Stealth Wheels, which work perfectly fine for tank drive, but won't be useful for Holonomic drivetrains.

Mecanum Drive:

One example of a holonomic drivetrain is the mecanum drive. The mecanum drivetrain utilises 4 mecanum wheels that are placed in tank drive position. Mecanum wheels have rollers that allow for side to side, forward and backward, and diagonal movement. Unlike Omni, mecanum wheels allow for 70 percent pushing power forward and 30 percent pushing power to the side. This is useful for playing defence or getting up obstacles. While it does have more traction than Omni and a less even power distribution, mecanum is more prone to slipping or being pushed than tank drive.



Omni Drive:

Another example of a holonomic drive is the Omni drive. The Omni drive uses 4 sets of Omni wheels (usually 2 wheels per set attached to each other) placed on perpendicular lines. With rollers on the sides of the wheels, Omni wheels can move in any direction with ease. It is slightly better than mecanum in terms of manoeuvrability. Also, since the wheels are placed at 45 degree angles, each side could be considered the front and can be used as such. However, Omni often has difficulty manoeuvring over obstacles because of low traction and split force vectors. It also means it is difficult to play defence with and easy to play defence against. Furthermore, the placement of the wheels cut into the centre of the robot, potentially taking up more space. For these drawbacks, Omni is now becoming less common and successful in FTC, although some teams still manage to do well with them. An example of a good Omni drive can be seen from many robots by team 4220 Landroids during the Get Over It!, Bowled Over!, and Ring it Up! games.

Track/Tread Tank

Using tank treads is also an option for a drivetrain. In general, tank treads are more advantageous with getting over various terrains and having greater traction than other drivetrains. However, some treads often break easily and lack turning manoeuvrability. In general, tank treads are not commonly seen due to those drawbacks.

Manipulators

Generally, an FTC®robot will have three different types of manipulators in order to get as many points as possible. This includes a mechanism that draws whatever field element into the robot, **an intake**. Then another manipulator will require that field element to be moved and placed somewhere, **the acquisition**. And finally, for most FTC®games, the robot will have to shoot or eject their game piece somehow. This could simply be by reversing the intake, or the team could make some sort of **shooter.**

Intakes

The intake mechanism determines how quickly game pieces can enter and (sometimes) leave the robot. Game pieces usually don't leave the intake until they're scored. They should be able to intake any appropriate objects quickly, whilst working efficiently with the rest of the robot design.

Passive

There are many different types of intakes. The most simple of these is a passive intake. This type is not powered, making it easy to manufacture and find space for on the robot, but it has some major drawbacks when it comes to speed. Passive intakes require the robot to drive into a very precise position to pick up an object, and in many cases the same goes for when the robot must score the object. This needed precision makes for a slow intake and thus this type is only used as a last resort.

Collector/Roller

Collectors are a common type of intake typically seen when a game involves small objects. Often making use of one or two rotating axles, collectors can intake a large number of objects in a short span of time. Collectors can also sometimes be reversed and used as an output, but they generally only take objects in for them to be scored by another mechanism on the robot.

Claw/pincer

When game pieces are not a good shape, or are too large or too heavy for a collector to be used, a claw or pincer mechanism can be a good option. As the name suggests, these are used when something needs to be grabbed or pinched, and are generally best put to use for handling larger game pieces. This type of intake is fairly easy to make, but is limited by its ability to only take in one object at a time.

Manipulation

Arms

When building a manipulator arm, making use of a linear force mechanism to push and pull the arm gives the advantage of leverage. If a range extension is needed for the arm, consider using an elbow with a snaplock mechanism to lock the arm in place once has extended to desired position. Remember that arms can be geared for high torque and still maintain speed because it takes less than one rotation of axle to extend to full position, but spring assists can reduce stress on the motor and allow for less gearing. In situations where a high precision is needed, encoders mounted to the motor output shaft (or any shaft between motor and pivot axle) can be will give more accurate readings.

There are two main types of arms: pivot and 4-bar. Pivot arms use a simple pin or axle pivot point, most often used in conjunction with the intake mechanism. They can also be fitted with an “elbow” for increased range and mobility, but this adds complexity to the design and operation of the arm. Pivot arms can be powered by a gear or sprocket fixed to the arm, or by a linear actuator attached to the arm (making use of leverage rather than motor torque). Pivot arms are compact and leave space on the robot for other mechanisms, and (depending on the rest of your robot), can rotate a full 360 degrees. However, unlike 4-bar linkages, the carriage rotates with the arm, meaning that when lifting an object, it does not stay level.

4-bar linkages, as the name suggests, make use of four bars to make the carriage or hand stay level at all times. This simplifies tasks where the carriage needs to stay level by eliminating need for movement between the intake and arm. 4-bar linkages are stable in all directions, and, like the pivot arm, can be powered by linear actuators or using sprockets or gears rotating around any pivot point of the arm. Though stable, 4-bar linkages are limited in mobility: they can only rotate around 130 degrees (dependant on the distance between the pivot points), it’s difficult to build an “elbow” range extension, and they take up a large amount of space on the robot.

Lifts

Lifts powered bidirectionally can overcome binding and friction, increasing their speed, but not all types of lifts are so easily reversed. Likewise, not all lifts can be used both vertically and horizontally as sliding and telescoping types can. Spring assists can be used when motor torque is limited as they increase lift speed and carriable weight, but again are not always applicable. When building a sliding lifter, standard cabinet drawer slides are COTS parts that work well for FTC®uses.

Telescoping lifts make use of concentric (and ideally low-friction) tubes that extend out of each other. These are usually powered by a string (tensioned to prevent jamming) wrapped around a winch drum. Telescoping lifts are very compact, but should not be used for lifting heavy game elements.

Forklifts are a more traditional type of lift, and can be used with either a cascading or a continuous mechanism. This type of lift uses bars that slide up and down on each other (think of a vertically-oriented cabinet drawer) with rollers that support the carriage on both sides. Forklifts are usually driven by a chain that runs up and down each bar on the lift. Because each bar is supported on both sides it can support heavy loads without pinching or binding. If chain isn't used, to avoid jams, it is recommended that the lift is driven bidirectionally.

Launchers

Launchers come in many shapes and sizes. Below are a few of the more common types.

Linear shooters generally use a spring or some elastic material to shoot an object, often similar to a slingshot. These can shoot quite far and their range is adjustable, but take up quite a lot of space and are slow to reload.

Flywheels use one or two heavy, fast-spinning wheels. Their range can be adjusted, and they can fire objects in quick succession as flywheel mechanisms don't exactly require reload time. However, this type of launcher can only effectively fire spheres or discs. These are not very accurate since every shot will be launched at a different voltage.

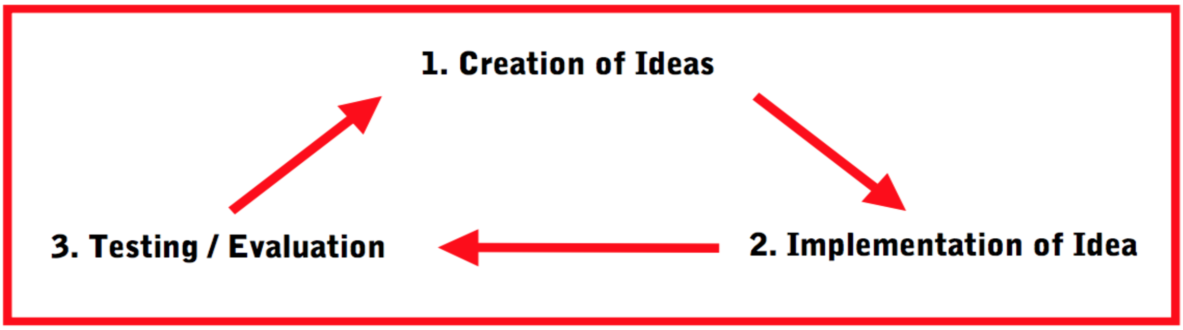
Catapults work exactly how one would expect; they "throw" the loaded object. Catapults, like linear shooters, are slow and must be individually loaded between each shot. They are generally fairly accurate, can be powered by motors or by springs, and their range is usually adjustable. A rapid fire catapult is a modification of the normal catapult that uses a specific linkage system to increase rate of fire. Unfortunately, this linkage system is mechanically tedious and can lead to mechanical failure, and the firing rate improvement prevents the shooting distance from being altered.

Flickers (a.k.a. poppers) make use of some flexible material attached to a motor; when this material comes in contact with some sort of bar, it bends back and flicks the object out of the robot. Flickers are accurate and require negligible reload time, meaning that objects can be shot quickly, but unlike flywheels, the shot distance is not adjustable.

Useful resources

Design process:

In this simple design loop an idea is generated → this idea is implemented → after the idea is implemented, the design group would test the product or evaluate the result of the implementation. Typically, during this testing and evaluation, additional ideas are generated, and the process starts over again.



Group work feedback:

- Keep an open mind. It is important to allow crazy ideas to develop. The best time for innovation to occur is early in the design process.
- Don’t become overly attached to any single idea - especially one of your own.
- Do not become defensive; don't blind yourself to logic and the arguments of others. Defend your opinions and your ideas but always focus on the ultimate goal of providing the best solution possible.
- Try to stay positive, even when pointing out negatives.
- Engineering is based in logic. Do not allow emotion to interfere with the process.
- Don’t let feelings be hurt if someone disagrees with you, even if they give into emotion and are (overly) harsh.
- An unjustified opinion is a worthless one. Describe WHY you like or dislike something.
- This is NOT rhetoric, it is engineering. It is not the one who can speak the best but the one who can provide quantitative proof that will win an argument and prove their idea is better!

Sources:

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