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Promoting STEM Education through the Preparation of Multicultural National Robotics Teams in Qatar (Evaluation)

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Abstract

In recent years, university outreach programs have increased as an effective method of imparting a comprehensive perspective into science, technology, engineering, and mathematics (STEM) careers and disciplines to school students. Different models of STEM education exist and the implementation of educational robotics to pre-college students has been deemed impactful in influencing the students' interest in STEM fields. This is due to the accessibility of educational robotics as well providing an engaging, hands-on method of combining technology, engineering, and design. Therefore, with the increase in educational robotics programs, having an end goal for the students is necessary for learning motivation. That is why involvement in international robotics competitions would meet this component. Moreover, combining the multicultural aspect that has been increasingly predominant in STEM helps raise the educational structure to a melting pot pedagogy. This provides a solid foundation for the students' development as they experience diversity consciousness even in a technical setting.

This paper highlights the importance and the techniques behind joining groups of multicultural backgrounds in Qatar to represent national teams in international competitions – notably the well-renowned FIRST Global Challenge, an Olympics-style robotics competition that brings teams from different countries to solve the challenges facing our world. Preparing for the FIRST Global Challenge includes gaining effective communication and problem-solving skills as the students work as a team to devise creative solutions to real-world engineering problems. The approach with which the students representing two different nations – Afghanistan and Qatar – were trained in a shared workspace will be presented. Qatar is known for its cultural diversity, and the schools across Qatar include students from over 100 nationalities. Therefore, determining a technique to be delivered to a multicultural environment is essential to the learning process involved. The details explained in this paper include the preparation, the topics and instructional materials taught, the structure of the training, and the end results.

Keywords – STEM education, multicultural learning, educational robotics, international competitions

1. Introduction

In recent years, the field of robotics has seen tremendous growth and advancements, leading to a high demand for individuals with expertise in STEM (science, technology, engineering, and mathematics) fields. In Qatar, this demand is particularly high, given the country's focus on developing its technological capabilities. To meet this demand, it is crucial to provide students with opportunities to learn and gain hands-on experience in robotics. One way to do this is by exposing students to new methods of incorporating STEM disciplines – and specifically engineering design – in educational robotics training with a motivating end-goal to participate in international robotics competitions [1]–[4].

The importance of diversity in STEM education has been well documented in numerous studies [5]–[8]. It has been well established that diversity in team composition can lead to increased creativity and innovation in problem-solving. It can enhance team performance by bringing together a wider range of perspectives and experiences. Furthermore, diversity and inclusion can improve organizational culture and contribute to a more positive work environment within teams.

To address this topic and promote STEM education in Qatar, this paper presents the approach for preparing multicultural national robotics teams. In Qatar, schools have a diverse student population, where each school can have students representing up to 100 different nationalities, making the country a unique and ideal setting to explore the benefits of incorporating multicultural perspectives and experiences in the preparation of national robotics teams. However, preparing students for such competitions can be challenging, particularly in a multicultural environment where students come from diverse backgrounds and, in some cases, have experienced gender separation in their cultural and educational settings. Additionally, they may have varying levels of experience and knowledge. To ensure that all students have the opportunity to participate and succeed, it is essential to adopt a comprehensive and inclusive approach to training. Therefore, the following sections detail the structure of the training that was undertaken to ensure a pluralistic framework which is an important feature in creating a unique diverse team with individuality and, simultaneously, blended together as one [9], [10].

The following sections outline the importance and the technique used for incorporating multicultural perspectives and experiences in the preparation of diverse national robotics teams that will be representing two different nations – Afghanistan and Qatar – in a shared workspace. Through the formation of such teams, students from diverse backgrounds will have the opportunity to work together, learn from one another, and gain hands-on experience in the field of robotics. This will not only enhance their STEM education but also foster a more inclusive and diverse STEM community that will be especially useful for preparing this next generation for their future.

2. Planning Phase and Team Assembly

Prior to the start of the training, the planning phase was completed to ensure that the students will gain the best learning experience. This included creating a task list as well as resource and communication plans to establish the roles and responsibilities of the team members with the prior knowledge that they will be assembled from different schools around Qatar to work together as a team. The following steps taken are part of the general program development stages of long-term programs organized by the STEM outreach team at Texas A&M University at Qatar.

Step 1: Forming the Team by Assessing Students' Skills and Interests

The first step to assembling the team members was to assess their skills and interests. The students are selected through a competitive process where they are asked to submit a registration form online. That involved the collection of basic information of the students through short essay-form answers that would help evaluate selected criteria such as the students' technical abilities, problem-solving skills, communication skills, and their general interests in participating in the STEM programs. Some examples of the questions asked include: "what discipline are you most interested to study for a university degree?", and "why are you interested in learning about robotics? What

are your career goals?". The answers would help demonstrate the students' writing and technical skills, previous involvements, and interests. The students are selected from schools all around Qatar that are interested in robotics and have shown to possess great group dynamics. Typically, the students are selected based on their performance in previous interactions from the STEM activities and programs hosted by the university where the outstanding and skilled students are identified and invited to be participate. However, there are instances where the students reach out to participate in such programs or schools would nominate their high-achieving students.

Assessing students' skills and interests helped determine the appropriate level of training required for each student, as well as identify the skills of each student and how that can be applied to create a well-rounded team.

Step 2: Developing a Curriculum

A training curriculum was tailored to the needs and abilities of the team. The curriculum considered the diversity of the students, including their cultural backgrounds, prior experiences, and language abilities. It was also inclusive, with a focus on creating a positive and supportive learning environment for all students. Moreover, the curriculum had to take into account the theme of the competition as each year, a real-world challenge is presented from the existing 14 grand challenges for engineering.

Step 3: Encourage Mentorship and Peer Support

It is beneficial to encourage mentorship and peer support among the students. This was done by creating sub-teams based on the competition requirements. This included having a social media team responsible for the creativity in capturing the team's journey and connecting them with other teams all over the world, a team for researching and determining the design on the robot lifter, a team for creating the robot shooter design, a team for building the robot driving base and intake mechanism, and a programming team that worked with the other sub-teams to operate the robot. The students were split into the teams based on their interests and skills where they ultimately decided with some interventions from the educators to allow for an efficient and cooperative learning experience.

In each sub-team, the students were paired with team leaders who have prior experience in robotics. Also, by selecting a student mentor who had participated in international robotics competitions to oversee the work helped guide them and connect with them at a peer-level. Additionally, communication platforms were utilized to form chat groups where students can work together and provide feedback and guidance to one another. Encouraging mentorship and peer support will help students to build relationships and develop a sense of community, which will be crucial for the success of the team.

Step 4: Incorporating Team-Building Activities

Team-building activities are an essential component of training students in robotics, especially in multicultural teams. These activities help students to develop communication and collaboration skills, which are critical for success in international competitions when working or competing with other teams. A variety of team-building activities, such as group projects, group discussions, and

team-building games, had been incorporated into the curriculum to help improve the team dynamics and keep the students engaged and encouraged.

Step 5: Providing Hands-On Experience

Hands-on experience is crucial for preparing students for international competitions in robotics. Educators provided students with opportunities to work on real-world projects by training them to use tools and technologies commonly used in the field. This hands-on experience helped the students develop their technical skills, as well as their problem-solving and critical thinking abilities.

3. Training the National Teams

When creating a curriculum for training students in robotics, there are several key considerations that educators should keep in mind. It is important to ensure that the curriculum is aligned with the goals and objectives of the international competition the students will be participating in – namely, the FIRST Global Challenge. This will help to ensure that students receive the training they need to succeed in the competition and will give them a narrower scope of what they are expected to achieve. Moreover, the curriculum should be designed to be inclusive and accessible to all students, regardless of their cultural background, diverse schooling methodologies, skills, or prior experiences. This paper focuses on the "Carbon Capture" FIRST Global Challenge theme that aims at creating a robot that would solve the problem of global warming and includes mechanisms to capture and store CO_2 as the rudimentary game elements. It also includes creating a team engineering portfolio where the students need to document their process and include a research section that encapsulates literature review around global warming and carbon countermeasures.

Due to the diverse student population of the schools in Qatar, the demographic diversity of the teams created a melting pot of different cultural, religious, and educational backgrounds and has led to a harmonious and unique working environment for the students. The team representing Qatar was selected based on the first step of the process listed in section 2 of this paper. Team Qatar was composed of 15 students from nine different schools and from eight nationalities and was 40% female and 60% male. As for the team members representing Afghanistan, they are formed of the Afghan Dreamers, an all-girl robotics team that had been relocated to Qatar due to the circumstances occurring in their country and for them to be able to continue their education.

The training period was split into four stages – each three to four weeks long – to enable the teams to be well-prepared through an enriching and educational journey leading to the international competition with teams from around the world.

3.1 Phase One: Introduction, Project Conception and Initiation

After the teams were formed, the two teams to represent Afghanistan and Qatar internationally were introduced to the training program as well as the requirements for the competition for which their robot design will be created. The two teams shared a common workspace: the STEM Hub at Texas A&M University at Qatar – a cutting-edge facility designed to encourage the innovative use of engineering and science. It served as a meeting place for students to collaborate on various projects and receive the training required. They had been provided with a comprehensive

introduction to the field of robotics, including key concepts, theories, and techniques by incorporating a mix of theoretical and practical components into the training sessions. For example, students could learn about the fundamental principles of robotics through lectures, readings, and videos, and then apply these principles by working on hands-on projects and building their own robots. The students met afterschool on a daily basis in the weeks leading up to the competition date.

During phase one of the training period, the teams plan, strategize, and determine the team members' skills and strengths and progress accordingly. This included the sub-teams' formation according to the competition requirements. A timeline was set to ensure that the progress flows well and for accountability.

3.2 Phase Two: Robot Building, Research, and Social Media Challenges

There have also been many opportunities for students to develop key skills and competencies, such as critical thinking, problem-solving, and collaboration. The students were introduced to the engineering design cycle (as shown in Figure 1) and encouraged to follow the process to come up with a suitable solution to their design problem. Since the students come from different schools, their learning techniques were different and the skills they brought to the team were diverse and resulted in a more effective brainstorming method as they narrowed down their designs.

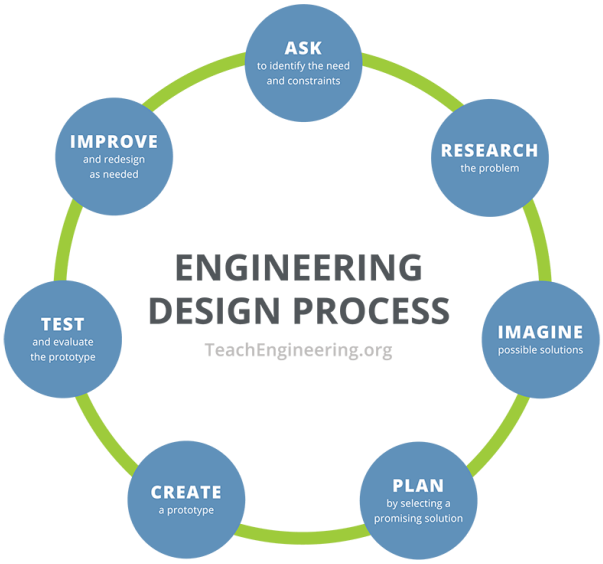


Figure 1: The engineering design cycle

The students determined the requirements of the competition and the design elements, researched and brainstormed multiple ideas to approach building their robot design, used a decision matrix to select their final designs, build different prototypes, test their designs, then modify and improve as needed. Moreover, one of the competition requirements involved social media challenges to enable the participating countries to connect with each other and ensure that collaborations occur internationally. It also helped the teams document their engineering journey that led to the competition. The fact that the students come from diverse schooling systems enabled them to learn

from each other as they brought in different skills to the team in terms of technicality, creativity, writing styles for the engineering notebooks, and ideas in constructing their designs.

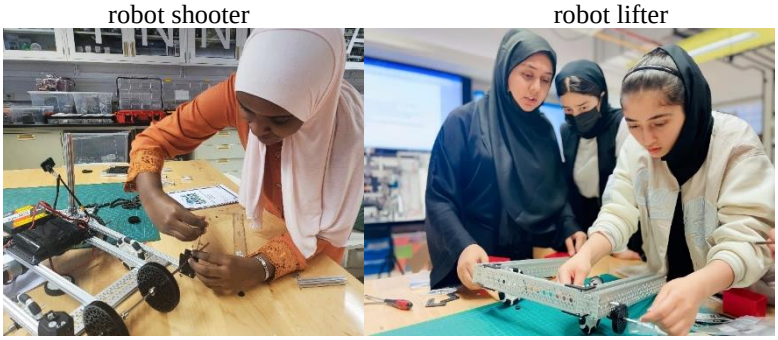
As the students followed the engineering design process in their selection of the most suitable robot design, all of the sub-teams worked together to ensure that the final design will be compatible when the elements of the robot are assembled. Figure 2 below depicts some examples of the work the students were doing in separate groups while working together.

It is important to regularly assess students' progress and adjust the training sessions as needed to ensure that they are receiving the support they need to succeed. This can be done through regular assessments of the students' progress and receiving feedback from the team members, as well as through ongoing discussions with students.

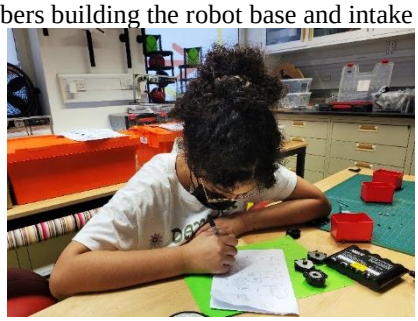
In summary, creating a comprehensive and inclusive curriculum is an essential step in preparing students for international robotics competitions in multicultural teams. By considering the diversity of the students and incorporating a mix of theoretical and practical components, educators can help students to develop the knowledge, skills, and confidence they need to succeed.

(a) Team member building the robot shooter

(b) Team members building the robot lifter



(c) Team members building the robot base and intake mechanism



(d) Team member working on team shirt and logo design

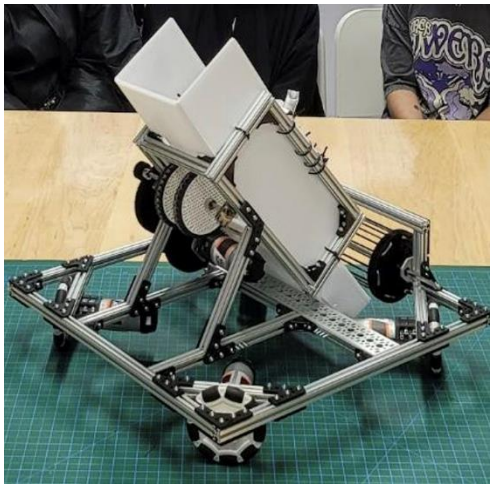
Figure 2 (a-d): Sub-teams formation based on students' skills

3.3 Phase Three: Robot Testing

As the teams continued to work to finalize their robots, the students were instructed in designing tests of their mechanisms to determine if it meets the requirements. Each test was recorded and documented to refer back to when evaluating their final designs.

Figure 3 shows the different testing stages of the robot linear slider lifting mechanism and the robot shooter with varying motor gearing to determine the strengths and weaknesses of their design or programming involved. Any redesigns needed were completed during this phase and the final testing was completed. This stage came before assembling the elements together as they needed to ensure that they were functioning well.

(a) Testing the lifting mechanism



(b) Testing the robot shooter

Figure 3 (a, b): Different testing stages of the robot

3.4 Phase Four: Finalizing the Design, Preparing for the Competition, and the Engineering Notebook

By the end of the training period, the students worked on finalizing their robots as they were ready to compete internationally with other teams from countries all over the world. This also included compiling the documentation of their journey towards achieving the end results by finalizing the engineering notebook. Through the documentation of the teams' engineering notebooks, the students learned the importance of it as an essential design tool especially in the engineering aspect. The students kept track of their progress and the refinement that had to be made along the way. It was an essential method to ensure that their work is organized, their ideas are backed up, and the information that was researched is tracked. The students then made final tests prior to traveling for the competition using the basic elements of the competition that have been constructed to ensure that the robot is performing as expected. Figure 4 shows the final robot that was built by the students.

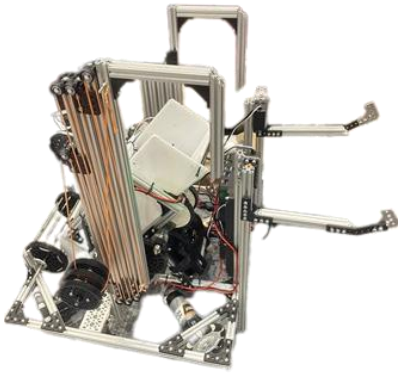


Figure 4: Final Robot Design

4. The International Competition

During the international competition, team Afghanistan and team Qatar traveled to Geneva, Switzerland and met with the other teams that were participating from 179 countries worldwide. This enabled the students to connect with the other teams representing physically as opposed to the communication method used throughout their preparation and training phase where they reached out to teams virtually and met through online platforms. It was an excellent opportunity to help bring the world's youth together to learn from each other, exchange ideas, help other teams from the skills they have gained and that was done with ease given their diverse backgrounds.

The students were able to have practice matches by creating alliances with teams from other countries to learn from them and teach them tips and tricks to perform well during the competition. During the match rounds, the teams are randomly selected in alliances to compete with each other. Coincidentally, the two teams – team Qatar and team Afghanistan – who shared the same workspace as they trained and built their robots in Qatar were teamed up in one of the matches and a few members of each team during one of the matches is shown in Figure 5. This unique experience was a great learning opportunity especially when communicating with other teams.

Figure 5: Members of Team Qatar and Team Afghanistan competing internationally

5. The Outcome

The curriculum developed to train and prepare students to participate in an international competition has resulted in a positive outcome that was tangible within the team members. The responses received were supportive and complimentary to the experience the students went through. One participant has mentioned how participating in the FIRST Global Challenge was a tremendous learning opportunity as a student to consolidate their knowledge and experiences. Moreover, the students mentioned how the experience provided them with "a platform for a diverse community of members to find solutions and collaborate on issues of purpose." The student went on to say: "One of the things that make our team unique is that we have a wide range of viewpoints on almost everything! We have gained an extensive amount of technical knowledge, while also realizing the role we play in climate change mitigation. Certainly, we will make a significant difference in the world, once we come together, and I think that is the most valuable outcome even beyond winning and scoring high ranks."

Another team member said: "This experience has not been just about learning about robotics and engineering, but also learn about many cultures and common factors that we share among each other. It also helped us learn how to manage time, be organized, and bond well as a team."

This cemented the importance of combining the multicultural aspect that has been increasingly predominant in STEM to help raise the educational structure to a melting pot pedagogy. It also deemed the structure of the curriculum a great success.

Due to the success of the training method used and the technique with which the teams were prepared and mentored locally using the expertise, resources, and facilities at Texas A&M University at Qatar, it has led to the expansion of STEM education in Qatar using robotics. This included the introduction of additional competitions such as being the certified partner to create the national FIRST Tech Challenge at Qatar – a robotics competition for a wider range of students from grades 7-12 that involved teams from schools all over Qatar where the finalist team would then be eligible to compete internationally.

Moreover, the Ministry of Education and Higher Education at Qatar was fond of the outcome and feedback received as an aftermath of the participation in the FIRST Global Challenge that they have invited the university's STEM outreach department to help mentor, organize, and participate in the annual nation-wide robotics championship that includes other countries in the region.

6. Conclusion

Bringing together a diverse team leads to a more inclusive and innovative community – which is promoted through the STEM programs created at Texas A&M University at Qatar. It has been seen through the students' interactions with each other where they bring a wide range of perspectives, experiences, and ideas, which in turn leads to more innovative solutions to complex problems. Additionally, it can be concluded that the teams that represented their countries on an international level are essential for meeting the current and future needs of the global economy.

From the experience and the results listed in section 5, there has been a positive impact that multicultural national robotics teams can have on STEM education in the region and it can

encourage other organizations to adopt similar programs. Through this effort, we hope to inspire the next generation of STEM leaders in Qatar and help close the diversity gap in STEM fields and promote integration.

These findings demonstrate the importance of incorporating diversity in education, particularly in STEM fields (as also mentioned by other researchers [11]–[15]), to improve student outcomes and increase the impact of STEM on society. By creating multicultural national robotics teams, the students in Qatar and globally can be provided – with the increasingly diverse communities all around us – with the opportunity to learn from each other and gain hands-on experience in the field of robotics, while also contributing to a more inclusive and diverse STEM community.

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