Creating an Educational Robotics Curriculum for the Mauritius Institute of Education

An Interactive Qualifying Project Proposal
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Abstract

As part of a major ongoing effort to renovate the nation's curriculum, the Mauritius Institute of Education (M.I.E.) and the Ministry of Education in Mauritius are looking to include more hands-on learning of STEM concepts in their secondary school curriculum. Our project goal was to provide them with the online materials necessary to allow secondary school instructors to teach a pilot course in robotics and programming principles to their students (ages 12-15).

We developed a curriculum with lessons and related projects. These were complete with a slide deck and teacher manual outlining the objectives, required materials, and procedures for each lesson/project pair. We hosted these resources on a Moodle site hosted by the M.I.E. for any Mauritian teacher to access, and we gathered feedback on our lessons as we developed them for both faculty at our university, Worcester Polytechnic Institute (WPI), and faculty at the M.I.E. to ensure students would be challenged while enjoying the course.

The development of this course is a small part of a massive STEM education revolution in Mauritius. These renovations will allow students to hopefully find a passion for engineering and open more doors for them in the future.

Acknowledgements

To our sponsor, the Mauritius Institute of Education, thank you for your unwavering willingness to provide support to us in multiple ways. In particular, Dr. Fawzia Narod and Dr. Roddy Lollchund were eager to meet whenever we needed background information on Mauritian education or feedback on our lessons. Without the valuable insight you provided, none of what we created would have been possible.

To our advisors, Kimberly Hollan, Joseph Doiron, and Brad Miller, thank you for assisting us at every step of the way. Your advice and guidance was incredibly valuable, especially since none of us had ever worked on a project this massive before. Your ability to lead the project and ask us the right questions allowed us to learn how to manage a project of this size on our own and deliver such an amazing curriculum to the M.I.E.. Your research insight and valuable experience with similar projects was crucial, and you all always made sure we stayed organized and on track. Lastly, your substantial experience in the field of Robotics, teaching, and project based learning was vital to the development of our lessons, and none of this would have been possible without your feedback.

To the other WPI faculty we consulted along the way, thank you all for your gracious support. To Dr. Kathy Chen from the STEM Education Center, thank you for teaching us about course design and what to look for in terms of differences between American and Mauritian education and classes. This insight allowed us to ask the right questions to everyone in Mauritius and gain information about how to structure our course. To Ms. Ruth McKeogh from the Institutional Review Board, thank you for supporting us in having our survey of Mauritian teachers and students approved. You were very patient with us and willing to guide us in navigating the IRB application process.

Executive Summary

Problem Summary

Mauritius aims to become an education hub through the introduction of new, innovative, and co-creative curriculum. In the current global society, a strong technical foundation and critical thinking skills are given a lot of importance; however, the current STEM education in Mauritius tends to focus on science and math but lacks technology and engineering components. Therefore, the introduction of a robotics course could be the perfect solution to address these concerns.

With rapid globalization, developing countries seek to decrease the gap in their technological knowledge, starting in the classrooms. Likewise the Mauritius Institute Of Education (M.I.E.) hopes to close this gap and approached WPI for assistance. To improve its students' technical skills and computational thinking, the M.I.E. requested an educational robotics curriculum. Educational robotics provides the opportunity for students to gain exposure to project-based learning and allow them to develop the underlying multidisciplinary skills associated with educational robotics.

Goals and Objectives

We aimed to create a curriculum that would allow Mauritian secondary school students, students of ages 12-15, to gain real-world problem-solving experience to complement their existing skills from their Computer Science courses.

Specifically, we defined our objectives as follows:

1. Develop a hands-on robotics curriculum with the goal of inspiring STEM within the classroom.

2. Create an online learning platform with a compilation of additional resources such as videos, tutorials, and challenges for students to solve either through code or with specific robot kits.

3. Design more specific lesson plans for instructors to use alongside the general online materials.

Methods

We started by studying similar IQPs in the past, focusing on 3 projects that worked with the Physically Active Youth (PAY) organization in Namibia to create a robotics curriculum and develop it into a competitive team. The first 2 projects created a website that instructed systems in 3 main areas:

1. General concepts in Robotics and Mechanical Engineering.
2. Concepts in Computer Science using the Scratch programming language.
3. Using the VEX IQ robotics platform to design, build, and program robots to illustrate the concepts taught in areas 1. and 2.

Our project is also based around the VEX IQ platform, but we primarily used the previous projects to help plan our research and roadmap instead of basing our lessons on theirs. This decision was made due to the different circumstances of the program we developed, due to 3 primary factors:

1. The previous groups designed their courses for students within a wide range of ages (6-18). The M.I.E. specified that our program should be intended for primarily 8th grade students meaning our curriculum must be more focused.

2. The M.I.E. specified that we should create a 10-lesson curriculum to be delivered by their computer science instructors after school to test the viability of a longer-term course. The previous projects created 27 lessons (9 per grade level) delivered through a website with more flexible pacing and asynchronous teaching style than the course requested by the M.I.E., which was to be delivered in-person with module-based lessons through Moodle.
3. The M.I.E syllabus for their students includes classes on the Scratch programming language in 7th and 8th grade, meaning students in our course would have already completed one year of instruction on the platform and would be taking more advanced Scratch classes concurrently with this robotics course. As the VEX IQ robots are programmed using a lightly modified variant of Scratch, we were able to skip some lessons on its basic use and focus on its unique features when introducing students to the language.

Despite these differences, we were able to obtain information from the previous projects that guided our research and discussions with WPI faculty.

Results

Our meetings with WPI faculty yielded helpful information on surveying students internationally and creating our curriculum. Dr. Kathy Chen from the WPI STEM Education Center gave us advice on creating a STEM curriculum with regards to its adaptability and focus on depth versus breadth. This was especially helpful when creating our syllabus and educator manuals. We also met with Ms. Ruth McKeogh, director of Human Subjects Research at WPI and IRB Secretary. She provided assistance tailoring our process of surveying potential students and teachers for our course to fit the requirements of conducting international surveys. She also helped us construct our survey questions to target specific topics that would produce the most useful data. Regular meetings with our project advisors gave timely and relevant feedback on our material and helped keep us on track to complete the project. They also guided us as we worked with our sponsors from the Mauritius Institute of Education.

This led to our creation of a syllabus of draft lessons. These lessons contained instructional slides and challenges to exercise skills learned during the lesson. This strategy of integrating hands-on challenges into lessons was taken from WPI robotics classes which concurrently combine slideshow-based lectures and hands-on assignments.

Through our meetings with Dr. Fawzia Narod and Dr. Roddy Lollchund from the M.I.E, we were able to clearly understand their view for the curriculum and its delivery. We needed to design course materials that would allow a teacher with a computer science background to learn and teach basic robotics. This led to our creation of comprehensive educator manuals in addition to the slideshow presentations. We also included example code and demo videos to help the instructors assist students with the challenges.

We didn’t receive as much feedback as we would have liked on our draft curriculum due to time constraints. While we were unable to survey or interview Mauritian educators and students, we were able to get direct feedback from our advisors, sponsors, and fellow students at WPI. This helped us refine our curriculum and improve how we presented the material to the students. For example, we completely rewrote our lesson on angular velocity and torque to move it more towards practical applications within the robot code instead of the original Mechanical Engineering-based approach we had.

We received valuable data from our sponsors on our lessons, especially with regards to keeping them concise and engaging. We also got feedback on including external references in our educator manuals for additional information and on ensuring the feasibility of the challenges within the set time.

As noted earlier, we were unable to receive responses to both of our surveys for instructors and students before the deadline. However, the responses to questions about preferences on course delivery, difficulty, and background will still be recorded and available in the future. The questions recorded students' preferences between online and physical materials as well as their experience with concepts such as computer science. Some of these topics were covered in discussions with our sponsors, which allowed us to move forwards with development.

Conclusion

On the whole, our iterative design process helped us through multiple iterations of draft curriculums and feedback sessions. We hope to inspire students through our course and help Mauritius achieve their vision of making the nation an educational hub.

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Chapter 1 : Introduction

1. Introduction

The Mauritian Ministry of Education is in the process of implementing major systemic reforms to its educational system. The aim of these reforms is to improve the public education system to expand educational access to all Mauritians, ensure that teachers are using best practices in their instruction, and that the curriculum will adequately prepare students for their futures. Education authorities have composed a mission and a vision to reform Mauritius into an innovation driven society to meet the youth's increased interest in Science, Technology, Engineering, and Mathematics (STEM) education. These reforms seek to make Mauritius an international education hub. The government seeks to achieve these goals through the improvement of their curricula and the addition of more project driven content, including a comprehensive robotics education.

The Minister of Education and Human Resources, Tertiary Education, and Scientific Research, Ms. Leela Devi Dookun-Luchoomun, addressed these goals and the intentions of this comprehensive reform effort in part with her statement on the Higher Education Bill. She stated that the "higher education sector has to be modernised, it has to be revamped and, above all, it has to be more responsive to the emerging needs of the country."(Anonymous, 2017) The "revamp" here refers to the need for an improved curriculum in addition to the incorporation of Educational Robotics. "This reform effort is therefore also aimed at supporting the young population of Mauritius to drive employment and growth in a context of changing labour market needs. [...] Mauritius is also ambitious to become a major knowledge-hub for the region by attracting brand-name providers of tertiary education. This however requires the creation of a robust, transparent and independent regulatory framework for post-secondary education."(Anonymous, 2017)

Mauritius aims to radically reform its education system to become an education hub and prepare their students for the future. They plan to improve STEM foundations as part of their educational renovations, and robotics is one such area. WPI's partnership with M.I.E. will help them achieve these goals by developing a robotics curriculum for Mauritian students and instructors. As a result, the goal of our project is to review their syllabus and accordingly develop a course to reinforce their programming skills through robotics.

Chapter 2 : Background

2. Background

The goal is to create an educational robotics curriculum that meets the needs of Mauritian students and teachers. Therefore, we aim to understand the history of Mauritius and its educational system, as well as their current challenges and goals for the future.

This background section will present important events throughout Mauritius' history that shaped its current problems and opportunities. Then it will provide a discussion of current best practices in teaching and learning, and lastly, it will talk about educational robotics and how it will play a crucial role in aiding Mauritius in achieving its future goals.

2.1 About Mauritius

Mauritius is an island country located off the eastern coast of Africa. It lies about 500 miles east of Madagascar in the Indian Ocean. The capital of Mauritius is Port Louis, and in the next section, we will see how Port Louis has played a crucial role in the nation's educational background. About two-thirds of the population is of Indo-Pakistani origin, and about a fourth of the population is Creole, or mixed French and African descent. Despite the fact that English is the country's official language, it is spoken by a very small percentage of the population. Creole, a French-based dialect, on the other hand, is the more commonly spoken language in the country. The government has worked hard to diversify the economy after the 1980's. The economy is now based on manufactured exports, agriculture, tourism, and financial services, and is no longer solely dependent on sugar production. The government now is working to add education to the list of key contributors to the economy. (Anonymous, 2021)

2.2 Mauritius Vision 2030

In the past decade, Mauritius has attracted more than $3 billion in foreign direct investment (FDI). Education, financial services, and information technology are providing the services for Mauritius to become a gateway to Africa. “We have more than forty years of history in terms of economic diversification, which rests mainly on the education and talents of our human capital,” notes Gurib-Fakim, the country’s President. This is where their competitive edge lies.

In recent decades, their education system experienced major reforms. Mauritius’ Tertiary Education Committee (TEC) devised a plan labeled the Digital Mauritius 2030 Strategic Plan. The mission is to form an interconnected society with access to knowledge and driven by innovation. They aim to boost the digital economy and broaden the delivery of public service to enable participation in an innovation-driven society. Subsequently, a Higher Education Act was passed in 2017 to promote and build towards the 2030 vision of making Mauritius an education hub.

Education plays a crucial role for their economy, and they aim to grow further. Under their mission, they wish to improve their STEM education and provide a higher quality education for future generations.

2.3 The Mauritius Institute of Education (M.I.E.)

In 1973, the Mauritius Institute of Education was formed. They mainly focused on teacher education, curriculum development, and research in education. The institution has since played a key role in the development of Mauritius’ education system. They offer courses and programs for people to earn higher education degrees. They also provide a range of academic and non-academic facilities to instructors and students alike (Anonymous, 2021). Given Mauritius’ vision for renovating their education system by 2030, the M.I.E. plans to introduce curricula better aligned with the social and economic development of the country. The M.I.E. will continue to play a major role in helping achieve the nation's goals.

2.4 Pedagogical Practices and Project Based Learning

To create an effective curriculum for the Mauritian teachers to use in their classroom, we must first understand Active Learning. Active Learning often involves fluent communication in addition to engaging and proactive learning within the classroom (Best Practices in Education, 2019). Active Learning is an instructional approach where students are taught course material through projects and activities (Anonymous, 2019). Active learning has seen "improved student perceptions and attitudes towards information literacy." Studies have also shown that Active Learning makes learning more engaging for not only the students but also the teachers (Thaman et al., 2013). Students absorb material taught by teachers much better when reinforced through projects and hands-on lessons.

Active learning can be reinforced within classrooms with the help of projects. "Project Based Learning (PBL) is a teaching method in which students gain knowledge and skills by working for an extended period of time to investigate and respond to an authentic, engaging, and complex question, problem, or challenge" (Anonymous, 2021). As students move out of classrooms and into the world of work, they will most likely face problems on a much larger scale and will have to learn to break down those larger tasks into smaller sub tasks. They are going to have to use their problem solving abilities and critical thinking skills to analyze, break down and solve those problems. "A growing body of research supports the use of PBL. Schools where PBL is practiced find an increase in attendance, cooperative learning skills, and student achievement. When technology is used to promote critical thinking and communication, these benefits are enhanced (Anonymous, 2007). Moreover, "it is known that children have various learning styles. They build their knowledge on varying backgrounds and experiences. [...] PBL addresses these differences, because students must use all modalities in the process of researching and solving a problem, then communicating the solutions" (Anonymous, 2007).

Because of Active Learning and PBL, lecturers have seen a positive attitude towards learning in classrooms. Students have also developed skills such as critical thinking, problem solving abilities, as they are forced to practice such skills when faced with challenges. Therefore, we believe it is beneficial for the students to be exposed to such challenging projects in the early stages of their growing careers. Our project was built on the fundamentals of Active Learning and Project Based Learning to achieve this effect.

2.5 Educational Robotics

While Active and Project Based Learning are methods of teaching and learning, educational robotics constitutes the subject matter of our course. Robotics is a subject that encompasses every aspect of STEM. Likewise, educational robotics is a discipline capable of teaching students about robotics and programming, even at a very young age.

Educational robotics enables students to gain a deeper understanding of programming and robotics fundamentals while simultaneously learning other cognitive skills (Anonymous, 2021). Some of these skills include: critical thinking, teamwork, preparation for the future. Robotics is a very practical field, with many opportunities for labs or projects. Not every field offers such opportunities for creativity and teamwork. Students can come together, interact, brainstorm and see their work come to fruition.

The subsequent section talks more about how exactly it is that students can engage with educational robotics. It sheds light upon the various educational robotics platforms, and we talk about how and why we have chosen VEX IQ as the platform for our project.

2.5.1 Educational Robotics Platforms

There are a myriad of educational platforms such as Lego Mindstorms, VEX Robotics and First Robotics that aim to indulge the youth into the world of educational robotics and introduce them to the robotics culture. Each platform caters to a different age group and these platforms each have a ranging technical compatibility with respect to hardware and software.

For this project, we decided to use VEX Robotics for several reasons. Firstly, our Interactive Qualifying Project (IQP) builds off of previous IQPs that have used VEX. Secondly, Mauritian faculty and students' familiarity with VEX and our own previous work with VEX made it the right choice for the educational robotics platform for this project. VEX offers kits for a range of ages:

Table 1: The VEX product line (Anonymous, 2021)

VEX Kits	Recommended ages
VEX.123	4+
VEX.GO	8+
VEX.IQ	11+
VEX.V5	14+

The kits meant for younger children often include plastic components; however, as we move further down the table into more advanced kits, VEX uses metal components that offer much more robustness and functionality. For the purpose of this project, we used VEX IQ kits for the Mauritian secondary school students who have little no prior robotics experience.

Figure 1: VEX IQ Clawbot

2.6 Summary

Mauritius is working towards its 2030 vision of becoming an education hub. Achieving that vision requires major educational reforms, however. To achieve those goals, the M.I.E. aims to improve their curricula with the addition of educational robotics.

In addition to course material within the curricula, teaching methods such as Active Learning and Project Based Learning are widely used as a means to inspire innovation. Consequently, the M.I.E. intends to develop their curricula in a manner that promotes these teaching methods.

Since their vision aligns perfectly with that of WPI, WPI has partnered with them to assist the M.I.E. in their efforts. Our next step was to combine our knowledge of Robotics and Active Learning with their vision to create a Robotics curriculum.

Chapter 3 : Methodology

3.1 Methodology

3.2 Summary

We outlined some objectives to guide us through the process to develop and deliver a Robotics Education curriculum to the M.I.E. These objectives were established to help us to create an engaging and valuable set of lessons and projects that will provide a foundation for the M.I.E. and the Mauritius Ministry of Education to grow the program into something that can be integrated into the nationwide curriculum. The following are the four objectives we set to accomplish this task:

1. Understand curriculum development best practices and our target audience.
2. Develop lessons and projects.
3. Collect feedback about our curriculum from instructors.
4. Integrate the feedback into our finalized curriculum.

As we collectively had little experience with course design and no experience with the Mauritian education system, our first objective was to understand how to design a curriculum that would be engaging and relevant to students and instructors in Mauritius. This included course design principles as well as information about the materials we planned to use.

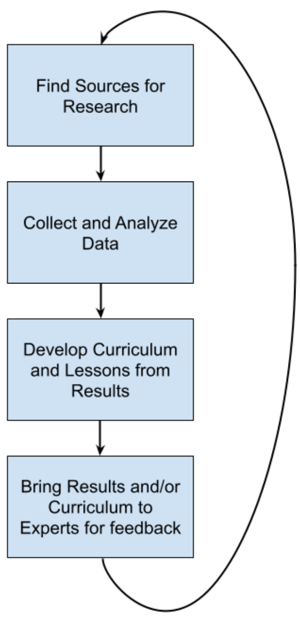
After we became more confident with our knowledge of instructional design best practices, we started developing the curriculum. We employed an iterative design process that included creating initial draft versions of the lessons and other materials. We seeked to create a rough draft of our curriculum during this stage to receive feedback later.

Then, after we completed our initial lessons, we planned to solicit feedback from a variety of experts such as WPI professors, our sponsors at the M.I.E., and instructors and students from Mauritius which was then used to create the next draft version. We gathered as much feedback as possible on our materials, even if some of our sources did not pan out. We intended to have feedback spread out evenly during the development phase so that we could shape our materials as we developed them rather than waiting until the end. After we collected additional feedback from experts, we revisited our curriculum and integrated their recommendations into final drafts. This iterative design process will be explained in greater detail below.

3.1 Methodology

The iterative design process is a design approach where developers work on a project, and with continual feedback, they revise the project and follow the same procedure until they reach a final product that fulfils all their objectives (Eby, K., 2019). When one is not as knowledgeable on a subject, this approach can be beneficial. The researcher does not lay out a concrete plan at the beginning but rather lets the information guide their approach, like a detective. We decided to incorporate these principles into the structure of our own project and have iterations where we learn, develop, and refine.

Figure 2: Diagram of Methodology



Rather than work on each of our objectives separately, we decided that our curriculum would be more effective if developed through the iterative structure of research followed by development and then feedback, as shown in Figure 2. This flexible approach means that we let the data and feedback guide our development process. We also would have a work-in-progress curriculum to showcase to experts for feedback during the process rather than simply discussing ideas with nothing concrete to look at.

3.1.1 Objective 1: To research curriculum development methodologies and understand the context

We split our research into two separate phases to first gain a broader understanding and then gradually narrow our focus to secondary schools in Mauritius.

The first phase focuses on our initial research into the history and educational policies in Mauritius, information about the tools and materials we plan to integrate into our course such as the VEX IQ platform, and general course design principles. This step served as a broad introduction to the project and came before any curriculum development or feedback. This was the foundation for our initial curriculum design, which we then got feedback on as part of the first iteration of the process shown in figure 2 above.

Our second phase narrows our focus more towards the design of our course for secondary school students. We reached out to faculty at WPI and looked more deeply at educational design resources to help us plan out the learning objectives and overall structure of our curriculum. We aimed to learn from experts in course design and secondary school education to gain insight into what we should and should not do with our course.

3.1.1.1 Phase 1: To gain a deeper understanding of the Mauritius Education curricula

For the general background research as part of phase 1, we looked at the history of Mauritian Education and their current initiatives to renovate the nationwide standards to better understand how our project fits into their mission.

Secondly, we consulted resources from experts on general course design principles to gain a broad understanding of how to create a curriculum. Our primary resources for this portion were other IQP papers, presentations, and websites, specifically the ones working with P.A.Y in Namibia. These projects, which were also around designing a new extracurricular Robotics and STEM curriculum for students and teachers.

Next, we reviewed the core resources we would be using as the foundation of our lessons. These included the VEX IQ kits and accompanying materials used for hands-on projects, the VEXcode language used to teach programming concepts to those with no prior experience, and the course development platform Moodle used to host our materials and present them in an accessible format for both instructors and students. We each had one of the VEX IQ Super Kits (as shown in figure 1), which were the same ones we distributed to the M.I.E. for use in the course. We first followed the given instructions for the generic "clawbot" (see figure 1 above) to determine the time, previous skill, and required additional help needed to assemble a robot which could be used as a tool for our programming and Engineering lessons.

The final portion of our phase 1 research was to experiment with Moodle as a medium to provide class materials to both instructors and students. Moodle is an open source platform which allows one to easily create a course site, similar to Canvas, which is another course management system that supports online teaching and learning, with resources, assignments, files, and more for instructors and students. People with different roles, such as students and instructors, can have different views and separate access to various materials. We had not yet finalized any of the lessons or other materials that would be put on the final Moodle site, but we still were able to follow tutorials and create a template version that allowed us to gain familiarity with the platform and its capabilities.

3.1.1.2 Phase 2: To gain a broader understanding on curriculum development

Phase 2 was about refining our basic curriculum with the expert opinions of WPI faculty. We interviewed instructional designers at WPI on how to create a curriculum valuable for both students and instructors. People from the STEM education center will hopefully be able to tell us about developing materials for teachers and students at this project's specific level of secondary school. Lastly, we believe professors will be able to provide valuable insight on the difficulty levels and pacing of our curriculum given the vast number of students with differing needs they teach every year. All of this will still be general curriculum advice that leads up to the next phase where we focus on working heavily with instructors in Mauritius.

We spoke with Dr. Kathy Chen from WPI’s STEM Education Center about general tips and advice for starting a secondary school course in another country. She works with teachers who approach WPI to help them develop curriculum, lessons, and materials for their classes. She has much experience with course design as well as fitting curriculum to meet the needs of both instructors and students, which is something none of us had any experience with. Even though she had only worked with teachers from the United States, we hoped she would be able to tell us what to expect in terms of similarities and differences between how each nation runs their education sector. In addition to our advisors, Dr. Kathy Chen from the STEM Education center, and a handful of WPI professors, we hoped to have a lot more conversations with experts at WPI and elsewhere during Phase 2.

3.1.2 Objective 2: To develop engaging curriculum content

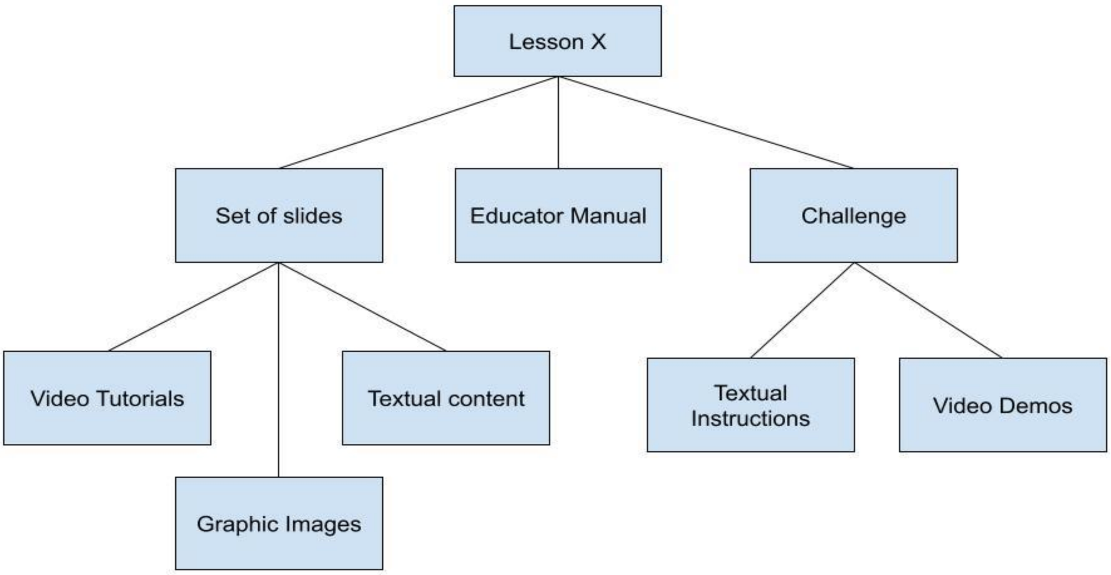
It was clear we would need to plan the structure of our content before we could start developing it. Thus, the first step of development was to plan out the structure of our curriculum by developing a syllabus and template for each lesson. By translating our data gained from background knowledge into materials for the course, we can effectively kick off the content creation phase. The initial curriculum development would consist of planning out course objectives, learning outcomes, and general structure as well as filling in that information into a syllabus and lesson template. Taking inspiration from how curricula are designed at WPI, we started with first developing a syllabus for the course.

The syllabus would guide everything about our course from the content to the structure. We recognized the importance of having a guiding set of principles for what we want to teach and how we want to teach it. Thus, we realized the first thing we needed to come up with was a set of learning objectives to dictate what our students should be able to take away from the course. With learning objectives in place, we could then start planning how we want to accomplish those objectives over the length of the course. This would involve creating a schedule for lessons and projects, making a template for each lesson based on data collected in our background research, and brainstorming content ideas to present for feedback.

We had only planned for the initial iteration of our methodology cycle. We knew that the first stage of curriculum development would be very broad and heavily based on our initial research, but, as our iterative design process would state, we waited on planning later stages of development until we had more data and confidence from feedback and research of previous iterations. The plan was dynamic and changed as we progressed.

Once we understood how our course was supposed to flow, we could begin creating actual content for those lessons. Here's how we planned to deliver each lesson:

Figure 3: Lesson Plan



The objective of this IQP was to create deliverables for the instructors to use with students. The key here is that everything we create may indirectly be for the students, but it was meant for the instructors first. Therefore, we created educator manuals to go along with every set of slides. These manuals were essentially meant for the instructors to use as a means of preparation for those slides they were going to present.

We also planned to create a challenge to go along with every lesson. For example, if they were introduced to the basic VEX IQ elements, their task would be to use those and create a small clawbot that they would use for the rest of the course. The idea was to create these challenges in a way that would build up to a final project that would require students to understand or review all of the previous lessons. This would be the last part of the course, like a capstone for the students.

3.1.3 Objective 3: To solicit feedback on our draft curriculum

To receive feedback on our ideas and materials, we first needed to identify sources which we could regularly receive input from throughout our process. We thought it was important to meet with the same people so that they could see the curriculum develop as we did and be able to give more informed advice. Like with the last two of our three phases for tackling objective 1, we sought feedback from both WPI faculty as well Mauritian experts to have variety and differing perspectives.

If needed, we would also reach out to the same instructional designers and STEM education center members from our research phase. We planned that we would primarily collect our feedback from our WPI sources early on in the project, and then we would transition into meeting more frequently with people from Mauritius who could give us more informed advice.

Gathering data and feedback from experts in Mauritius would be crucial because the course needed to be designed to fit their needs and expectations. Thus, we anticipated to receive feedback from a variety of sources to have as much input as possible. Our contacts from our sponsor, the Mauritius Institute of Education (M.I.E.), were eager and willing to help us with any questions and feedback we needed, so we proposed to set up regular meetings to both check in and receive input on our materials. In addition, we wanted to gather advice directly from the secondary school instructors and students to whom the course would eventually find its way to. For this, we planned a survey and possible interviews if time permitted, although we knew that both would take much time to receive approval from both the WPI IRB, the M.I.E., and the Mauritian Ministry of Education.

3.1.4 Objective 4: To integrate feedback into our finalized curriculum

We planned to only develop a few introductory demo lessons with an educator manual with an example challenge at first. Then, we would present these lessons and receive feedback applicable for our future lessons.

1) The course material within our slides: to incorporate this we modified our content accordingly. Here, we either simplified the language of the material, which would mean that we had to use jargon that would be age appropriate, or we cut or added more material within our slides.
2) The educator manuals: in this case, we had to make sure that we presented the instructors with sufficient and well explained material. As a result, here, we were expected to add more detail and more jargon than we did for the slides.
3) The challenges: here the expected changes were to explain our challenges better, perhaps with videos and demos. Subsequently, we were prepared to not only write those challenges, but also complete them with our personal robot kits.

We expected feedback on nearly every aspect of our curriculum, and we were prepared to incorporate all possible recommendations and changes into our project.

3.2 Summary

First, we needed to understand how curricula were developed and what could possibly be taught within our curriculum. After some background research, we hoped to start developing the syllabus and define the structure of the course and lessons. Then, we would begin creating the individual lessons, where each lesson would contain a set of slides, an educator manual, and a challenge. Each set of slides would consist of graphical and textual content which would further be explained to the instructors within that lesson's educator manual. As part of Active and Project Based Learning, the students will be tested with interesting challenges that will require them to use what they learned from the lecture. Once we develop a few lessons, our goal is to ask for feedback on our content and accordingly remodel our content and structure based on the results. This cycle would repeat a few times until we had a solid curriculum grounded in the data collected from our research and feedback.

Chapter 4 : Findings

4.1 Research Findings

4.2 Findings from creating draft lessons

4.3 Findings from receiving feedback on our draft curriculum

4.1: Research Findings

4.1.1: Findings from our systematic review of previous IQPs and Curricula

Thanks to the M.I.E., we had access to the syllabus for the entire national curriculum. All subjects from Computer Science to Foreign Languages to Arts had detailed learning objectives and expected competencies separated by subject and grade level. We were able to learn about our future students' experience level with coding and robotics. Students in secondary school, grades 7-9, learn a great deal about engineering through "Technology Studies" and computer science through "Information and Communication Technology" courses. These disciplines cover the basic hard sciences, a broad overview of many engineering fields such as material science and design, programming with scratch, and many other useful skills not directly relevant to our project (Anonymous, 2021).

Since our students will be competent with computers and have a solid background in coding and engineering physics, we knew to cover the basics briefly as a refresher but quickly move on to new material. This will be discussed more in the section on developing our lessons below. We knew they had no Robotics experience, but they had knowledge of coding, electronics, and mechanics separately from previous years. Thus, most of our lessons were designed to introduce them to Robotics as a combination of concepts they were already familiar with.

Looking over similar IQPs from previous years gave us insight into how to approach the large challenge of creating a curriculum from scratch. We mainly looked into two different IQPs, "Educational Robotics for Physically Active Youth (P.A.Y.)" (Anonymous, 2020) and "Renovating an Educational Robotics for Physically Active Youth (P.A.Y.)" (Anonymous, 2020). Both projects took place in Namibia for an after-school program called P.A.Y. that provides education and activities for children, with the second IQP being a subsequent iteration of the first. Like our project, the Namibia teams created a robotics curriculum by developing their own lessons and materials for teachers to use with students, with everything hosted online. As such, we based much of our project structure, methodology, and curriculum materials on their work and findings.

From the first iteration, we used a similar project structure of research, development, and feedback because they had great success with it. They had three steps for their IQP structure, “Equip”, “Create”, and “Refine” (Anonymous, 2020). The first phase consisted of background research on robot kits, financial sponsors, and online platforms. The “Create” phase then focused on developing the curriculum materials based on the background knowledge, but without any feedback during the development process. Finally, the feedback phase was where they received input from educators and students, and they modified their materials and curriculum accordingly. We thought the process of research followed by development and feedback was effective, but we wished to have more outside input during the development process as opposed to waiting until after the first draft of all of the materials had been finished. Thus, we came up with our iterative structure that went through the cycle multiple times as opposed to once. This allowed us to save time by developing our course resources with Mauritian instructors and students in mind rather than making them as we saw fit and waiting until the end to modify them.

The first iteration also had success with developing a set of course objectives and a template for each lesson before diving into the development of the individual sessions. By planning out the curriculum as a whole as opposed to developing the course lesson by lesson, they ensured that the materials would work together to effectively teach the students everything. Their research in course design allowed them to create a template for each lesson that would successfully teach one piece of the course while tying it together with the previous activities. They followed the pattern of starting with a main objective, incorporating the students' knowledge from elsewhere, introducing new concepts, developing experience through hands-on activities, and ending with a set of questions to guide the students' thinking and takeaways (Anonymous, 2020). The combination of the course objectives that covered the whole curriculum and a template that could be copied for each lesson created a solid skeleton that could easily be sculpted into anything based on their research and feedback. Since this structure had worked out well for them, we decided to develop our curriculum in the same way by developing our own course objectives and template.

Even though the Namibia teams worked with the same VEX IQ kits and VEXcode platform, we were unable to make use of their lessons beyond examples because of the different content and target audience. P.A.Y. in Namibia hosts children from ages 6-18, and the other IQPs developed a curriculum that had lessons for all age groups. They had a couple of lessons for each demographic with the idea that students could be placed according to their individual experiences and advance beyond their age group's materials if needed. This system worked out well to cater to children of different backgrounds, but provided very few lessons of any one difficulty. In Mauritius, secondary school education is highly regulated and we can expect all of the students to have a solid background in STEM. As such, it is much more useful to have a deep curriculum targeted towards our narrower audience than a broader one where students would finish quickly. In addition, they decided to use Wix for their website and structure, whereas Moodle is designed for hosting courses and has different features.

Similarly, the educator feedback included in their paper is not as relevant because of the different course structure and age group. However, there were some interesting takeaways that we applied to our work. The survey questions and feedback all collectively talked about student engagement. To keep people engaged during a lesson, it seemed like the lesson needed to be age-appropriate and interactive. From the feedback they received, some lessons that were too basic or too complex were not engaging, and as a result not effective at conveying the desired objectives. Thus, we made it a priority in our work to ensure that our lessons and projects were engaging to our audience. Another prevalent issue when designing the specific lessons was the assumption of prior knowledge. It seemed like they tended to skip introductory topics, such as physics, when talking about parts of the robot and the instructors thought the lesson was moving too fast. This was not as much of a concern with Mauritian students that had a solid background, but we made sure to explain everything thoroughly while starting from a recap of information the students should have already covered. After all, it is easier for students to understand new concepts if they are reminded of what they previously learned and can see the connections.

The second iteration of the IQP, "Renovating an Educational Robotics for Physically Active Youth (P.A.Y.)," focused on building off of the existing work of the first IQP. Their main objectives included gathering feedback on the current materials, adding more content to existing lessons, and creating new ones, and incorporating more projects. They followed the same structure as the first IQP and our project, except with an additional feedback step before the first research phase. Those two were then followed by a development phase and a final feedback phase, which further justified our decision to organize our work in a similar way. The methodology and findings from feedback were also similar with those of the first IQP, so we were confident in what common traps to avoid when making our curriculum materials.

In terms of recommendations, both projects stated the same list of objectives. Both IQPs put much effort in making a few lessons for many different age groups and recommended that others make the content more deep within each level. Since our project is only targeting one level, we will prioritize the depth of our curriculum to make it more engaging and valuable for our students. The Namibia teams also heavily recommended similar projects and IQPs, such as ours, utilize their strategies and materials as much as possible to expand the course into other sites.

With a solid understanding of the work other teams had done on similar projects, we decided to start reviewing the materials we had planned to use for the delivery of the course material.

Given the previous IQP's successes with the VEX IQ kits and our sponsor's use of Moodle as a platform for hosting courses, we investigated these two tools to see how we could best utilize them when developing our course. Unlike with the previous IQPs in Namibia, our sponsors and advisors had already chosen these materials based on their proven effectiveness. As such, our research was not focused on evaluating the value of the VEX IQ kits and Moodle but rather planning how to best design lessons around them.

We were using the VEX IQ super kit, which included all of the parts and instructions needed to build a basic clawbot. This includes the programmable brain, four smart motors, various sensors, a controller, and beams and plates to attach everything together (see Figure 4 below). One benefit of the VEX IQ kit is that little prior experience is required to figure out how the pieces fit together, as the parts snap together and the electronics just need to be plugged into any port on the brain. As such, it is easy to assemble and beneficial for students to start learning and testing without wasting much time. We were able to assemble the base clawbot in under an hour, and we figured that this would be about the same for students with the help of an experienced instructor as well as guiding videos.

The kits have a large variety of parts as well, which allows for many different robot configurations. We planned on walking every student through the build process of the standard clawbot, but we also wanted customizability so that our students could spend time experimenting with different builds for their final project. The kit includes a distance sensor, a color sensor, two touch sensors, and a gyroscope. The smart motors have built-in encoders and feedback controllers for both velocity and position. This may not seem like much, but this was simple enough to not overwhelm students while being sufficient to teach them about the basic concepts such as control algorithms and sensor integration. Overall, the pieces were simple and versatile, making it perfect for our introductory robotics course.

Figure 4: Contents of VEX IQ Super Kit

We were reasonably pleased with the VEXcode platform used to program the VEX IQ robots. After building our initial clawbots, we then followed the basic programming tutorials also included in the kits to figure out how to best relay these concepts to our students. VEXcode makes complex tasks, such as controlling actuators from sensor feedback and combining multiple parts of the robot into one subsystem, easy and fast (see Figure 5 below). The smart motors for the drivetrain and the gyroscope can be grouped together into one Drivetrain, which can then be easily controlled by the blocks below such as move and turn. The grouping features and simplicity of the code is very useful because it allows us to teach students the concepts of subsystems and control loops but not have to wait long before seeing them in action. It may be more valuable for the students to create the implementation themselves in some cases, but we believe the drag and drop method works better for our introductory curriculum.

While the simplicity of the block-based system can be useful, there are many useful features which are not included. For instance, the robot is not capable of driving and turning at the same time when the Drivetrain grouping system is used. To drive in curves or arcs, you must control each of the motors separately and lose the convenience of having one drivetrain to control. In addition, the color sensor attempts to map its input into one of several predefined colors which are arbitrary and often misclassified. The color sensor is very sensitive to changes in light and location, so it is very hard to detect similar colors or the same color in different environments. Overall, these challenges will not impact our student's ability to learn the material and projects, but it was important that we discovered these flaws early to account for them in our materials. By testing out the clawbot build instructions and creating functionality for the robot's drivetrain, arm, and claw through VEXcode programming tutorials, we also gained a sense for how to structure our curriculum and split up lessons based on what could reasonably be accomplished in the time span of one session.

Figure 5: Screenshot of VEXcode Blocks

In addition to using VEX for robot kits to accompany our curriculum, we also planned to use Moodle to host our materials for students and instructors to access. Our sponsor uses Moodle for all of their own curricula, so they wished for us to use the same platform. Since

Moodle is open source and widely used, we were able to set up a local example site quickly. Moodle is very similar to Canvas, with different views for both students and teachers. Teachers can access all of the materials and choose what is published and when. It is easy to integrate quizzes, assignments, files, slides, and more into the pages to customize the curriculum in any way imaginable. In addition, little programming knowledge is required but can be used to further customize the site. We did not make use of all of these features, but we found the customizability of the pages to be very useful. We had a page for each lesson, which was split into a lecture section and a project. The lectures included slides, videos, and links for further reading, which we were able to put all in the same place for ease of access. We were also able to make manuals for each lesson that were only available to the teachers, whereas the instructors could make the previous slides and other materials available for the students to review after each session. The Moodle platform was easy to learn and use, and it worked well for our project since it was able to be integrated easily with the Mauritius Institute of Education's existing Moodle site.

4.1.2: Findings from interviewing WPI faculty and professors

After our initial background reading, we decided it would be best to consult some experts at WPI about course design and general advice for teaching curricula. We had originally planned to interview many WPI faculty from various areas, but this phase was cut short due to time constraints. As such, we were able to meet with Dr. Kathy Chen from WPI's STEM education center about what to look out for when designing a curriculum for high school students. Regarding our plan to carry out a survey of Mauritian instructors and students, we reached out to Ms. Ruth McKeogh from WPI's Institutional Review Board (IRB) to learn about survey best practices and ethics. Lastly, we also met extensively with our advisors for feedback on every part of the process.

We decided to reach out to Dr. Chen for broad advice relating to our project with the hopes of becoming more knowledgeable about both how to structure our course and what were the important questions to ask during Phase 3. As a member of WPI's STEM Education Center, she works with outside teachers and schools from the U.S. that approach WPI for help with designing courses or for general advice. She had worked closely with many teachers to design lessons and curricula for introductory engineering courses, so we knew that she would have valuable insight that would help us with our project. She immediately pointed out to us that designing a course for schools in Mauritius would likely be different than doing so for ones in America because of national regulations. She noted that we would need to carefully follow any national regulations and be very sure about these rules so that we could design a course that would be usable. She recommended basing our materials off of the U.S. standards initially, which involved laying out a detailed course plan with learning objectives to accomplish. This would help us plan for our development as well as document our course's overview, which she explained that Mauritius would likely need to see given that the U.S. does. From this and our background research, we knew our first step was to create a syllabus for our course that would guide the creation of our lesson template and then our lessons.

Dr. Chen also had great insight about how to teach engineering and coding through robotics. She explained that it is important to not focus on the building and programming of the robot but rather the skills learned in doing so. In other words, the course needs to explain why constructing the robot in a certain way or programming it so is important and how it relates to other parts of the robotics industry. As an introductory course, it is our job to teach the basic concepts but also connect everything to broader skills, such as the engineering design process or problem solving techniques. She helped us realize that this was a course for problem solving skills, coding experience, and engineering rather than building a robot from a kit and having it move around some. This mindset heavily influenced the development of our syllabus and lessons, as everything was designed to introduce our students to useful concepts and then showcase them through work with the robots and software.

Ms. Ruth McKeogh, the director of Human Subjects Research and member of the WPI IRB, was kind enough to meet with us to answer our questions about how to conduct a survey in another country. Firstly, all research on human subjects needs to be approved by the IRB to ensure that participants know their rights and risks. We decided to make our survey completely anonymous so that there was no possible way the results could negatively impact the participants, even though there was negligible risk with the few simple questions we were planning on asking. Because we were surveying minors as well, the IRB required us to receive parental consent. This meant that we had to distribute our surveys to the parents of secondary school students and have them pass the forms on to their children. For the integrity of the results, Ms. McKeogh stated that we must make it very clear that this is a joint survey with WPI and the Mauritius Institute of Education and that no one is receiving compensation for these results. She greatly helped us navigate through the weeds of approval to ensure our survey would be successful.

Ms. McKeogh also gave valuable insight on our questions and delivery. She recommended that we first determine what conclusions we want to make and then group them into categories. For instance, if we wanted to know how long we should make each session in our curriculum last, we needed to find the best question to ask and analyze instead of just sticking that question directly in the questionnaire. Once we had the categories of information that we wanted, we could go down the list and brainstorm what questions to ask and how to analyze the results. She noted that the analysis of the results was as important as the question itself because we needed both to make the conclusions we wanted to. From all of this, we learned that a successful survey requires careful planning and attention to detail, and we knew that we had to design each question individually based on the result we wanted. In addition, we knew we also had to come up with a plan on how we were going to analyze the results and incorporate our findings into our curriculum.

Over the course of several weekly meetings, our advisors also had much advice about planning the development of our curriculum. The most important thing they urged us to consider was to plan the objectives of the course before diving into the lessons. It was important to consider the skills and concepts we wanted the students to take away so that we could plan the lessons around those objectives. There was an important distinction between concepts to be taught with lectures and skills to be shown through projects and hands-on work, as both rely on the other. Another key part of curriculum design was that it must be done in close collaboration with Mauritius instructors and our sponsors in order for the course to be useful to them. They noted that this co-design philosophy is important to ensure that our target audience is our first priority when making a curriculum for them. In addition to the development of our materials, they also recommended that we document every step of the process so that we can revisit our previous findings and give effective recommendations for other teams and projects.

After meeting with Dr. Chen, Ms. McKeogh, and our advisors, we would know what to expect and what questions to ask when we spoke with educators in Mauritius. The only real way for us to learn about the specific secondary school students in Mauritius was to talk with instructors and students in Mauritius, so we knew they would be our most important contact.

4.1.3: Findings from interviewing Mauritian instructors

Having completed our initial background research and received general advice on curriculum development from WPI faculty, the next step was to take our knowledge and apply it to the specific of our project in Mauritius. Thus, we formulated questions for our

Mauritian contacts to better understand how we can best make a course that will fit their needs. We met multiple times with our sponsor, the Mauritius Institute of Education, which works with the Ministry of Education to create the nationwide curriculum. We also planned for surveys and interviews with secondary school students and instructors, although this was cut short due to time constraints.

After meeting with our sponsors, we were able to answer a lot of our questions regarding not only the course structure, but also regarding the student culture in Mauritian schools. We understood the precise needs of our Mauritian team. We noted how the fundamental idea was to teach advanced coding through robotics, and how the course was to be designed for instructors to teach rather than for the students to follow on their own. Additionally, we learned more about how COVID was still a problem in Mauritius and the curriculum materials needed to be available remotely. Moreover, we learned more about our target audience, the teachers and the students.

The expectation was for an Information Technology (IT) instructor to teach our lessons to Mauritian students. Therefore, we had to rethink our syllabus. We decided to exclude some mechanical concepts and to focus on more programming ones. We also found out that the students were going to be 12 to 15 years of age, and we had to tone down the use of jargon within our lessons. We had to redesign our content to match the understanding of an average grade 8 student. Lastly, we noted details about the course structure: we were asked to have a course designed with approximately 10 lessons and that we were going to cater to roughly 10 educators and 100 students in total.

We used our surveys and questionnaires as a means to interview the team in Mauritius, but we unfortunately did not receive responses in time. Additionally, we also ran out of time for interviews with Mauritian secondary school students and teachers. Instead, we decided to focus on creating draft lessons that we could submit for timely actual feedback from our advisors and sponsors.

4.2: Findings from creating draft lessons

Because this syllabus was developed for 12-15 year old children, the language had to be made age appropriate. In addition to objectives, the syllabus also needed a lesson plan, which included the order of the lessons and the material that was going to be covered in those lessons. The advantage of having such a lesson plan was that it would give a clear directive in regards to what the course was going to look like to not only instructors and students, but also to us while developing the lessons.

Figure 6: Schedule given in the syllabus

Schedule

Lesson 1:
- Platform (VexIQ) best practices / robot essentials (motors, sensors)

Project 1:
- assemble clawbots, teleop driving
- Challenge: Manual driving and dexterity practice

Lesson 2:
- Reading remote control inputs, integrating within code.

Project 2:
- Advanced remote control of the robot
- Challenge: Controls Experimentation

Lesson 3:
- Navigation sensors, Encoder-based driving

Project 3:
- Basic auto driving
- Drive in arbitrary shapes

Lesson 4:
- Angle control in geared mechanisms

Project 4:
- Auto control of robot arm to grab / lift objects

Lesson 5:
- Basic Interaction Sensors (color, distance, buttons)

Project 5:
- Find / grab object autonomously

Lesson 6:
- Control Algorithms

Project 6:
- Proportional Distance Following

Lesson 7:
- Drive Navigation

Project 7:
- Precise drive for final project

Lesson 8:
- Decision Making

Project 8:
- Final project control

Lesson 9:
- Troubleshooting / testing code

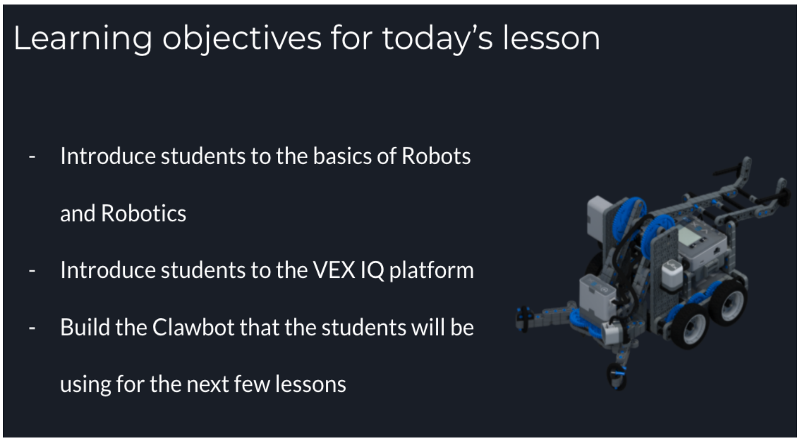
Project 9:
- Work on final project

Project 10:
- Test / finish final project, show off final robots.

4.2.1: The Slide decks

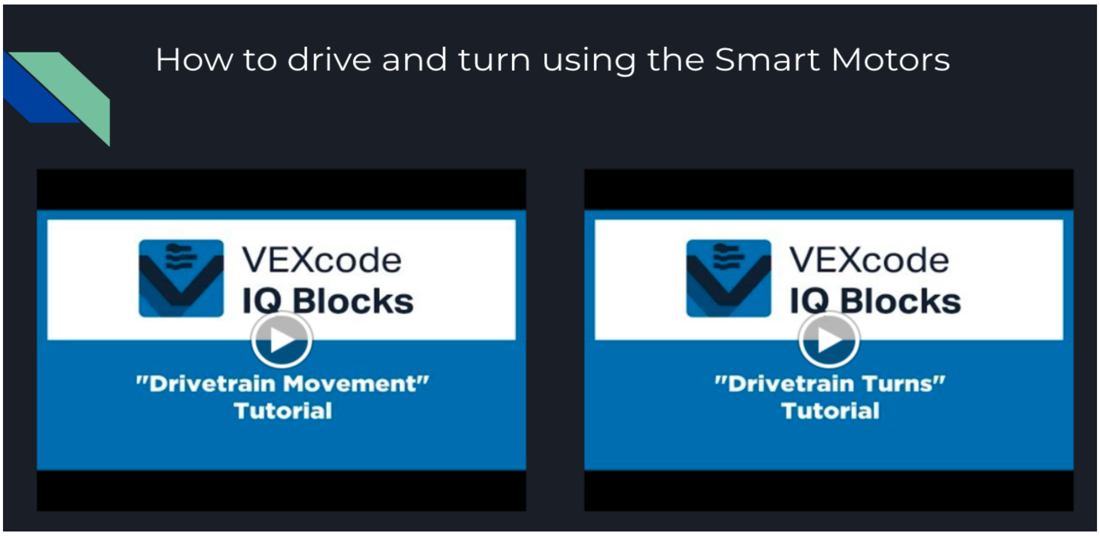
Every lecture begins with lesson objectives to explain to the students what they will be learning throughout the lecture.

Figure 7: Lesson Objectives



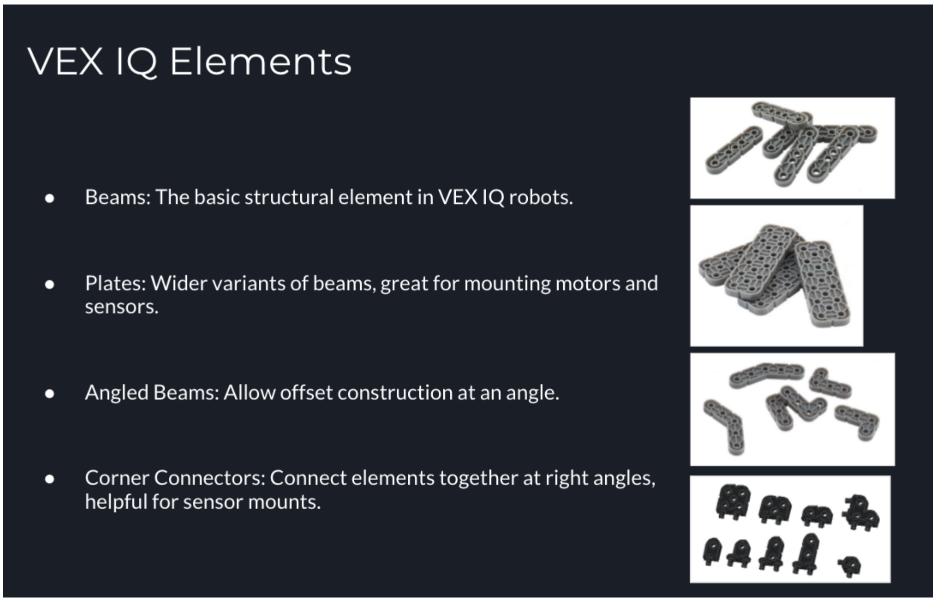
We believe that having a well-defined set of learning objectives helped the slide deck flow better. Once we established the learning objectives, we dove right into the world of robotics and computer science. Every lecture hoped to cover various mechanical and software aspects of the VEX Robot that we utilized throughout the course. Moreover, we found that VEX itself had really good course materials for students similar to our target audience. Therefore, we utilized Youtube Video Tutorials developed by VEX to supplement our content. These videos were perfect, short tutorials that covered just the content we wished to deliver.

Figure 8: Example Video Tutorials



By utilizing such short videos, we made sure that the lectures did not get too monotonous for the students. With the simplicity of these videos, we wished to make it easier for instructors to follow up and keep up with students' doubts. Since VEX has created an entire series of such tutorials, these videos flow seamlessly as the course progresses.

Figure 9: Example Content and Images



We keep our content as simple and concise as possible. With the aid of images and visuals, we can explain key concepts in a simple manner and cater to our secondary school audience. We designed our slides with the idea that instructors should simply be able to take our slides and teach the content. If the lesson's main topic is VEX IQ elements, our slides should aim to cover all content regarding VEX IQ elements both textually and graphically.

4.2.2: The Educator Manuals

These documents covered the content within slides in much more detail. While the content on those presentation slides was meant for the students and instructors, the content within the manuals was meant only for the teachers. Here, we used more technical language to describe our objectives, content, and concerns in more detail.

Figures 10 & 11: Example Educator Manual Content

Session 1: Introduction to VEX IQ

This session is intended to introduce students to building and wiring robots using the VEX IQ platform based on instructions by VEX. If the kits are pre-sorted into the included trays, the build process should take half an hour to an hour based on the group size. The building process is split into 3 segments:

- Building the chassis
- Adding the arm
- Adding sensors

Groups probably have enough time to complete all 3 steps within a single session, but if they are unable to finish the second and third sections by the end they should be fine. There should be enough time to finish up at the start of Session 2.

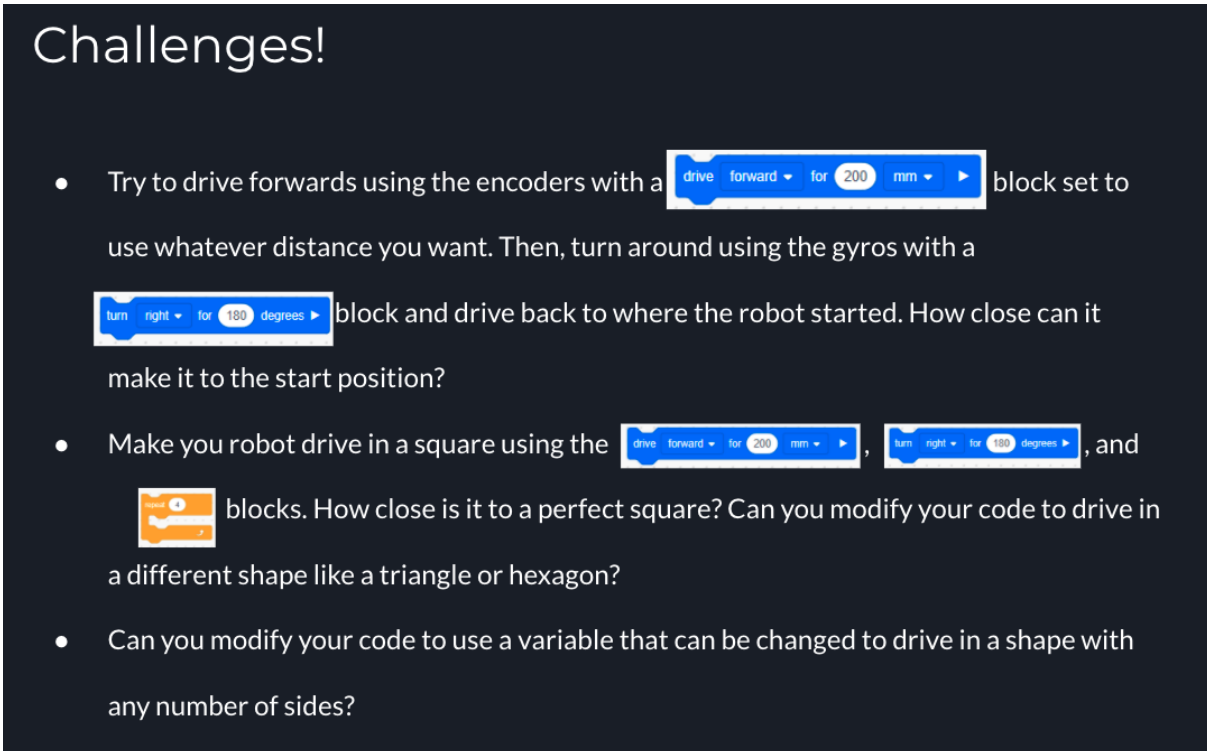
- Slide 5: What is a robot:
  - Explanation given, try and connect the idea of a robot with a human
- Slide 6:
  - Similar to above, connect it with the idea of a human
- Slide 7: Basic Components of a Robot
  - Everything is explained within the slide. Note: examples for sensors would be a good idea: ultrasonic sensors, infrared sensors, temperature sensors, et cetera.
- Slide 8: Basic steps in building a Robot
  - Design a strategy for a robot to complete objectives reliably. Decide on full "game plan" before beginning to design the robot.
  - Come up with concepts for mechanisms to achieve goals from step 1, and design / build basic prototypes to test concepts.
  - Assemble the full robot using mechanisms based off of prototypes.
  - Check if the robot can achieve objectives, and make changes based on tests to improve its capabilities.

We found that with the use of educator manuals, we could cover all required jargon while keeping content within our slides age-appropriate. Each manual contained a brief overview of the lesson, as well as any required materials the instructor would need to bring to the lesson. For each slide in the presentation, the manual elaborates on the content and provides talking points for instructors to use if they wish.

4.2.3: The Challenges

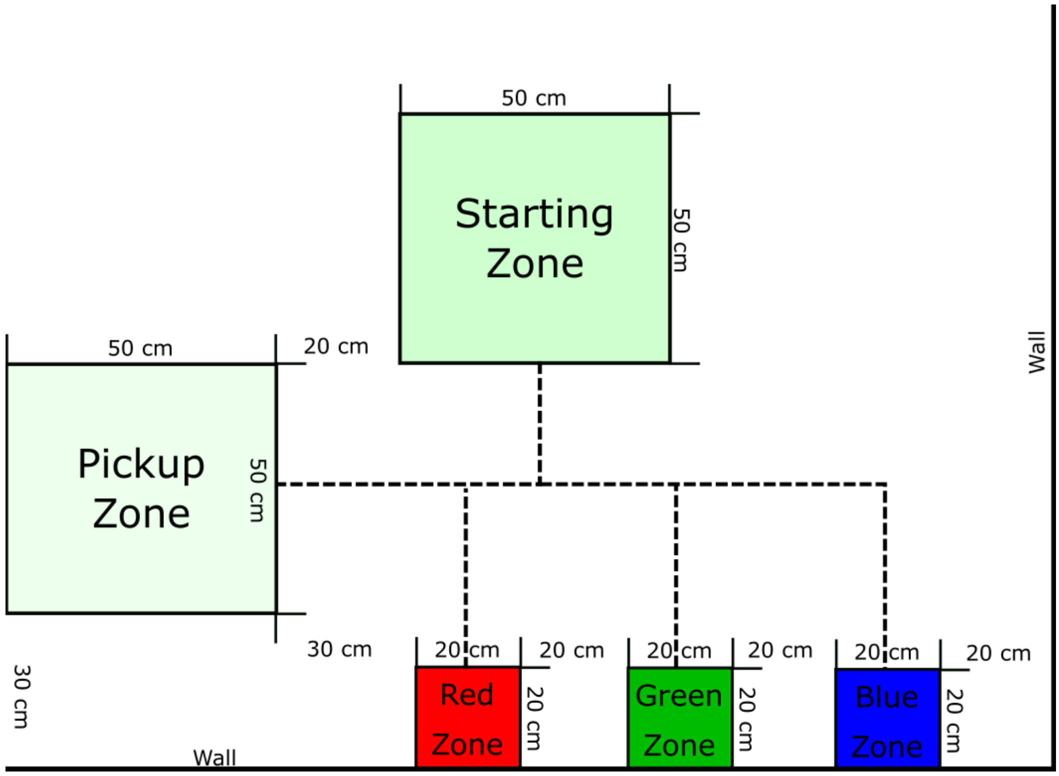
Once again, we took inspiration from our classes at WPI and tried determining what challenges we could assign to students. An example from a Robotics Engineering course at WPI would be giving students the challenge of wall following as they learn about infrared and ultrasonic proximity sensors. Additionally, we figured that having a fun and interesting challenge at the end of each lesson kept the lesson from being monotonous for students.

Figures 12: Example end of lesson challenge



We needed to figure out how to design these challenges such that they would build up to a final project that would take place over the last few sessions. This also leads us to our final capstone, the students' final project.

Figures 13: The Final Challenge



The challenge involved understanding of previous lessons like using the color sensor, using the remote control, and using the arm and claw motors. We ask the students to use parts of their solutions to previous challenges and compile that with some more logic to complete the ultimate challenge. We believe that a challenge like this is the perfect wrap to the entire course and to inspire students to pursue robotics in the future.

4.3: Findings from receiving feedback on our draft curriculum

Due to time constraints, the feedback phase of our project was not as comprehensive as we would have liked. We had to settle for much less variety in our feedback than we had hoped, but we were still able to receive a significant amount of advice from the sources we met with regularly. The main time constraint was in sending our surveys to instructors and students in Mauritius. Institutional approval took much longer than we initially expected, since the surveys needed to be approved by both the WPI IRB and the Mauritian Ministry of Education. This influenced our decisions with feedback for the rest of the project, and we decided to use direct sponsor meetings instead of relying on polling data. Next, we discuss the feedback we received as well as our findings upon meeting with our advisors and sponsors.

4.3.1: Advisor and Sponsor Feedback

Once we created draft lessons, we presented and submitted them for feedback. We were given feedback on every component of our curriculum.

For our lecture presentations, we learned that it was crucial to have more graphics and less text within our slides. We realized that we were missing images for most of the concepts we were covering and the majority of slides were boring walls of text. Moreover, it was brought to our attention that each lesson should be short enough for the teachers to complete within an hour, therefore, leaving them with enough time to get the students started on the challenges.

For our educator manuals, we learned that we should provide sources and further reading for curious students or instructors. This helped us modify our educator manuals to include links to additional materials that we used when developing the lectures and manuals.

For our challenges, we learned that videos showing the task would substantially help the students understand and enjoy the activities. By fully completing challenges ourselves, we also ensured that each challenge was feasible in the given time.

Through fresh perspectives on our draft lessons, we were able to tailor our lessons to meet the needs of our sponsors.

4.3.2: Mauritian instructors' and students' feedback from the Grade 8 Survey

We had sent out surveys to secondary school instructors and students throughout the country, but we were not able to receive the results in time to analyze. Our plan was to develop some questions to ask our target audience in Mauritius and then send out the forms to every Grade 8 teacher and student in the nation through the Ministry of Education. Our questions were based on our initial background research and designed to learn how to structure our course in terms of pacing, difficulty, and other aspects. However, the process to receive approval from the WPI IRB as well as the Ministry of Education in Mauritius took much longer than expected, and our sponsor's deadline for the deliverables passed before we could receive and use the data. However, we will try our best to include and analyze any feedback we do receive for future use.

We created the questions for the Mauritian Grade 8 students and teachers in mind with what we had learned about course design and Mauritian education from our phase 1 research. Our questions for both students and teachers were split into three categories: curriculum delivery, difficulty and pacing of the content, and relevant prior experience.

While we didn't receive responses to the survey, we were able to cover these topics with our sponsor. We received information on the students' educational background, but we were unable to gauge student preferences on factors like digital versus physical lesson materials or instructor preference on the balance between premade versus self-made lessons.

4.3.3: Focus Group Feedback

In addition to asking professionals and faculty, we also asked a number of our peers and fellow students with a varying range of robotics experience. We wished to understand how university students, who themselves are studying a range of courses, perceived this course that we had developed. We presented the course just as a teacher would to a class of students, and here's what we learned:

1. The course seemed like a secondary school or university introductory course, which showed that we had covered basic fundamentals for students newly introduced to Robotics. This was the level we were aiming for.
2. Our slides were text-heavy and students would easily lose focus. While the slides covered the required content, they were not engaging.
3. Our presentations would be more appealing through slide transitions and animations. Images, graphics, and videos would also help, but only when appropriate.

While our course material seemed concise and appropriate, we had to change our format so that students would be more engaged. We incorporated all feedback given throughout a range of sources and designed a curriculum that met the needs of everyone involved.

Chapter 5 : Conclusions and Recommendations

Mauritius aims to reform its education system, and the M.I.E's partnership with WPI is a step in the same direction. Subsequently, we were tasked with the goal of reviewing their syllabus and accordingly helping students reinforce their programming skills through robotics, and we did so through a 10 lesson long robotics course that covered a range of fundamental robotics and programming concepts. The design process that we used required us to first establish a range of objectives which in our case were: research the educational background of Mauritian students and teachers, develop course lessons, receive feedback and update the lessons accordingly. Hence, this chapter summarizes our team's key findings as we developed the course as well as some recommendations for teams at the M.I.E. and WPI.

To begin with, through surveys and interviews we conducted with WPI faculty as well as the M.I.E. faculty, we determined the precise course structure they wanted. We knew that we had to create 10 lessons that could be spread over the course of a few weeks. Additionally, we knew that we had to make the course appropriate for the students' skills and grade level. We learned that we were developing this course for instructors, and not the students directly. We created slide decks for teachers to present and educator manuals to provide further guidance. The manual was designed to educate the instructor and outline the course material for the corresponding lesson. We aimed to provide enough quality resources for the instructors such that they could be better prepared for all queries and students' doubts within the classroom.

Alongside research and development, our last objective was feedback. After we created initial prototypes of the lessons, we solicited feedback from academic advisors at WPI and the M.I.E. The recommendations focused on making the lessons more engaging, decreasing the amount of text in the lectures, and adding more videos, images, and activities. We, also, added challenges at the end of every lesson with the idea that the course would promote project-based learning within the classroom. We believe our structure of a lecture followed by a challenge would work well for both instructors and students. We were prepared to make the recommended changes as we said in the previous chapters, and so we knew that this was a key step in our iterative design process. We made decisions on reducing several technical content and adding more graphics to make the lessons more engaging for grade 8 students. We also recorded our robots completing the challenges we had designed as that would give students a reference to refer to if and when they were facing troubles completing the tasks.

5.1 Recommendations

As we spent time developing the curriculum and working with VEX IQ, we made mistakes along the way and took numerous approaches with our technology that slowed us down. We noticed several benefits and drawbacks to the techniques we used and as a result, we have a range of not only curricular recommendations but also technical recommendations for future IQP teams that will work with the M.I.E. Similarly, we also have some pedagogical recommendations for Mauritius that we believe could aid the integration of our course into their current syllabus.

5.1.1: Technical recommendations

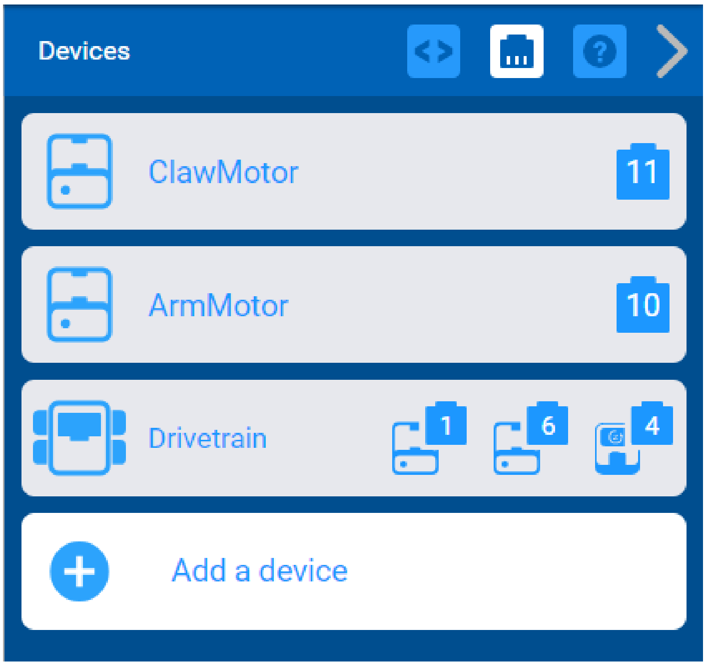
Recommendation 1: Integrate VEXcode VR

The VEX IQ system was fairly easy to set up for use, with the clawbot taking under an hour to fully assemble. VEX's video tutorials were easy to incorporate into our lesson materials as a more engaging alternative than recreating them through the slideshow. However, sometimes, there were issues connecting the software with the robot's hardware (i.e. sensor input not being recognized by code), and that stalled our software testing. Hence, VEXcode VR allows students to see how their robot would ideally run in virtual reality with the code they have written. Therefore, integrating course material on how VEXcode VR could be an alternative to testing with actual robots could help not only Mauritian students experiment their code but also the IQP team members develop challenges and write code relatively quicker.

Recommendation 2: Adopt C++ as the programming language for students in higher grades

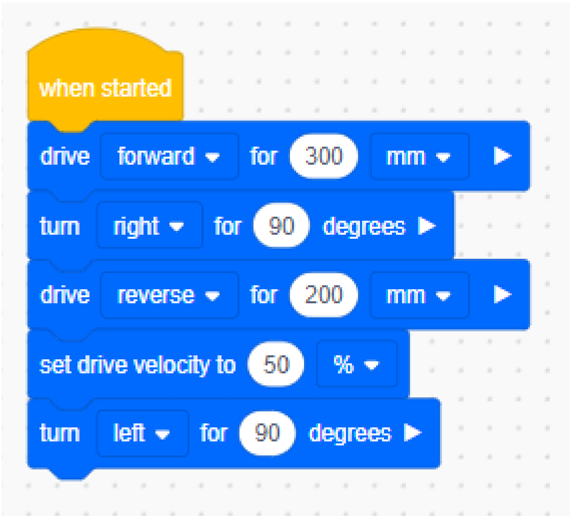
VEX IQ robots can be programmed using either a modified variant of MIT's Scratch 3.0 language or C++. Since Mauritian students already had a class on Scratch in 7th grade, we decided to use the Scratch-based language instead of C++. However, this provided several limitations, especially with regards to motor control. VEXCode IQ uses a "Devices" tab within its workspace to manage all motors and sensors connected to the platform.

Figure 14: The Devices tab within VEXCode IQ.



Any motors used on the robot would need to be added through this interface. When adding the motors for the drivetrain, VEXCode IQ provides the option of creating a Drivetrain object by selecting ports for both motors and optionally a gyroscope. When creating a Drivetrain object, the user then inputs the gear ratio of the drivetrain (1:1 with the default Clawbot design) and the wheel circumference (200mm on Clawbot). This allows for easy operation of the robot during autonomous driving due to several blocks that use the motor encoders and gyroscope to track its position.

Figure 15: A basic program showing some of the Drivetrain blocks



The Drivetrain object had a major drawback in that its only drive options were driving forwards or backwards or turning in place. There is no way to control the individual motors used within it or to directly interface with the gyroscope. This meant that the robot was only able to drive in straight lines or turn in place, resulting in us removing line following and wall following from consideration as a challenge. Therefore, implementing C++ will allow students to control their individual motors much more effectively, and in general C++ is more robust. Thus, for students in higher grades, it is very much recommended that the course should be taught using C++ instead.

Recommendation 3: Utilize additional educational robotics kits in addition to VEX IQ

The design of the basic Clawbot was easy to assemble, but it had a few physical drawbacks. The biggest issue was the decision by VEX to use a 4-wheel drive chassis design. The wheels would slip sideways when turning in place, since the center of rotation was roughly in the middle of the 4 wheels. As the wheels slid, they would cause the robot to shake, resulting in lateral movement. If the center of mass of the robot was moved by lifting or lowering the arm, the lateral motion during turns would change. On the other hand, other educational robots, including the current VEX V5 system, aimed at older students solve this issue by only using 2 powered wheels and using casters or omni wheels to support the rest of the weight. This results in a platform with no wheel slip unless on a steep slope, thus moving the center of rotation directly between the two powered wheels regardless of weight distribution. Moreover, by comparison, other kits do ship with test objects to manipulate with the robots, such as Mindstorms NXT education kits or the EV3 education kit. We were able to come up with several ways to build copies of the VEX cubes using cardboard or LEGO bricks, however these were not exactly the same size or color as the VEX cubes and thus presented difficulties. The VEX program worked well overall, but another system may be more consistent and convenient for future programs and curricula. LEGO Mindstorms EV3, which is discontinued but possibly obtainable from other organizations, is comparable in hardware characteristics to VEX IQ but is programmed with a modified version of NI's LabView system. The newer LEGO Spike Prime comes with fewer sensors than VEX IQ and is programmed with a similar Scratch-based language or Python. Dr. Chen from the STEM Education Center also recommended the Edison robot platform for use, which is a more affordable platform without the modularity of VEX or LEGO systems. It is a single module containing the processor along with both drive motors and several sensors, programmed through a Scratch-derived language as well as Python. It also has LEGO-compatible mounting points on its top and bottom. The hardware is less versatile than the other systems discussed, but it is significantly cheaper and well-suited to courses that focus more on computer science than mechanical engineering. For classes focusing more on computer science and sensor-based navigation, the Edison platform would be a better fit due to its lower cost. It may also allow for more “hands-on” activities in smaller groups, since each robot costs $33 instead of $379 for a VEX IQ kit.

5.1.2: Curricular recommendations

Recommendation 1: Create a range of lectures focusing on reviewing all required background

A range of feedback on our lesson prototypes focused on how the content may be too advanced for Mauritian students in the 7th Grade. Therefore, our advice for future IQP teams is to develop numerous initial lessons covering all the important concepts and required educational background that the students would need going into the more technical lectures taught later in the course. This would ensure that all content is being covered without worrying about if students were well versed with the concepts beforehand.

Recommendation 2: Include in-lecture polls and quizzes

We added challenges for each lesson to reinforce project-based learning, and to make sure that the students could practically implement everything they learned in lecture. However, a good idea would be to test their theoretical knowledge as well. Hence, in class quizzes or polls using software like Poll Everywhere could make certain that the students are well versed in both theoretical as well as practical aspects. Moreover, these short quizzes could also act as small checkpoints at which the teacher could check in with the students to certify that they have understood the content and to check if the children have been paying attention in class.

5.1.3: Pedagogical recommendations

Recommendation 1: Employ student groups of 3 at most, and arrange for spare kits for students

The course requires students to complete challenges using their robots, and this could be achieved in teams. However, we recommend that, given these relatively smaller scale challenges, a team should not have not have more than 3 students, as otherwise, the work will be too simplified and each student may not learn as much as they would in smaller teams. Moreover, with respect to these projects, since kits may have hardware issues from time to time, and given how short the course is, it is advised that the teachers have arranged for spare kits or major components such as motors and sensors beforehand. This will guarantee that no team of students falls behind in case of problems with their kits.

Recommendation 2: Demonstrate live programming of robots in class

As part of our course materials, we also include exemplar code illustrating how those challenges could be completed. Hence, it would be beneficial for the students if teachers could use parts of their code and program the robot live to demonstrate some of those tasks.

For example, displaying how to start up the VEX IQ software and running a task as simple as driving straight for 30 centimetres could aid students' understanding of those programming fundamentals.

5.2 Conclusion

Mauritius aims to become an education hub in the coming years, and they aim to improve and update their curricula in hope to achieve the same. Our team achieved the goal of making an educational robotics curriculum for the Mauritian teachers and students, and we did so in a way such that the M.I.E. could use our curriculum as a backbone to scale our experimental project into a nationwide project. We hope to inspire STEM within the Mauritian youth, and we hope that they apply the principles they learn within the classroom to concepts in the real world.

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