RENOVATING AN EDUCATIONAL ROBOTICS CURRICULUM FOR PHYSICALLY ACTIVE YOUTH (P.A.Y.)

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Renovating an Educational Robotics Curriculum for Physically Active Youth (P.A.Y.)

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Abstract

Physically Active Youth (P.A.Y.), an after-school program in Katutura, Namibia, equips students with fundamental STEM knowledge through interactive projects and collaborative problem-solving. Our goal was to renovate the existing robotics curriculum to further instruction at P.A.Y. As we worked to ship six VEX IQ robotics kits to Namibia, our team tailored deliverables to the needs of P.A.Y. while formatting them to be accessible by other communities, in the hope of bringing STEM education to underserved youth worldwide.

Acknowledgements

Although we have worked extensively on this project, we could not have completed it without the assistance from several individuals.

We would like to thank our sponsors at Physically Active Youth; Thuba Sibanda, Mauren Kleopas and Macdonald Kapukare. Without their dedication to this project and constant communication despite the circumstances, we would not have had the insight to develop appropriate deliverables for the organization.

We would like to thank Professor Joe Doiron for his passion and investment in unifying the fellow P.A.Y. teams to foster a relationship with Physically Active Youth.

We would like to thank a member of the Robotics Engineering Department at WPI, Professor Brad Miller. Professor Miller assisted us in making the curriculum appropriate for our target age range.

Lastly, we would like to thank our advisors, Nancy Burnham and Alexander Smith, for their extensive feedback and dedication to our success.

Executive Summary

Summary of Problem

Namibian education currently faces a variety of technical and social challenges due to decades of systematic segregation dictated by the policies of apartheid. Due to generational education inequalities, there are minimal systems of Science, Technology, Engineering, and Mathematics (STEM) education in place to advance technological proficiency for Namibian youth. With the new generation of youth displaying more interest in STEM topics, there is an increased need for comprehensive robotics education. The current education system in Namibia lacks curricula based on hands-on co-creative thinking and project-based learning. The outdated nature of the current system results in inadequate skill development, thus further introducing the need for an updated STEM curriculum.

Project Goal and Objectives

Therefore, the goal of this project was to collaborate with Physically Active Youth (P.A.Y.) to augment their current robotics program by enhancing and cultivating a scalable educational robotics curriculum to further promote STEM to Namibian youth. Our team, as well as the 2020 IQP team, used VEX IQ kits within this educational program. VEX robotics is an educational robotics tool catered towards immersing students ages six through eighteen in hands-on robotics education. With the VEX IQ kit resource, we developed four objectives used to achieve our project goal, which were to:

1. Obtain feedback on current curriculum and learning environment preferences,
2. Renovate existing content and implement more elaborate lessons and video content,
3. Develop a challenge at the end of each level to test cumulative knowledge, and

4. Tailor the program to meet P.A.Y.'s needs while planning for expansion.

Background

The long history of apartheid created lasting effects on the education system in Namibia. In the pre-independence era, the Namibian education system was designed with the purpose of reinforcing the systems of division perpetrated by apartheid. Schools were split along racial and ethnic lines, as the schools for white students received more resources and a higher quality of education (Amukugo, E. 2017). Currently, classrooms are unintentionally segregated as the result of generational settlement in previously segregated districts of the country. The segregated districts of the country are still prevalent in modern times. The township of Katutura is located in the suburbs of Windhoek and still struggles from poor living environments. The community of Katutura and the education system continues to be affected by the lasting impressions of apartheid, much like the rest of Namibia.

Physically Active Youth was established in 2003 as a free after-school program for grades one through twelve to help Katutura's students succeed educationally and physically. P.A.Y's main goals are to promote self-confidence, critical thinking, and active citizenry to equip students for future endeavors. P.A.Y. prides itself on its three pillars: quality education, sports (a physically active lifestyle), and life skills. From these pillars, the after-school programs were formulated and have continuously impacted students. The after-school programs consist of educational tutoring and homework help, followed by monitored sports activities to promote a balanced lifestyle. P.A.Y. has significantly impacted the academic performance in Katutura. In 2016 only 54% of students passed grade 10 and 40% of students passed grade 12 nationally in

Namibia. Comparatively, students who participated in the P.A.Y. after school program had a 76% pass rate in both grades 10 and 12.

In recent years, Physically Active Youth has partnered with students of Worcester Polytechnic Institute (WPI) to mitigate systemic issues within Namibia’s education system through the introduction of a robotics curriculum. As the robotics program gained traction, the U.S Embassy Namibia Public affairs sector granted P.A.Y. a $25,000 grant to continue to develop the robotics program (P.A.Y, n.d). With P.A.Y.’s limited academic resources and large disparity in exposures to science disciplines among students, the organization affords WPI project teams the opportunity to share their knowledge in a collaborative manner.

The 2020 IQP team worked to introduce this robotics curriculum using VEX robotics, which is an educational robotics tool catered towards immersing students ages six through eighteen in hands-on robotics education. By familiarizing students with programming, sensors, and automation, VEX aims to hone critical computational thinking skills needed to succeed in both the twenty-first century's workforce and in everyday life. VEX Robotics kits allow students to tinker and learn on their own or to utilize the option of a guided curriculum to expand the learning process. These kits encourage creativity, teamwork, leadership, passion, and problem-solving among groups. Through VEX, students can excel their educational and personal development with an educational robotics curriculum.

Methods

To execute our four objectives, we surveyed a number of sample populations through personal connections and used this feedback to enhance the preferred content delivery modes. The most preferred content delivery mode was videos, while respondents also submitted custom responses preferring a combination of videos and other delivery modes. Further, the respondents preferred to work collaboratively as long as they would not get stuck doing all of the work. To address these preferences, we created a myriad of instructional videos to supplement the existing curriculum content. Also, we created review lessons, quizzes, interactive activities, and collaborative challenges to encourage more active-learning.

Our team found our survey respondents by contacting the WPI Pre-Collegiate Outreach Office through the WPI Engineering Ambassadors program. We created these surveys using the Qualtrics software, which is a platform in which WPI informational surveys are created and secured. These surveys gave insight into how students prefer to learn material. With the quantitative data obtained through this survey, we were able to appropriately build the curriculum content.

We created the instructional videos to complement the existing curriculum content by following a four-step process of record, voice-over, edit, and integrate. We conducted the filming in the Foisie Innovation Studios' Maker Space at WPI, which is a high quality video setting that remained constant throughout the process. We followed a specific script when recording voice-overs, to ensure all core content was accurately discussed and shots could be executed efficiently. In the voiceovers, we explained the processes of programming and building with the VEX IQ kit as well as connected the activity to larger applications students may have seen in their everyday lives. We added a recall feature so students who were struggling with certain concepts could be linked back to specific instruction points in the videos. Furthermore, we revised the facilitator manual to reflect all content changes. To allow for faster content downloads, we kept each video below two minutes in length and compressed the file using a software called Handbrake to ensure no file exceeded 50 megabytes, the equivalent of about 25 image files. Smaller files succeeded in rendering under low bandwidth as well as downloading quickly enough to preserve time for the lessons.

While creating the review lessons, quizzes, interactive activities, and collaborative challenges, we followed a backwards design process. We accomplished this by first outlining which robotics engineering skills and general knowledge we wanted the students to know after completing each component. From here, we developed content to present succinctly in the review lessons, allowing students to recognize the material taught in the previous section. Next, we developed quizzes to reinforce this knowledge and to assess the students individually. Lastly, we developed hands-on activities and collaborative challenges that utilized the desired skill sets both with and without the VEX IQ kits.

Results

Objective 1: Obtain Feedback on Current Curriculum and Learning Environment Preferences

Through our surveys sent out to Worcester families through the Pre-Collegiate Outreach Office at WPI, we learned students prefer to learn material through activities over lectures. We also learned students prefer to learn through a variety of delivery modes and enjoy working collaboratively on coursework. We discussed these Worcester student preferences with the students at P.A.Y. and they supported the same preferences. This confirmation from students both in Worcester and at P.A.Y. positively reinforced our revisions and suggested we should continue to use different modes of delivery in conjunction with our additional videos to engage the most students.

Objective 2: Renovate Existing Content and Implement More Elaborate Lessons and Video Instruction

Primarily, we revised the existing curriculum content by reorganizing the lessons and explaining the concepts more thoroughly. These revisions were warranted as some lessons in the Beginner section were not suitable for the targeted age range. Therefore, they had to be moved to another section and replaced with more suitable content. As reinforced by the student feedback obtained from Objective 1, we developed content that is interactive and allows learners to develop the skills to work in teams, with one other student, as well as alone. Also, our team created videos to accommodate the preferred learning style and provide a variety of content delivery modes. In addition to these instructional videos, we created an introduction video for the curriculum website that displays our team constructing the parts of the VEX kit that students would be using. This video promoted teamwork, normalized mask wearing, and ultimately motivated students by concluding with a title frame reading “The science of today is the technology of tomorrow.” Furthermore, this video allowed students to see us, the creators, before beginning the curriculum to help establish more of a personal connection.

The 2020 team used videos outsourced from YouTube to give learners an overview of STEM, engineering, and robotics. The team also used low-quality photographs of the VEX IQ kits to demonstrate simple machines and basic build instructions. To address this, we developed a series of instructional videos that guided learners through the steps of building the Simple Machine Lever and the Chassis. We upgraded all the photos taken by last year’s team to high quality and professional images. The new enhanced photos gave learners clarity when constructing the VEX IQ kits and video content offered a visual aid to students who were struggling with learning material.

Objective 3: Develop a Challenge at the End of Each Level

The challenges we created help achieve our core goal of including more active-learning in the educational robotics program in Namibia. In addition to these competitive challenges at the end of each section, we also developed and incorporated review lessons, quizzes, and interactive activities to precede these challenges in each section. We designed the review lessons and quizzes to prepare the students to succeed in completing each competitive challenge, while also assessing their individual capabilities. We organized the competitive challenges to foster the most linear progression from our curriculum to P.A.Y.'s competitive robotics team, which was established by one of the other 2021 IQP teams working with P.A.Y. This challenge structure allows students to build the skills to succeed on a competitive team, while also introducing them to an iteration of a past VEX robotics competition.

The review lessons, interactive activities, comprehension quizzes, and collaborative challenges each aid the learners in different aspects and give facilitators confirmation that the learners are prepared to move onto the next level. The "Let's Review" section works as a quick review of the level that students can use to recall any key points. The interactive activities were designed for students to do without the use of the VEX IQ kits. In the interactive activities, we ask students to do short activities with everyday classroom items to give parallels to the STEM topics they learned in the lessons. The comprehension quizzes were developed for two purposes: expectation of students to retain material and facilitators' assurance that students are comprehending material. These quizzes consist of 5 to 10 multiple-choice or short-answer questions that facilitators can access. Lastly, the collaborative challenges bring fun and competition into applied STEM topics. The collaborative challenges test students to be creative and work in a team to complete a task. These collaborative challenges streamline students to be prepared to compete on P.A.Y.'s competitive robotics team.

Objective 4: Tailor the Program to Meet P.A.Y.'s Needs while Planning for Expansion

To meet P.A.Y.'s needs and allow for expansion, we reduced the file size of content on the website for easier downloadability, implemented virtual tools such as VEXcode VR, and integrated lessons and activities to minimize the need for a physical robotics kit. After we created our videos, we compressed the file size to about 50 megabytes to account for P.A.Y.'s limited bandwidth.

We tested viewing capabilities at P.A.Y. by presenting compressed and uncompressed video files to students during a busy class period. With all the computers being used by students at the center, the longer compressed video (1.5 min., 35 megabytes) loaded seamlessly, whereas the shorter uncompressed video (1 min., 76 megabytes) failed to load. This result confirmed that our compression procedure aided not only with downloading but also with streaming capabilities in low-bandwidth settings. This procedure will ultimately allow our program to be available to other communities with limited internet access in the future. As a failsafe, we created a zip folder containing all video content. Through this zip folder, we allow facilitators to download the videos onto the fifteen computers in advance in order to save class time.

Conclusions and Recommendations

In conversations with our sponsors at P.A.Y. and the 2020 WPI IQP team, both groups advised our team to work to enhance the quality and material of the current curriculum. As a team, we discussed the efficacy of the original curriculum with WPI Robotics Engineering Department Professors to gain insight on the gaps that we could bridge. From these discussions, we created four objectives: obtain feedback on current curriculum and learning environment preferences, renovate existing content and implement more elaborate lessons and video content, develop a challenge at the end of each level to test cumulative knowledge, and tailor the program to meet P.A.Y.'s needs and remain applicable in other STEM-deficient communities.

For future WPI IQP teams, we developed four recommendations as follows:

1. Continue expanding curriculum content by delving into each concept more,
2. Develop more interactive activities and competitive challenges throughout,
3. Integrate this curriculum at other sites globally, and
4. Tailor this curriculum to the needs of different student demographics.

Our first recommendation is to expand the curriculum, even though the content is already a thorough and coherent educational tool. We recommend that a group of students who is continuing this project space out and present the content more thoroughly to afford students better content comprehension. Our second recommendation is to incorporate additional interactive activities and collaborative challenges to improve knowledge retainment and student interaction. We engaged the participating students at P.A.Y. by adding active-learning into the curriculum, which rationalizes our recommendation to continue developing project-based and collaborative curriculum content. Our third recommendation is that future teams using this curriculum begin by assessing the resources in their community. By analyzing the access to STEM resources, this future team can make any necessary changes to the curriculum. Although the curriculum is designed to be implemented anywhere, we still recommend that future teams explore opportunities to tailor the content more closely to their student's experiences. Our fourth and final recommendation is for the facilitators to follow the facilitator guide. This is imperative to fully understand the intent behind each component of the curriculum and to adjust the lessons to best fit the needs of their learners.

The revisions and new developments we incorporated into our educational robotics curriculum will benefit the students at P.A.Y. and eventually other global sites. Our improvements, along with the completion of the above four recommendations, are concrete steps toward advancing STEM to Namibian youth.

Authorship

Jacqueline Aaron: Edited for content, structure, and grammar. Background: Education in Namibia, Background: Best Practices In Teaching, Background: Project-Based Learning, Background: Educational Robotics, Methodology: Tailor the Program to Meet PAY's Needs while Planning for Expansion, Results: Tailor the Program to Meet P.A.Y.'s Needs While Planning for Expansion,: Recommendation 1: Expand Content and Spread Over More Lessons, Recommendation 2: Continue Developing Collaborative Challenge Material, Recommendation 3: Planning for Global Expansion, Recommendation 4: Reference the Facilitator Manual when Using the Curriculum.

Anna Catlett: Edited for content, structure, and grammar. Authored Background: Physically Active Youth, Authored Background: Project Based Learning, Authored Background: Educational Robotics, Authored Methodology: Objective 1: Obtain Feedback on Current Curriculum and Learning Environment Preferences, Authored Results: Objective 1: Obtain Feedback on Current Curriculum and Learning Environment Preferences, Authored Conclusions and Recommendations: Overview, Authored Conclusions and Recommendations: Summary of Findings and Deliverables. Authored Conclusion and Recommendations: Conclusion

Matthew Maloney: Edited for content, structure, and grammar. Authored Introduction, Background: VEX Robotics, Background: Previous WPI Project Work with P.A.Y., Background: Summary, Methodology: Objective 2 - Renovate Existing Content and Implement More Elaborate Lessons and Video Instruction, Results: Objective 2 - Renovate Existing Content and Implement More Elaborate Lessons and Video Instruction.

Joshua Thomas: Edited for content, structure, and grammar. Authored Introduction, Background: Namibian History, Background: Project-Based Learning, Background: Summary, Methodology: Goal and Research Objectives, Methodology: Objective 3: Develop a Challenge at the End of Each Level, Results: Overview, Results: Implementation Plan, Results: Objective 3: Develop a Challenge at the End of Each Level, and Results: Summary.

Figures and Tables

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CHAPTER 1
INTRODUCTION

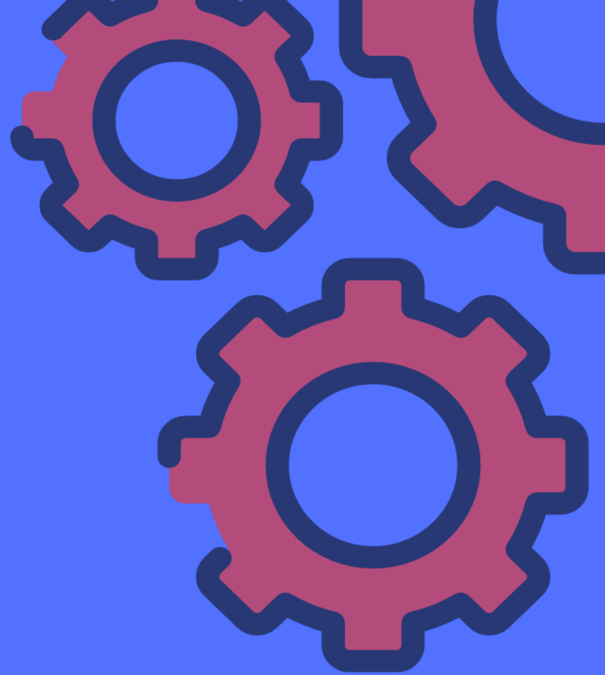
1. Introduction

Namibian education currently faces a variety of technical and social challenges due to decades of systematic segregation dictated by the policies of apartheid. Between 1948 and 1990, the frameworks of apartheid segregated students into different schools split along race and ethnic lines. Consequently, resources and funding were funneled into the schools with white students (Smalley, 2014). Even today, black students struggle to escape the lasting impressions of apartheid. Due to generational education inequalities, there are minimal systems of Science, Technology, Engineering, and Mathematics (STEM) education in place to progress technological proficiency for Namibian youth.

With the new generation of youth displaying more interest in STEM topics, there is an increased need for comprehensive robotics education. The current education system in Namibia lacks curricula based on hands-on co-creative thinking and project-based learning. The outdated nature of the current system results in inadequate skill development. Current curricula focus on direct content delivery with limited project-based learning. The present Namibian workforce lacks a new generation of employees with strong technical foundations and critical thinking skills. These components can be enhanced by inventive solution-oriented project education.

Physically Active Youth (P. A.Y.), an after school program center in Katutura, Namibia, aims to combat these systemic inequalities through promotion of self-confidence, critical thinking, and active citizenship. Last year, a project team from Worcester Polytechnic Institute created an educational robotics program in partnership with P.A.Y. to enhance the quality of education, the first pillar of P.A.Y's organization. The curriculum challenges students to ideate tangible solutions to local problems seen in everyday lives.

This year, the goal of this project was to collaborate with Physically Active Youth to augment their current robotics curriculum by taking into consideration remote accessibility and educational value while provoking the application of learned sciences in local Namibian communities. This report aims to detail changes made to the existing curriculum framework through the inclusion of segmented videos and active-learning techniques. The team expanded and adapted the robotics curriculum to make it universally accessible to students in STEM-deficient areas around the world. This project directly benefited Namibian students in their day-to-day lives and promoted personal development in alignment with the objectives of Physically Active Youth.



CHAPTER 2

BACKGROUND

2. Background

2.1. Namibian History

The history of Namibia is one of defense against foreign entities. In 1884, Germany seized Angra Pequena, which was referred to as South West Africa, in the "Scramble of Africa." This scramble was a period in time between 1884 and 1914, when European colonizers divided Africa into colonies (Michalopoulos & Papaioannou, 2017). Though there were many insurrections by the native tribes, such as the Herero and Namib, the German intruders maintained a hold on the country by brute force.

During World War I, South Africa allied with British forces and targeted the closest German-occupied territory to South Africa. This led to an invasion of South West Africa by South Africa, who then became entrusted with the administration of the territory through British mandate and incorporated the apartheid ideologies as WWI ended. After 30 more years of suffering at the hands of intruders, the South West Africa region prospered economically due to the abundance of highly sought natural resources. Tragically, the vast majority of the benefit from this prosperous time was enjoyed by the whites in the area while Black people experienced the harsh policies associated with apartheid. Apartheid systematicly segregated non-whites from all political processes, property ownership, commercial activity, and residence in South West Africa.The Natives Land Act in 1913 was mong the many harmful implications of this systemc that pushed native people into a land region we now know as Katutura (*The Natives Land Act of 1913 | South African History Online*, n.d.).

The incorporation of South Africa's apartheid policies was enhanced by British policies, which further inhibited the educational potential of non-whites in the South West Africa region.

British education policy in the region set out to prepare young Africans as compliant laborers by "develop[ing] a vast pool of cheap [and] unskilled manual labor" which created a sharp divide between the resources allocated for white and black education (Smalley, 2014). Under apartheid, the government mandated citizens to register their race to enable further restriction of public resources. These previously established inequalities set the tone for both the social treatment of non-whites and their educational opportunities. In the 1930's education for white students in South West Africa was free and encouraged, while the black education was suffering from urban influx, insufficient resources for students and teachers, and regular student absenteeism (Bantu Education and the Racist Compartmentalizing of Education, 2019). The long history of disparity initiated by apartheid has negatively impacted non-white citizens' socioeconomic development and educational capabilities.

2.2. Education in Namibia

The long history of apartheid created lasting effects on the education system in Namibia. In the pre-independence era, the Namibian education system was designed with the purpose of reinforcing the systems of division perpetrated by apartheid. Schools were split along racial and ethnic lines, as the schools for white students received more resources and a higher quality of education (Amukugo, E. 2017). These "Townships" resulted from black Namibians being forced to move into specific locations to segregate from the white communities. The families that lived within these townships lacked the ability to own land and were frequently displaced based on government orders. Currently, classrooms are unintentionally segregated as the result of generational settlement in previously segregated districts of the country. The segregated districts of the country are still prevalent in modern times. The township of Katutura is located in the suburbs of Windhoek and still struggles from poor living environments. The word ‘Katutura’ translates to, “we have no permanent dwelling place,” which mirrors the housing sentiment for members of the community of Katutura (Sparks, 1997). The community of Katutura and the education system continues to be affected by the lasting impressions of apartheid, much like the rest of Namibia.

Under apartheid rule, the government aimed to put eighty percent of black students through, at most, four years of schooling to address the “need for literate workers for the whites” (Dahlstrom, 2002). In the post-independence era, structures such as these were rightfully removed from the framework of the education system. Though remnants of these systems of division are still visible in the current infrastructure, there is an ongoing fight to eradicate them.

In fighting to end apartheid, the constitution of the new government was put in place and proclaimed a right to education for all Namibian citizens. Article 20 of the Namibian Constitution confirms that “All persons shall have the right to education, and that primary education shall be compulsory, and the State shall provide reasonable facilities to render effective this right for every resident within Namibia, by establishing and maintaining State schools at which primary education will be provided free of charge” (Namibian Const. art. 3 section 20). For Namibian students, free education is ensured by the state from grades one through seven. In the ten years after the new government was established, large strides were made to improve the education system. Three thousand new classrooms were built and there was a thirty percent increase in the number of teachers in the workforce (Amukugo, E., 2017). This resulted in skyrocketing enrollment of students in primary education. Enrollment numbers increased from sixty to ninety-five percent between 1990 and the early 2000s (Humavindu & Stage, 2013).

The Namibian government allocates over twenty percent of its national budget to education (DeKuiper, 2006). The benefits of this long-term investment in education are evident in the literacy rate of the population increasing from over seventy-five percent in 1991 to over ninety-one percent in 2021 ("Literacy rate by country 2020," n.d.). The adult literacy rates reflect the percentage of people ages fifteen and above who can both read and write a short simple statement about their everyday life. Education system investment has paid off when looking at the number of students who must repeat years of their education. Between 1991 and 2003 the number of students who advanced to the following level of education increased by over thirty percent (DeKuiper, 2006). Even though the education system has seen rapid advancement over the past thirty years, further actions are necessary to improve technological proficiency of Namibian youth. Physically Active Youth or P.A.Y. is a non-governmental organization in Katutura Namibia, focuses on the social and educational improvement of disadvantaged Namibian youth. Physically Active Youth's goal is to directly combat those inequalities and create a more equal and knowledge-based Namibia (P.A.Y, n.d).

2.3. Physically Active Youth (P.A.Y.)

Physically Active Youth was established in 2003 as a free after-school program for grades one through twelve to help Katutura's students succeed educationally and physically. P.A.Y's main goals are to promote self-confidence, critical thinking, and active citizenry to equip students for future endeavors. P.A.Y. prides itself on its three pillars: quality education, sports (a physically active lifestyle), and life skills. From these pillars, the after-school programs were formulated and have continuously impacted students. The after-school programs consist of educational tutoring and homework help, followed by monitored sports activities to promote a balanced lifestyle. There are weekly life skills sessions with a variety of topics: sexual and reproductive health, career guidance, mentoring, boys and girls clubs, healthy lifestyle choices, environmental awareness, and community service. P.A.Y. has significantly impacted the academic performance in Katutura. In 2016 only 54% of students passed grade 10 and 40% of students passed grade 12 nationally in Namibia. Comparatively, students who participated in the P.A.Y. after school program had a 76% pass rate in both grades 10 and 12. As shown in Figure 2, P.A.Y's pillars encapsulate the mission of the organization to equip future members of society (P.A.Y, n.d).

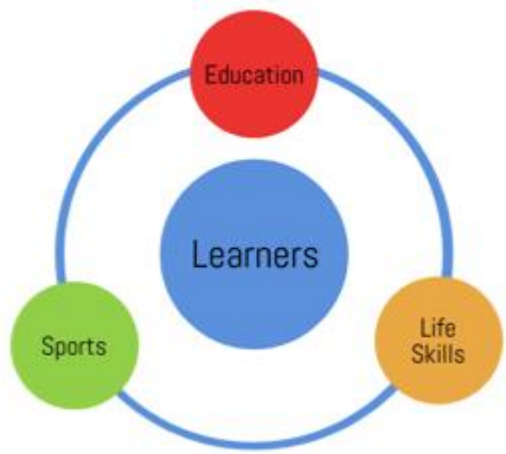


Figure 1: P.A.Y's Three Pillars

The first pillar, quality education, is executed with an emphasis on the learner's cognitive ability. A key aspect of their curriculum is strong communication skills in combination with interactive hands-on learning. Since P.A.Y's main goal is to promote a knowledge-based Namibia, they have moved to enhance their STEM curricula by integrating weekly robotics lessons into current programing. P.A.Y. offers teachings to five age groups varying from grades one through twelve to introduce students of all ages to STEM through the avenue of robotics. With students in every group varying in technical ability, technical skill courses are taught in conjunction with the robotics curriculum to establish competency in performing robotics activities. These robotics lessons and activities have been developed further by previous WPI project teams to create a comprehensive robotics curriculum with a focal point of project-based learning.

2.4. Best Practices In Teaching

Best practices in teaching largely depend on how content is directly taught to students. Learner-centered education focuses on the exploration of new ideas and the development of students' critical-thinking skills. Teacher-centered education is the direct approach of explicitly sharing information, which lacks a component of inquiry on the part of the students (Yamagata, 2018). One of P.A.Y.'s main goals is to develop independently-thinking students which is in line with the practice of learner-centered education. By implementing this educational approach, problem-solving will be required from learners, encouraging students to think critically and ultimately develop as independent learners.

Along with a learner-centered educational approach, the concept of active learning is vital for allowing students to play an active role in their education. Active learning engages learners and maximizes outcomes from lessons. Classroom content is “easier understood and remembered longer by students when students are actively involved in learning mentally, physically, and socially” (Setiawan et al., 2019, p.178). By using the model of active learning, there is a higher level of concept mastery and a more productive learning experience for the student. In addition to these components, students are able to develop their skills that are non-tangible, such as creativity, critical thinking, and problem-solving.

Another core component of education is the understanding of differing abilities, learning styles, and progression speeds of all students. To ensure the curriculum is created to aid the educational needs of all students, these factors must be taken into account. It is essential to create a supportive atmosphere because “cognitive, social-emotional (mental health), and physical development are complementary, mutually supportive areas of growth” (National Research Council, 2001, pg. 7). By offering a supportive environment where teachers build strong interpersonal relationships with the learners, students are exposed to the best possible learning environment to further their personal and educational growth. An aspect P.A.Y. prides itself on is its ability to adapt to the learning style of the students. Instructors at P.A.Y. work to personalize their curriculum to best suit the student they are working with.

2.5. Project-Based Learning

Project-based learning (PBL) is an educational tool where teachers pose problems to their classes, allowing the students to make various content connections and gain experience directly applicable to real-world scenarios (Euefueno, 2019). Students face many challenges outside of the school environment that do not have definitive problem statements or solutions. For this reason, PBL in the classroom helps prepare students to think critically and develop creative solutions for real world issues. In STEM curricula, projects are often “complex, and open-ended, sparking increased higher-level cognitive strategy use among students” (Stefanou et al., 2013, p. 117). The benefits of applying PBL in STEM classroom environments extend beyond the foundational learned skills. By having students collaborate in groups to work through these complex problems, learners are better prepared for the workforce where they can harness these valuable learned skills to optimize the industries they become involved in. These academic, professional, and social skills are vital for the Namibian youth to develop as they continue to join an evolving workforce that has become more dependent on both the technical foundations and critical thinking skills. The many benefits of PBL for students preparing to enter the professional world inspires our team to incorporate PBL into the educational robotics curriculum in Namibia. The successful incorporation of a PBL style for Namibian youth would entail improved co-creative problem solving skills, which will be evaluated through competitive challenges in the educational robotics program.

2.6. Educational Robotics

Just as active and project-based learning are essential for teaching students to adapt difficult skills easily, robotics has gained momentum as a leading subject matter for teaching STEM education globally. Through the process of building and programming a robot in the classroom, students explore many different learning pathways. For teachers, a robotics curriculum naturally allows for an individualized approach to each student's learning which helps to nurture their passions and interests within their education. There are many programs and curricula to engage students in robotics education, which are designed to push students to use cross-disciplinary STEM skills to solve complex problems. Some robotics programs are built into the normal school day while others are independent of traditional education with outsourced sponsors. VEX robotics, a hands-on tool used to teach robotics to youth, sparks student's interest in engineering and competitive problem solving. VEX is designed for American or European students and does not consider the many social and educational differences that make implementation into a Namibian classroom more challenging. These programs are created for classrooms with advanced access to technological resources. For Namibian students, access to WiFi and computers comes from their schools, so lessons and assignments must be contained to the classroom setting.

2.6.1. VEX Robotics

VEX robotics is an educational robotics tool catered towards immersing students ages six through eighteen in hands-on robotics education. By familiarizing students with programming, sensors, and automation, VEX aims to hone critical computational thinking skills needed to succeed in both the twenty-first century's workforce and in everyday life. VEX Robotics kits allow students to tinker and learn on their own or to utilize the option of a guided curriculum to expand the learning process. These kits encourage creativity, teamwork, leadership, passion, and problem-solving among groups. Through VEX, students can excel their educational and personal development with an educational robotics curriculum.

VEX offers a range of products suited for varying ages and experience levels. A breakdown of products can be seen in the table below:

Table 1: VEX Robotics product offerings and corresponding intended age range.

VEX Product Line	**Intended Grades**
VEX 123	PreK-2
VEX GO	3-5
VEX IQ	6-8
VEX V5	9-12

VEX PRO	12+
VEX VR	All grades

While there are offerings of varying complexities, each product line combines simple problem-solving with mechanical application. As the complexity increases down the product line, more advanced programming instruments are used to allow users the ability to increase robot operations. In conjunction with advanced coding tools, building materials also advance down the product line. While plastic components constitute the earlier products, sturdier, robust metals comprise the advanced kits and allow for increased functionality and durability. In response to the COVID-19 pandemic, VEX has published a new product VEXcode VR which serves to accommodate learners' inaccessibility to physical robotics kits. VEXcode VR is a completely virtual package suitable for all age ranges. The software utilizes a virtual robot that can be programmed to perform a series of tasks just like physical VEX robots. As this particular project concerns learners aged six to eighteen in physical as well as virtual environm ents, the intermediate VEX IQ and versatile VEXcode VR product lines will be explored further in later sections.

Figure 2: VEX IQ Competition Super Kit (left) and VEXcode VR virtual robot (right).

The VEXcode VR simulation tool is a new resource that can be used to virtually introduce project-based curriculum to Namibian youth. A past WPI project team established an educational robotics curriculum that utilized VEX IQ kits to educate Namibian youth in STEM topics.

2.7. Previous WPI Project Work with P.A.Y.

In recent years, Physically Active Youth has partnered with students of Worcester Polytechnic Institute (WPI) to mitigate systemic issues within Namibia's education system through the introduction of a robotics curriculum. As the robotics program gained traction, the U.S Embassy Namibia Public affairs sector granted P.A.Y. a $25,000 grant to continue to develop the robotics program (P.A.Y, n.d). With P.A.Y.'s limited academic resources and large disparity in exposures to science disciplines among students, the organization affords WPI project teams the opportunity to share their knowledge in a collaborative manner.

In 2020, P.A.Y's partnering team was tasked with introducing a hands-on robotics curriculum for their students aged six to eighteen. While the curriculum objective remained constant, the delivery was forced to change due entirely to the pressing concerns of the COVID-19 pandemic. A program, initially intended for a classroom setting, was immediately revised to satisfy remote accessibility and virtual learning. Prior to the travel restrictions and safety protocols, the team was able to receive funding for twelve VEX Robotics kits from the Robotics Education and Competition Foundation (RECF). Arguably the greatest change in the team's project was the inability to provide to the students these educational robotics kits that would have aided in development of the project curricula. To accommodate the new virtual learning standards, the team developed an intuitive website which aimed to proctor the sequential progress of a sound robotics understanding. In addition to the pedagogical website, the team provided a facilitator manual that provides delivery recommendations for educators (Charter et al., 2020). The curriculum appealed to the entire age demographic and allowed for self-pacing throughout the course with Beginner, Intermediate, and Advanced lessons as referenced in figure three (Charter et al., 2020).

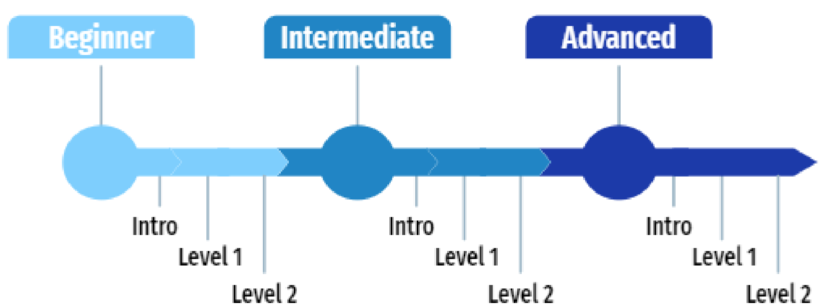


Figure 3: The three current education levels of the robotics curricula.

With each of the different curricula tiers, or sections, students were presented with a "main objective, presentation of new material, interactive exercises, review of prior knowledge, and guiding questions." With each course level, the website interface was formatted to suit the appropriate target age. For the beginner course, the interface consisted of shorter text messages with more images and colorful graphics. As the course difficulty progressed, the website was formatted to include more text containing complex words and less color. From the homepage shown below, students and facilitators can select their desired level from the main toolbar and begin work within the subsequent lessons.

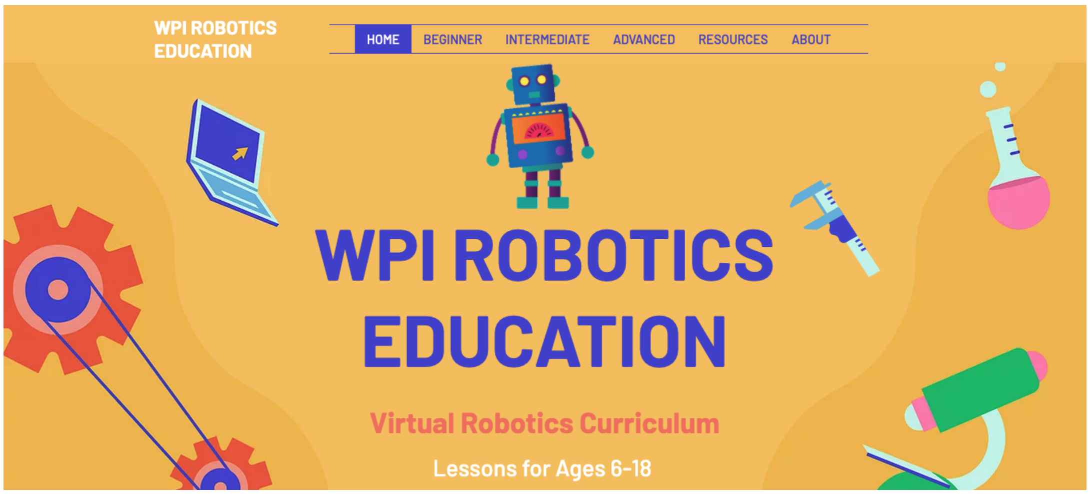


Figure 4: Homepage of the previous website.

In assessment of the program's efficacy, the team gathered feedback from both educators and students. Educator feedback helped the team refine their platform in regards to layout, age appropriateness, content, and engagement. To gauge the students' success with the program, the team provided short surveys at the conclusion of each lesson to evaluate the course's difficulty. Appropriate levels of difficulty were established with the cross referencing of previously obtained data that gauged each student's prior experience with robotics. In the feedback form, students claimed course levels did well to challenge without overbearing. In some responses, students claimed lack of access to VEX kits which tainted the learning experience (Charter et al., 2020). In continuation of this project, the supplying of VEX kits is warranted to further the educational impact of the program.

2.8. Summary

Apartheid has had lasting social implications on educational divides in Namibia, which Physically Active Youth aims to combat through joint learning environments. With aparteid inducing decades of academic segregation, teaching styles have failed to evolve. STEM education has emerged as one of the most prevalent studies and robotics programs serve well to introduce students to a wide range of scientific disciplines. However, without the adoption of project-based learning, it will struggle to succeed in Namibian education systems. Physically Active Youth aims to introduce students to collaborative activities through sports and academic programs that promote the development of cognitive and social abilities. In collaboration with Physically Active Youth, the 2020 WPI team succeeded in establishing a robotics curriculum in the form of a website and facilitator manual that have allowed students to gain a sound understanding of robotics. To further both the efficacy and scalability of the program, VEX IQ and VEX VR robotics kits will be utilized to grant learners the ability to physically or virtually build robotics in tandem with the website curricula.

CHAPTER 3

METHODOLOGY

3. Methodology

3.1. Goal and Research Objectives

In collaboration with P.A.Y., our team has democratized an educational platform that affords students the opportunity to apply scientific knowledge and develop social skills. Our goal was to enhance and cultivate a scalable educational robotics curriculum to further promote STEM to Namibian youth. Throughout this methodology, we outline the plan used to implement this goal through our four research objectives. We used feedback from students and teachers to optimize the current educational robotics program and improve the educational and cosmetic content of the website. This feedback provided our team a greater understanding of the learning environment for students in Namibia. Through the completion of our methodology, our team identified weaknesses of the current program that were defined by the students and facilitators. Our four primary research objectives were to:

1. Obtain feedback on current curriculum and learning environment preferences,
2. Renovate existing content and implement more elaborate lessons and video content,
3. Develop a challenge at the end of each level to test cumulative knowledge, and
4. Tailor the program to meet P.A.Y.'s needs and remain applicable in other STEM deficient communities.

3.2. Objective 1: Obtain Feedback on Current Curriculum and Learning Environment Preferences

When a previous WPI project team created the original curriculum in 2020, the COVID-19 pandemic altered the intended onsite learning environment to be a virtual platform. Given the return of in-person education at P.A.Y, our team adapted the curriculum to be offered in-person. While the curriculum was originally designed for independent learning, we applied the WPI learning style by revising content delivery methods to emulate a project-based learning environment. To do this, we studied different face-to-face learning preferences to understand all delivery method possibilities.

To understand how students best learn, we used three sample populations: students ages six through ten, eleven through fourteen, and fifteen through eighteen, in the U.S. This demographic created a benchmark for Namibian students to meet through the educational robotics curriculum by incorporating the same three sample populations responses from the U.S. The eligibility process for the sample populations were based on three inclusion criteria: enrollment in an academic program, access to primarily reliable internet connection, and enrollment in a public school. We did not choose students enrolled in academic programs at private schools because Namibian students do not have access to these same resources. This selection method helped us achieve consistent participant demographics to allow the project to capture differences in results between the U.S. and Namibian sample populations.

We surveyed students in the greater Worcester area to obtain feedback on their learning styles. Our team used Qualtrics software for the data collection. Qualtrics is a platform in which WPI informational surveys are created and secured. We designed a questionnaire that automatically filtered survey responses into one specific place where we can all access. We provided the survey that we distributed to US students in Appendix A. Through this survey, we elicited the student’s opinions about their learning environment preferences. Our team used the information from these surveys to update the original curriculum website, activities, and videos to fit the expressed needs of the students.

We updated the existing curriculum website, activities, and videos to fit the needs of the Namibian students. Appendices B and C show the surveys that we embedded within each lesson and level of the program to ascertain immediate feedback from the students before continuing to a new section. We used these to understand how students comprehend the educational content. From there we made changes or provided recommendations for a future IQP team to amend. The purpose of placing the Appendix B survey immediately after each lesson was to capture as much information as possible, as students will likely struggle to recall the content if the survey was instead placed at the end of the level. The Appendix C survey, however, will be placed at the end of each level since its purpose is to obtain information on the entire level.

3.3. Objective 2: Renovate Existing Content and Implement More Elaborate Lessons and Video Instruction

To ensure the students progressed through the curriculum sections with adequate understanding, we added more elaborate content to the existing platform. Our team aimed to promote cross-disciplinary learning through hands-on activities to establish a stronger understanding for students of all experience levels. To foster a more interpersonal delivery of content to students, we personalized video content through video tutorials. We created tutorials that allowed learners to see the creators throughout the curriculum, which did well to emulate a classroom setting. Feedback from students at P.A.Y. allowed us to assess how well students received the personalized tutorials, while the challenges at the end of each level (as detailed in Objective 3) allowed learners to share successes and failures with our team. This personal connection facilitated a comfortable learning environment and met P.A.Y. 's goal of fostering a strong interpersonal connection between the students and educators.

The previous team utilized YouTube videos within the curriculum to teach students about robotics concepts. With the beginner, intermediate, and advanced sections requiring varied levels of complexity, the concepts in the YouTube videos became increasingly more in-depth. The videos outsourced from YouTube did well to introduce topics like STEM, engineering, and robotics, but lacked high quality instruction for specific activities within the curriculum. To address this issue, we created original step-by-step construction videos to implement in each section that were not sourced through YouTube. Instead, we embedded the instructional videos within the website and compressed them to smaller files to allow faster downloading for students outside the classroom. By supplementing existing YouTube videos with self-made videos, we ensured that the students' additional content would remain solely modifiable by them and future website administrators. In conversation with some students at P.A.Y., they all agreed that creating an original series of tutorials would help to minimize confusion for learners. This is because the number of presenters was limited and allowed for more seamless transitions between lessons. If students required further clarification, they could re-watch, slow down, or pause videos to further advance their understanding. We completed the video making process using the following structure:

Figure 5: Video integration procedure.

We filmed videos in the Foisie Innovation Studios' Maker Space at WPI. It was a high quality video setting that remained constant throughout the curriculum. The videos followed a specific script to ensure that we discussed all core content accurately and executed the shots efficiently. We shot footage primarily in an overhead manner with the camera focusing on the work being done on the VEX IQ kits, while we embedded close-up shots, or B-roll clips, to concentrate on more intricate details. This production method allowed learners to see a direct feed of the content that they were working on through each step of the curriculum activities.

We edited the videos to ensure a natural flow and comprehensive educational progression. These videos supplemented the past content that last years' team outsourced from the VEX website and other YouTube sources. To make sure that the students understood the videos, even those for whom English is a second language, we added a voiceover with subtitles to each video. In the voiceovers, we explained the processes of programming and building with the VEX IQ kit as well as connected the activity to larger applications students may have seen in their everyday lives. We assessed the editing and content delivery styles of the new videos to ensure they were more informative than the previous content. After preliminary shooting, we received feedback from the advisors at P.A.Y. to ensure that the content was relevant and appropriate for the website.

As video production concluded, our team integrated content into the curriculum. We added a recall feature so that students who were struggling with certain concepts could be linked back to specific instruction points in the videos. Furthermore, we revised the facilitator manual to reflect all content changes. Our seamless integration process allowed students to participate in detailed activities as the content was published.

With the VEX IQ kits unavailable to P.A.Y. in the past year, the students were unable to complete the three sections of the curriculum to their full capacities. As we worked to get the kits to Namibia, we implemented activities that could achieve similar learning outcomes in the absence of the kits. As programming constituted large portions of each section, we utilized VEXcode VR activities to accompany the programming lessons. For Intermediate levels, in which we aimed to introduce learners to simple movement code, we implemented Distance Drive and Dynamic Wall Maze activities to allow for virtual replication of the previously-designed lessons. With the more detailed topics in the Advanced section allowing for more complexity in the section, we provided additional VEXcode VR activities such as Cross Every Number and Storm the Castle to challenge students and allow them to become more creative with their solutions.

Our main challenge with the implementation of the new content was the file size of each video and activity. To allow for faster downloads, we kept each video below two minutes in length and compressed the file using a software called Handbrake to ensure no file exceeded 50 megabytes, the equivalent of about 25 image files. Smaller files succeeded in rendering under low bandwidth as well as downloading quickly enough to preserve time for the lessons.

3.4. Objective 3: Develop a Challenge at the End of Each Level

One of the core goals of our project was to include more active-learning in the educational robotics program. This was important because such models of education have been systematically minimized as a result of apartheid. Our team accomplished the goal of establishing more hands-on, project-based opportunities through the incorporation of thought-provoking challenges. We implemented these challenges at the completion of each of the three levels: Beginner, Intermediate, and Advanced. As consistent with each level, these challenges varied in difficulty, and required learners to explore different aspects of the lessons in a hands-on collaborative environment. The following figure shows the structure used for the integration of these collaborative challenges:

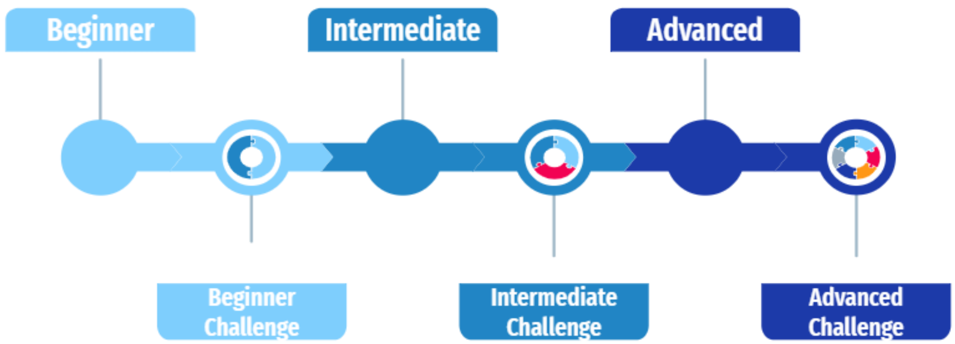


Figure 6: Collaborative challenge structure.

To construct these challenges, our team assessed the direct needs of students in Namibia through surveys and conversation with students and faculty at Physically Active Youth. This feedback suggested an immediate need for constructive thought-building exercises to develop the students critical-thinking skills. We then created the challenges to offer extensive opportunities for students to expand on these skills.

Our group enhanced the curriculum by creating these in-depth challenges at the end of each level. The challenge structure outlined in Figure 6 shows the streamlined progression through the curriculum. This progression allowed students to learn content before the cumulative challenge and advancement to the next level. The new challenges had students use their knowledge from the curriculum to address scenarios in their day-to-day lives. The practical scenarios encouraged students to work together in teams and solve tasks in a competitive manner. By showing the students practical applications of their education, the team fostered creativity and a drive to develop their problem-solving skills. The collaborative challenges of the section incorporated skills learnt from each of the lessons within the level. We designed the final lesson of the Beginner and Intermediate levels as tasks to be given to learners in groups of two or three to complete collaboratively. Our team structured the advanced level challenge as an open-ended problem for students to address and solve as a capstone project for the robotics curriculum. We intended to promote teamwork and the utilization of skills learned throughout lessons with these challenges. Through the implementation of these challenges, our team actively promoted growth in education, collaboration, and life skills, the three core pillars of Physically Active Youth.

The challenge at the end of each level provided useful feedback for the facilitators of the program as they could see the skills the students retained at that point in the curriculum. With fluid communication with P.A.Y., our team gained feedback about the quality and effectiveness of the levels. In addition to gaining this insight on the students' progress, the competition allowed facilitators to incorporate the co-creative problem solving techniques of the WPI learning style into their classrooms.

These activities are intended to benefit the students by providing a stepping stone that can translate linearly to their involvement on a competitive robotics team in the future. As practiced by traditional competitive robotics programs, students can develop STEM-based solutions to problems of varying complexity. Connecting the content within this educational curriculum to the skills required to succeed on a competitive robotics team was imperative to provide Namibian students the best opportunity for growth. These open-ended activities have challenged students to use their ingenuity and problem-solving skills, thus advancing their character development as per one of the core values of Physically Active Youth.

3.5. Objective 4: Tailor the Program to Meet PAY's Needs while Planning for Expansion

While maintaining the short term goal of curriculum implementation at P.A.Y, we aimed to prepare the program for global adoption in areas with a similar need for improved STEM education. The resources and intended learning outcomes embedded within the curriculum were and will continue to be useful for P.A.Y. in Namibia, but could also positively impact other communities in a similar fashion. The primary caveat of this long-term vision was obtaining sufficient resources from VEX to allow for expansion. Past donations and fundraising efforts allowed for the acquisition of 12 VEX IQ kits for students at P.A.Y. The curriculum was then structured around the knowledge and skills that could be developed using these robotics tools. We implemented curriculum modifications and content additions to ensure future project expansion. Notably, the incorporation of the VEXcode VR virtual package made this curriculum applicable everywhere, as any student with access to the website could complete the program holistically and achieve similar learning outcomes. This allowed the program development to continue with the maintained intention of international expansion.

To ensure the program remained universally applicable, the curriculum content did not target a specific geographic location and the Facilitator Manual was updated with guidelines illustrating all aspects of the review lessons, quizzes, interactive activities, and collaborative challenges. The competitions embedded within each section targeted topics similar to those students may encounter at a VEX competition. The VEX competition analogy allowed the program to be ubiquitously applicable, as VEX competitions occur in 40 countries around the world. Further, a recommendation for future WPI IQP teams was crafted to emphasize the possibility of expanding the reach of this curriculum to other STEM-deficient communities globally. Considering the time constraints of the team's project timeline and the wide-ranged objectives desired by the team's sponsor, expanding the reach of this curriculum could only be provided as a recommendation for future IQP teams.

CHAPTER 4
RESULTS

4. Results

4.1. Overview

By implementing our Methodology, we renovated the existing curriculum content and cosmetics, as well as developed review lessons, quizzes, interactive activities, and collaborative challenges. We made the renovations to the existing content and cosmetics to strengthen the structure and educational impact of the curriculum. We developed the new content in four main aspects to prepare the students to succeed on P.A.Y.'s competitive robotics team. While incorporating these renovations and new content onto the curriculum website, our team worked to keep the file sizes and video lengths short enough for students to download even with poor wifi connection. In this section, we delve into our tangible creations, and the supporting quantitative data thereof, that we have integrated into P.A.Y.'s educational robotics curriculum.

4.2. Implementation Plan

After establishing the new components of the robotics curriculum, we started implementation. When incorporating the website revisions, we published the content as we were updating it periodically throughout the project. Our team integrated the new content onto the website seamlessly, which entailed the restructuring of old content, introduction of new review lessons, quizzes, challenges, and the addition of instructional videos. We reorganized many lessons within the curriculum to better accommodate the target age ranges while keeping the content consistent. Our team ensured that we published all revisions at a time when Namibian students would not be using the curriculum, such as in the late afternoon in Worcester, which is late at night or early in the morning in Namibia.

Our team followed a seven-week timeline to complete each task to the extent described in our Methodology. Figure 7 displays this timeline:

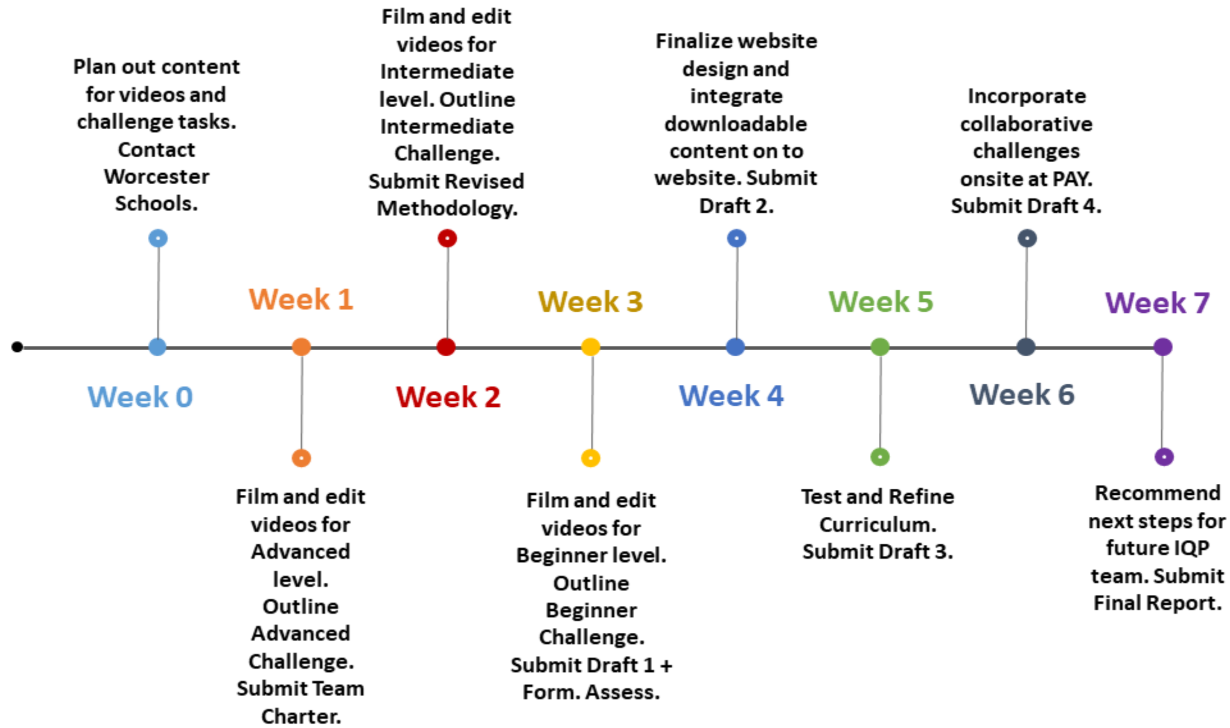


Figure 7: Seven-week timeline.

In week zero, we identified the content for each challenge, determined which videos we would modify, and contacted Worcester schools that administered our surveys to the students we were targeting. We used this contact to get additional feedback on the curriculum holistically and to assess the content flow. In weeks one through three, we filmed and edited advanced, intermediate, and beginner video content while concurrently finalizing the review pages, quizzes, and collaborative challenges for each level. During week four, our team finalized all content and cosmetic revisions for the website and incorporated this new material in an easily downloadable format. Throughout week five, our team tested and refined all of the curriculum content that was incorporated in week four. After this testing and refining stage, the renovated curriculum was ready to be implemented onsite at P.A.Y in week six. During week six, our team actively monitored the students progression through the newly developed challenges via Zoom. This week of monitoring allowed our team to establish a strong foundation for the challenges and to ensure that they were being implemented as intended. Within the last week of the implementation phase, our team reviewed and assessed the completed challenges from the students at P.A.Y. Lastly, we prepared recommendations for the next WPI IQP team that will carry on this project in the future.

4.3. Objective 1: Obtain Feedback on Current Curriculum and Learning Environment Preferences

Before renovating the curriculum, we gathered preferences on learning environments so we would know the best way to restructure the curriculum. As previously discussed, our team created three surveys that we distributed to different demographics. Our team worked closely with the WPI Pre-Collegiate Outreach office to distribute the survey in Appendix 1 and gathered data from 40 families in the Worcester area. Figures 8, 9, and 10 display data gathered from the survey sent to Worcester youth. Figure 8 displays data that was collected from the Worcester youth. The data reflects the ages of students that took our survey.

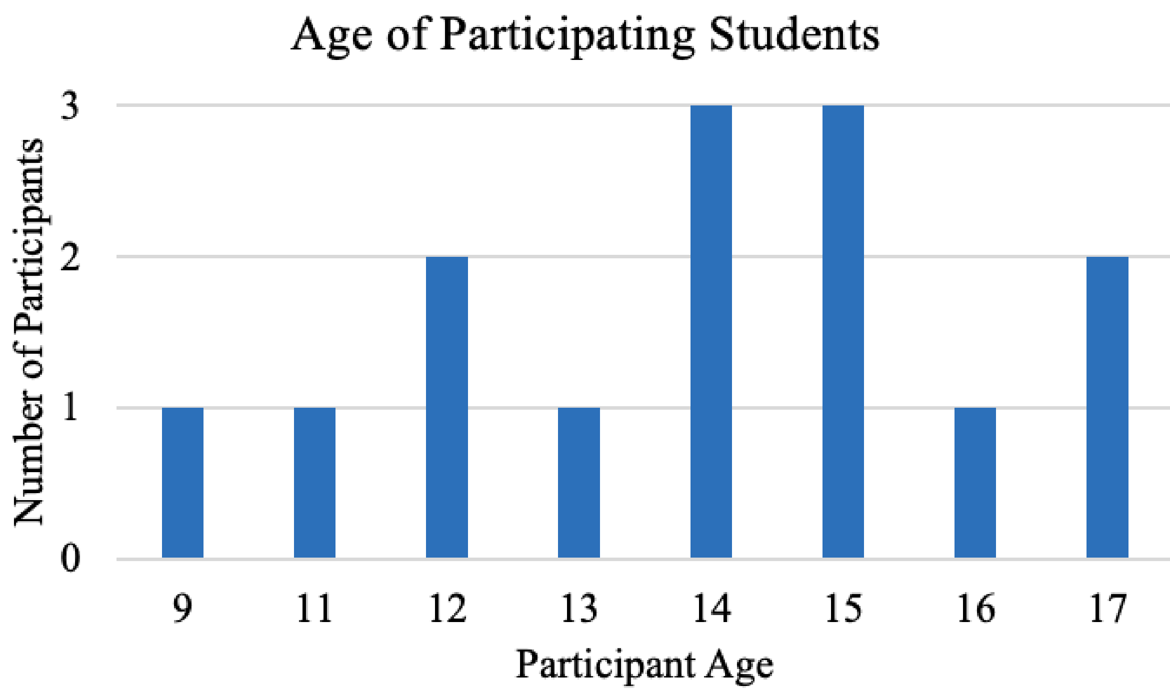


Figure 8: Participant age range of students filling out Survey 1.

The age range of the students who completed this survey was between the ages of nine and seventeen. Although this information is skewed higher than the age demographic of participants at P.A.Y., the data still reflect modern youth preferences on learning delivery mode. In one of the questions on the survey, we asked about the preference between activities and lectures when learning material. All of the respondents answered this question with “activities.” With students preferring to learn material through activities over lectures, the current structure of the curriculum remains appropriate. In discussion with students at P.A.Y., they also confirmed they preferred activities over lectures. This confirmation from students positively reinforced our renovations, encouraging us to continue building the curriculum as we initially intended. To develop new activities, we first needed to understand how students liked to work. These findings from our survey are shown in Figure 9.

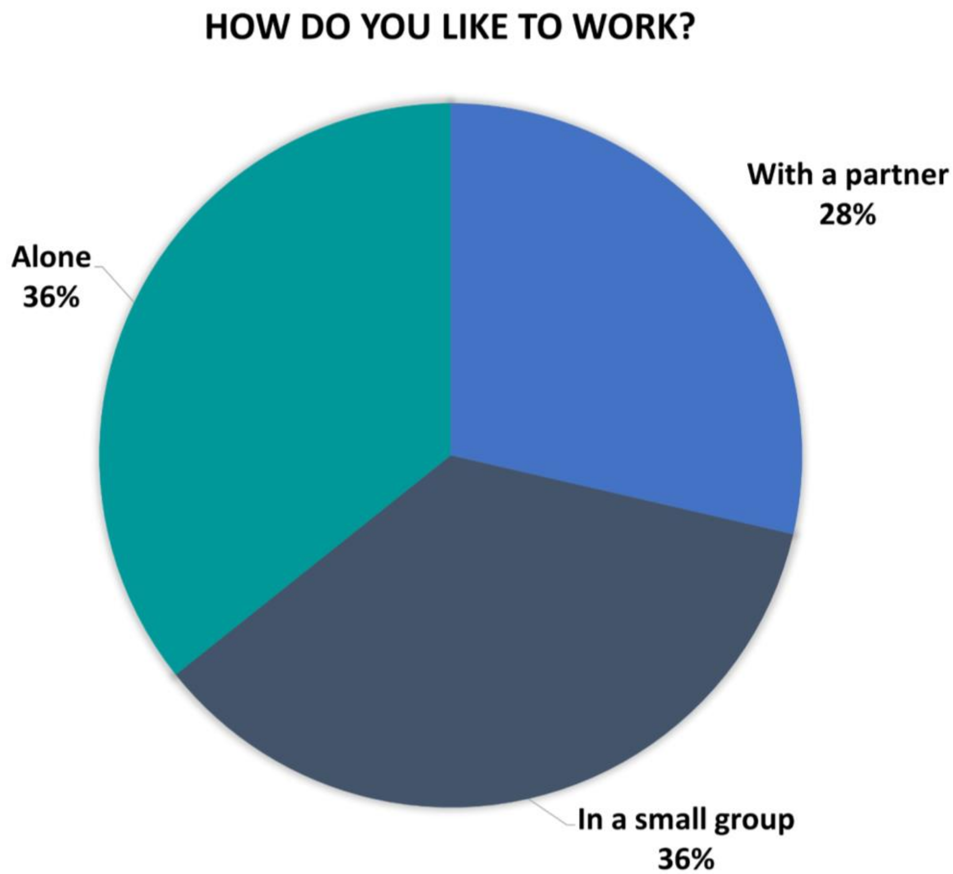


Figure 9: Student responses about how they like to work.

The results exhibited an evenly-split distribution of working preferences among students. With these findings, we structured our newly-developed content to have a variety of learning methods. As outlined in Objective 3 of this chapter, our team developed content that is interactive, allowing learners to develop the skills to work in teams, with one other student, as well as alone. This ensured each student developed the skills of working both independently and collaboratively.

As displayed in Figure 10, the majority of our representative student survey population respondents prefers videos over other methods of content delivery.

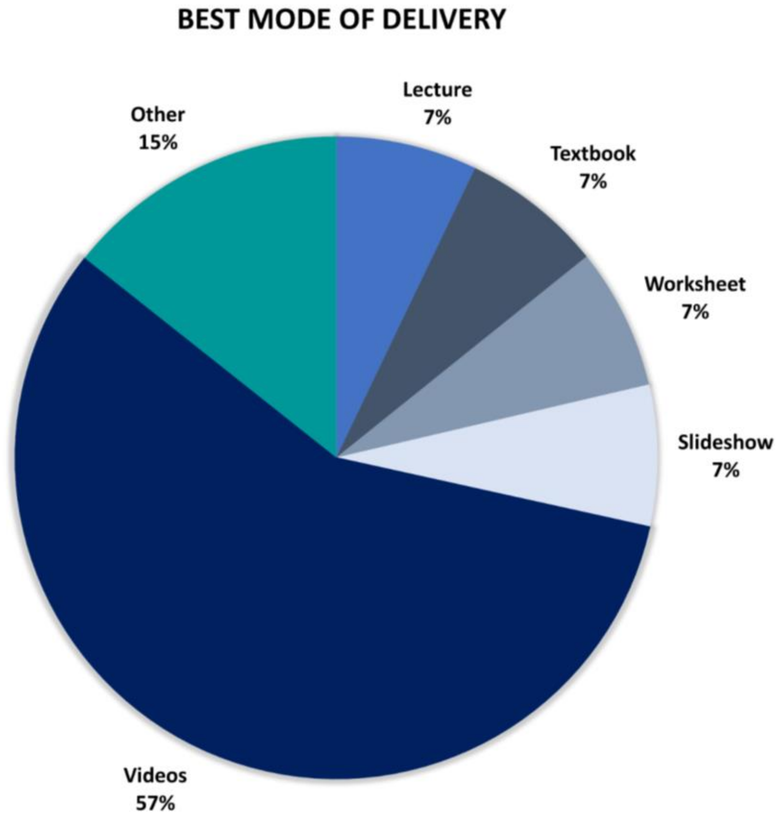


Figure 10: Responses to best mode of delivery from Worcester youth.

This survey solidified the development of instructional videos our team implemented onto the website. The "Other" section, which was the second most preferred, consisted of answers from students who preferred a combination of delivery methods. To target this, we continued to use different modes of delivery in conjunction with the additional videos to engage the most students. This is outlined more in Objective 2 of this chapter.

The responses to our survey helped our team develop the content for the comprehension check, interactive challenges, and cumulative challenge portion of the renovated curriculum. One key piece of the survey was the question "what is your *least* favorite part of working in a group?" This question was overwhelmingly answered with responses such as, "If a person doesn't help at all.” To combat this issue of social loafing, we developed challenges intended to have each student do equal amounts of work and take on different roles. This is apparent in the interactive activities for the intermediate section, where the facilitator assigns students within each team to a specific role that is imperative to the activity completion. The challenges are discussed further in Objective 3 of this chapter.

4.4. Objective 2: Renovate Existing Content and Implement More Elaborate Lessons and Video Instruction

We integrated significant changes to the curriculum platform consisting of content and cosmetic modifications. Table 2 outlines the revisions that were made to the existing program levels as discussed in the Methodology.

Cosmetic changes to the website were also important to improve its professional appearance. Last year’s team took photos in a poorly-lit kitchen which made it difficult to see the labelled parts and their functions. With our access to the Foisie Innovation Studio, our team shot and edited clear photographs with consistent backgrounds. The photos exhibited VEX parts in detail to allow for furthered understanding of the materials. An example of the revision can be seen below in Figure 11.

Table 2: Overview of modifications for each section of curriculum.

Section	Content Modifications	Visual Modifications
Beginner	1. Removed Chassis construction 2. Introduced more fundamental activities regarding simple machines and motor operation *Assessment* 3. Incorporated critical thinking Challenge at conclusion of Level 2 4. Provided summary of learning accomplishments	1. Replaced current VEX Kit photos with higher quality images 2. Replaced photo labelling with video demonstration/animation 3. Replaced difficult words with age-appropriate terms
Intermediate	1. Moved mechanical forces discussion from Advanced to Intro 2. Provided further analysis of programming techniques and sensors *Assessment* 3. Incorporated critical thinking Challenge at conclusion of Level 2 4. Provided summary of learning accomplishments	1. Added animations and visual aids to supplement large sections of text 2. Added videos to demonstrate robot builds
Advanced	1. Removed sensor content that was taught in Intermediate and replaced with more complex sensor content 2. Added additional building components *Assessment* 3. Introduced competitive challenge that prepares learners for larger robotics competitions 4. Provided summary of learning accomplishments	1. Included higher-level images and diagrams 2. Provided examples of current robotics innovation
Overall	1. Provided additional materials to fortify learning outcomes 2. Provided onsite access to alternative virtual curriculum material via VEXcode VR	.. Enhanced visuals and artwork to be more specific to topics

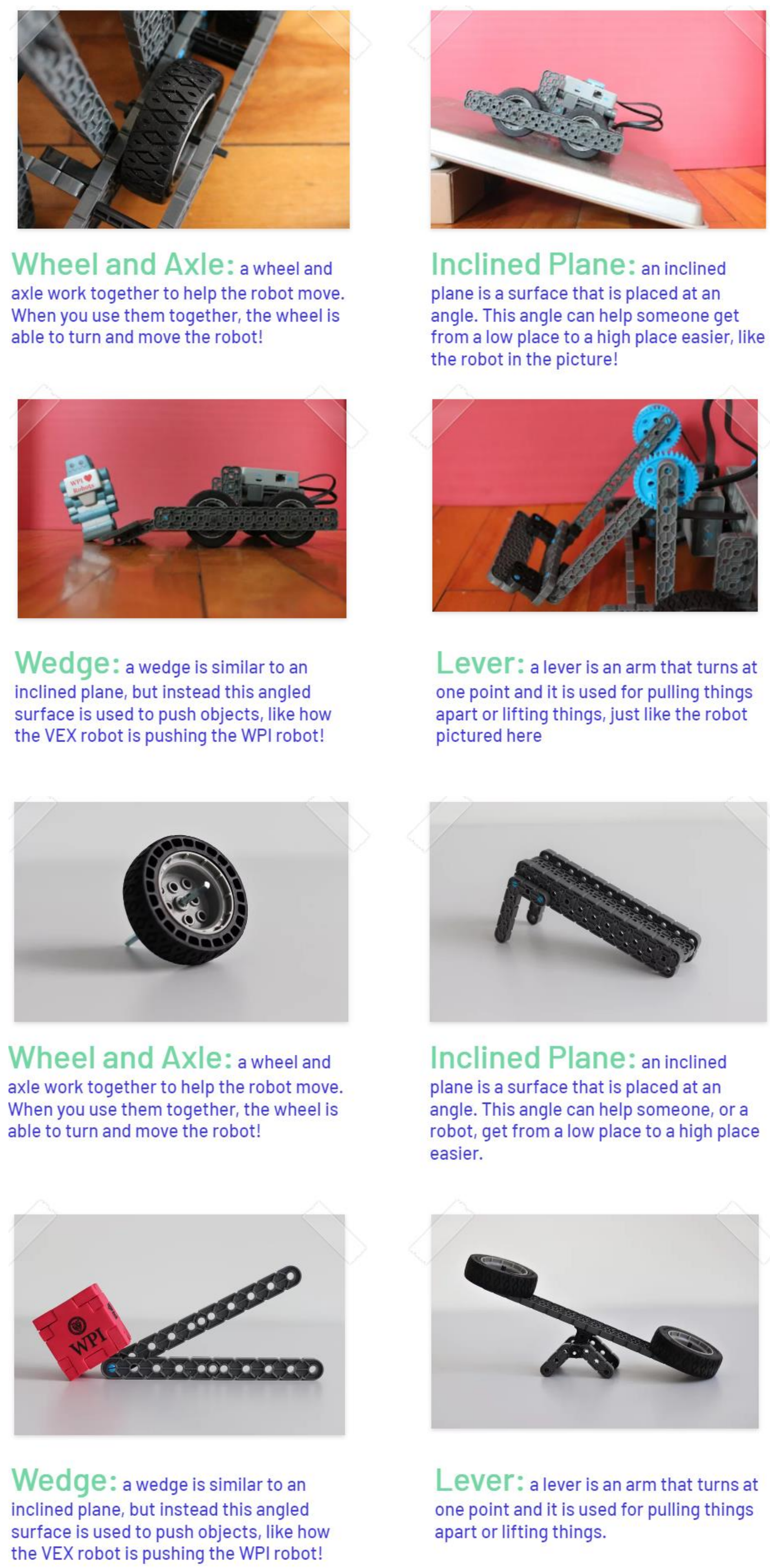


Figure 11: Previous photos (top) vs. current photos (bottom).

As suggested by Figure 10, most of our student respondents (57%) prefer videos as the means of content delivery. In conjunction with the curriculum structure revisions, our team created videos to accommodate the preferred learning style. Initially, content was delivered through text boxes and pictures that could be confusing to follow. We used state-of-the-art camera equipment to film high quality comprehension videos which detailed sequential construction of necessary parts for robotics activities. Examples of the videos included individual simple machine construction, chassis construction, as well as video solutions to challenges.

For fundamental concept videos, the construction component of each video was preceded by introductory lessons to provide more scientific understanding for the parts of interest, as presented in Figure 12. These sections of the videos illustrated examples of machines that may be seen in the students' everyday lives (i.e. a stapler is an example of a lever).

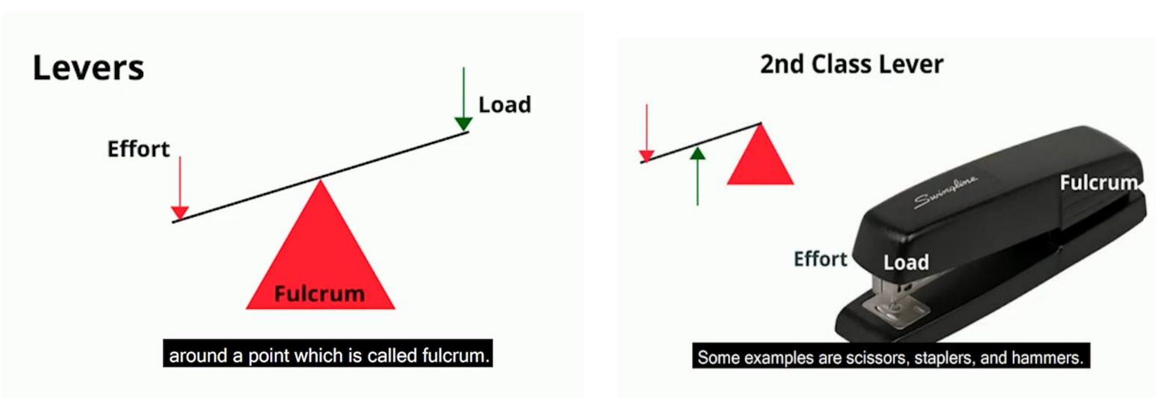


Figure 12: Introductory lesson material which precedes construction tutorial.

Regarding construction tutorials, we used the videos in tandem with instruction manuals provided within the VEX kits to allow students to check their builds and ensure they made the final product correctly. We shot each video from an overhead view with the camera fixed to keep the subject of each build centered as the main focal point. Additionally, each video detailed all necessary materials at the start of the tutorial so students could gather required parts ahead of time. The image below displays what students saw before collecting the materials.

Figure 13: Chassis material layout followed by pause prompt to allow students time to collect required materials.

Furthermore, we added subtitles to each video to accommodate students who have trouble understanding or hearing the words. An example can be seen in Figure 14. We made each video to be appropriate for all age groups. While we tailored the fundamental lessons in the beginner section towards the younger learners (ages 6-10), the style of each video was consistent with slow, detailed explanations and step-by step instruction so all learners and facilitators could follow along easily. In our first presentation of the videos to the instructors at P.A.Y., Thuba Sibanda, the Executive Director, commented that she felt she could build the robots easily despite having limited experience with VEX IQ kits. In a meeting with students from the older section (ages 14-18), we saw the videos succeed in maintaining engagement. The energetic atmosphere and constant collaboration at the P.A.Y. center can draw students in multiple directions, but our video demonstrations did well to hold students' focus. This confirmed our initial belief that videos would do well to maintain student engagement as they worked through the pages of the website.

Figure 14: Subtitle captions.

With the intention of engaging viewers, our team integrated a welcome video on the homepage of the website. In the clip, we displayed our team constructing the parts of the VEX kit that students would be using. It promoted teamwork, normalized mask wearing during COVID-19 safety protocols, and ultimately motivated students by concluding with a title frame reading "The science of today is the technology of tomorrow." Furthermore, this video allowed students to see us, the creators, before beginning the curriculum to establish more of a personal connection. Figure 15 below depicts a frame of the short welcome video.

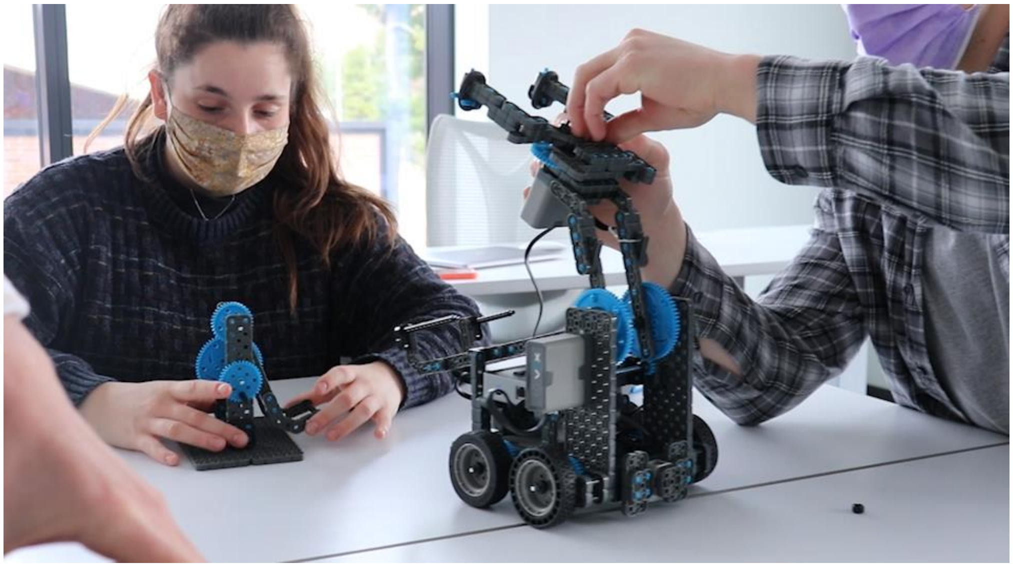


Figure 15: Welcome video frame.

To assess the efficacy of the videos, we surveyed both the Namibian learners and WPI Engineering Ambassadors who specialize in teaching STEM topics to younger audiences. In a meeting with older students at P.A.Y., we demonstrated the Lever Simple Machine and Intermediate Challenge Solution videos. After presenting to them, our team asked the students if the videos were clear in their delivery. The students said the videos were easy to follow and could be understood by the younger learners.

Additionally, the WPI Engineering Ambassadors (EAs) provided technical feedback which helped us make final revisions to the videos. We asked the EAs to watch the same videos presented to the Namibian students and provide qualitative feedback (see survey detailed in Appendix D). Without informing the respondents which age ranges the videos were intended for, we fielded the question: “On a scale from 1-5, how comprehensive would you rate this video?” Each ranking was associated with an age group and the ambassadors’ results can be seen in Figure 16 below.

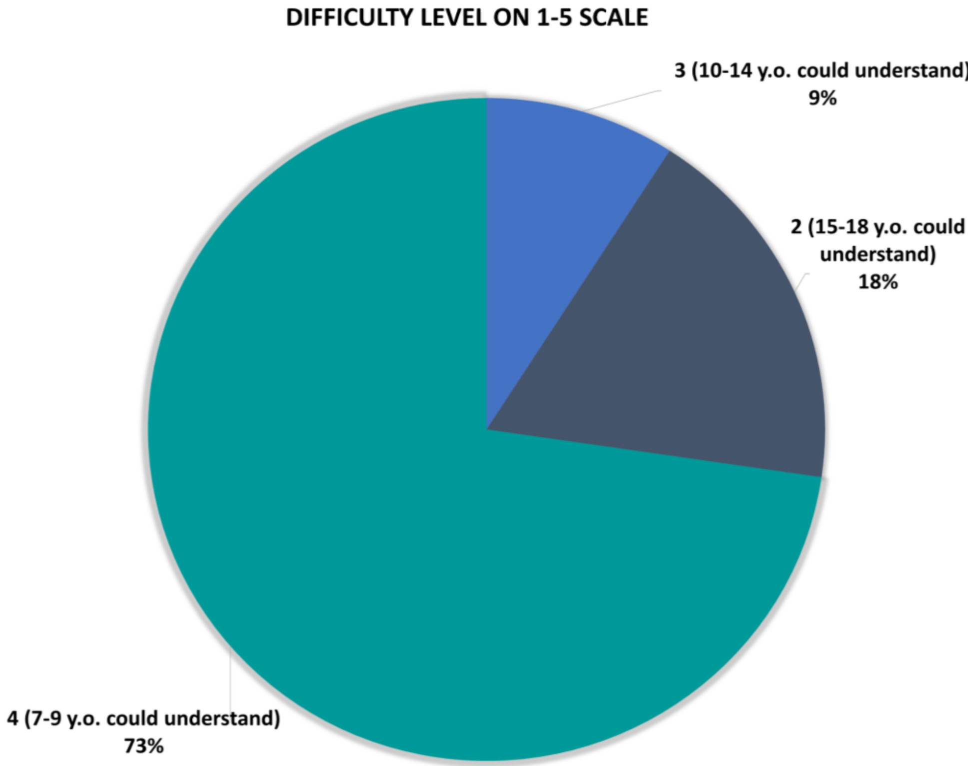


Figure 16: Engineering ambassadors' ranking of video comprehension.

The data suggested that our videos were relevant and appropriate for the intended age groups. We included the lever simple machine video in the beginner section which was intended for learners aged six through ten, and the majority of respondents rated the video as comprehensive for learners aged seven through nine. Other respondents claimed that possible difficulty in comprehension was due to certain clips being too quick or blurry. We addressed these concerns and edited accordingly. We also resized the graphics and added more pause prompts to guide viewing.

4.5. Objective 3: Develop a Challenge at the End of Each Level

The challenges we created help achieve our core goal of including more active learning in the educational robotics program in Namibia. In addition to these competitive challenges at the end of each section, we also developed and incorporated interactive activities to precede these challenges in each section. When a student using this curriculum completes Beginner Level 2 Lesson 4, they advance to the "Let's Review" page, which we added as a conceptual review of all topics covered in the Beginner section. Figure 17 below displays an example of the "Let's Review" page content. We reiterate the content from the previous lessons in the Let's Review pages, while also gearing our examples towards the typical experiences of young kids. Further, the student demographic at P.A.Y. specifically shares a great interest in bicycling, which will help to connect this educational content to their personal lives.

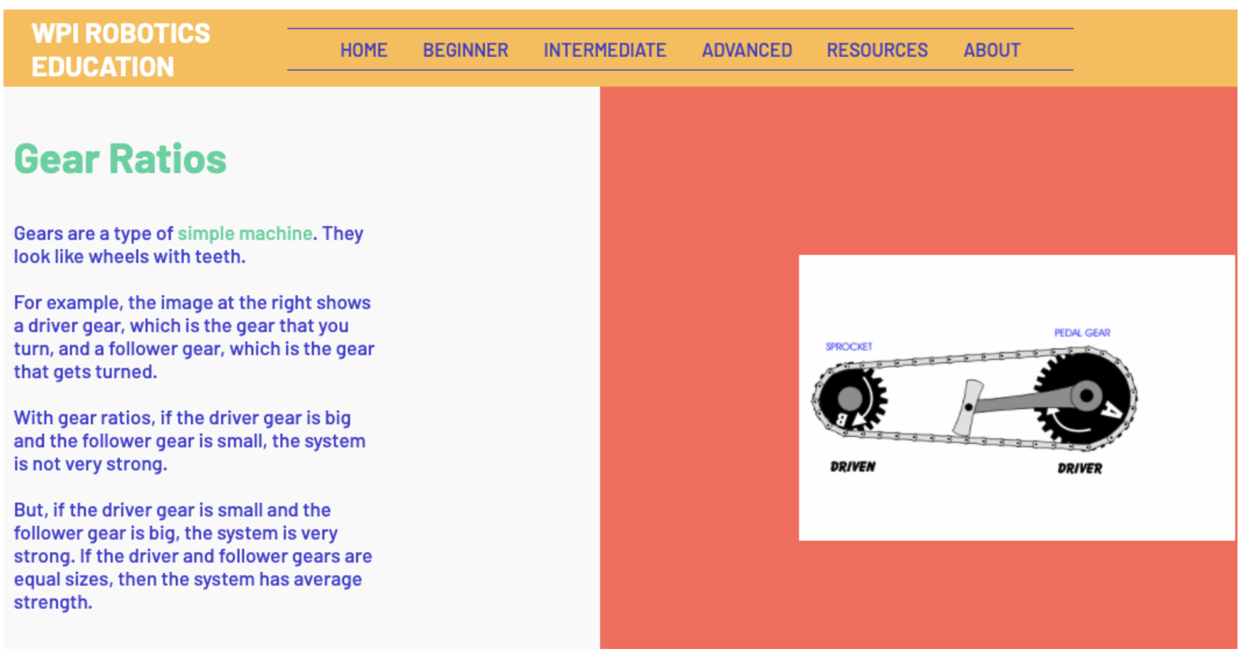


Figure 17: Screen capture of Beginner Let's Review page.

Once the student finishes the review section, they will advance to the "Comprehension Check" page, which we added to house the interactive activities for each section. We created these interactive activities to allow students the opportunity to exercise the knowledge they gain from the lessons in a similar format to the competitive challenges, but without a VEX IQ kit. Figure 18 below illustrates an example of these interactive activities, which test the students conceptually in a similar manner as the competitive challenges. Also, these activities allow for discussion afterwards to connect the exercise to skills used in robotics engineering.

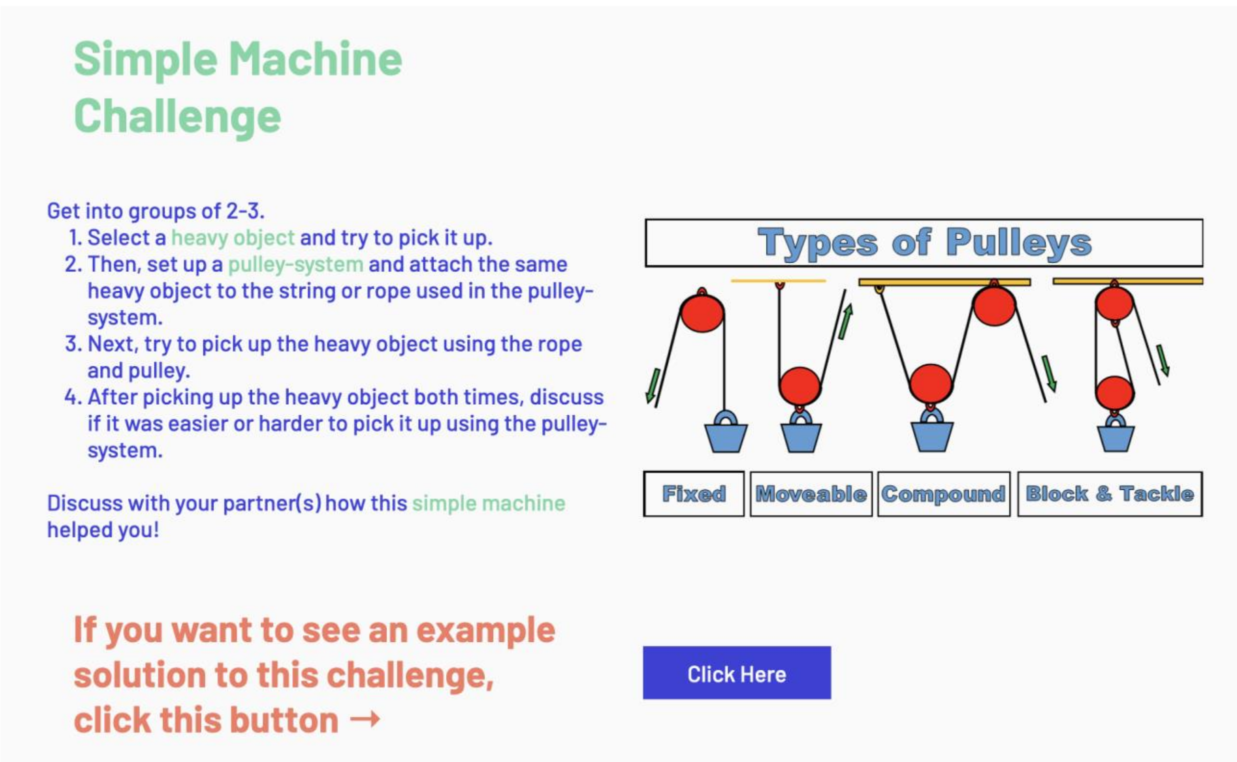


Figure 18: Screen capture of Beginner Comprehension Check page.

Upon completion of the "Comprehension Check," the student progresses to a concept-based multiple-choice quiz, which we created as a form of assessment by request from our sponsor. Finally, the student advances to the "Beginner Challenge" page, which consists of the instructions and details pertaining to the competitive challenge for the Beginner section. Once the student completes the challenge in each section, they are directed to a survey intended to provide feedback for the creators. After the survey page, the students are guided to the intro for the Intermediate section. Figure 19 below displays the structure of one section of the Intermediate challenge page. Within the website, we give the students hints to guide them as well as buttons that will redirect them back to certain sections that could be helpful for the challenge, as seen in Figure 19.

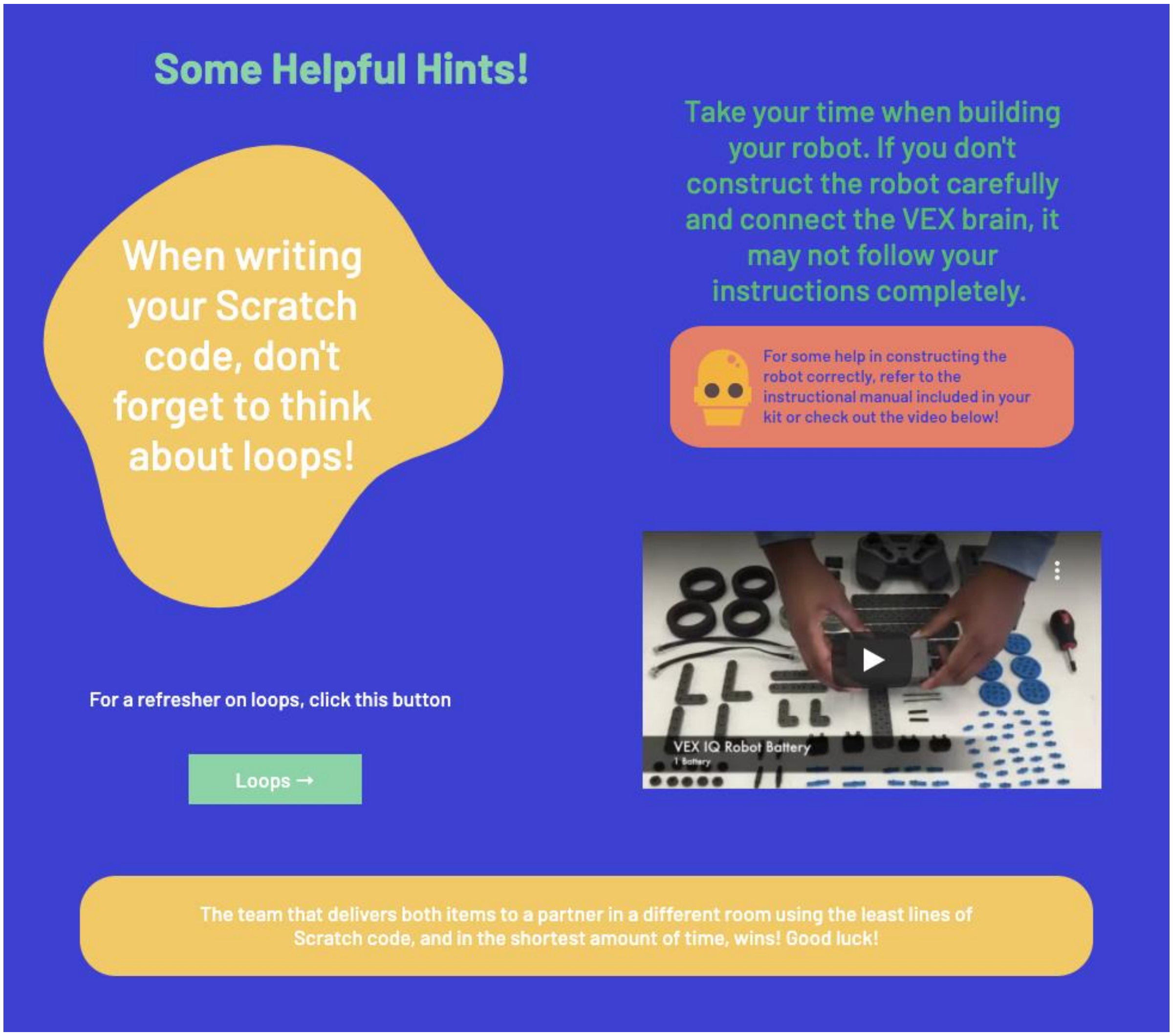


Figure 19: Screen capture of Intermediate Challenge page.

In each of our competitive challenges, we target a different aspect of one of our goals, which is for the students at P.A.Y. to progress through the curriculum and segue onto their competitive robotics team. Table 3 below displays the organization of each competitive challenge, as well as the estimated time of completion.

Table 3: Description of competitive challenge time estimate, type of challenge, and targeted concepts.

Competitive Challenges	Beginner (ages 6-10)	Intermediate (ages 11-14)	Advanced (ages 15-18)
Time Estimate (hours)	2	4	8
Type of Challenge	Manual Operation	Automated Operation	Remote-Controlled (Manual) and Automated Operation
Incorporated Concepts	Gear Ratios, Simple Machines and Mechanical Advantage, and Basic Scratch Programming	VEX IQ Robot Assembly, Loops and More involved Programming, Importance of Precision in Robotics	Object Manipulation, Lifting Mechanisms, Sensors and heavily involved Programming, More heavily-involved VEX IQ Robot assembly

We organized the competitive challenges to foster the most linear progression from our curriculum to P.A.Y.'s competitive robotics team, which was established by one of the other 2021 IQP teams working with P.A.Y. This challenge structure allows students to build the skills to succeed on a competitive team, while also introducing them to an iteration of a past VEX robotics competition. For students in different locations still desiring the same educational robotics experience, our team incorporated additional virtual tools that develop similar skills to the in-person curriculum components. In an effort to give all students in Namibia this same experience and opportunity, specifically targeting those with poor internet connection, we also worked to convert all content to an easily downloadable format.

4.6. Objective 4: Tailor the Program to Meet P.A.Y.'s Needs While Planning for Expansion

One of our objectives was to make the educational robotics curriculum globally accessible. To achieve this, we reduced the file size of content on the website for easier downloadability, implemented virtual tools such as VEXcode VR, and integrated lessons and activities to minimize the need for a physical robotics kit.

To ensure that students and facilitators have access to this curriculum from anywhere, our team compressed file sizes of web content and videos. In conversation with Macdonald Kapukare, ICT Officer at P.A.Y., we learned of the onsite wifi capabilities. He noted the limited bandwidth, occasionally caused lagging or prevented video streaming. Furthermore, Maruen Kleopas, a volunteer instructor at P.A.Y., informed us that he would typically use cellular data on his computer so students could gather around and watch a video. In an attempt to keep content concise and manageable on networks of differing capacities, we kept videos short, limiting them to three minutes and thirty seconds. This means that the maximum file size of the compressed videos was about 50 megabytes, the equivalent of about 25 picture files. Video compression ultimately resulted in reducing original file sizes by about 66% and allowed students and facilitators to download videos three times faster.

We tested viewing capabilities at P.A.Y. by presenting compressed and uncompressed video files to students during a busy class period. With all the computers being used by students at the center, the longer compressed video (1.5 min., 35 megabytes) loaded seamlessly, whereas the shorter uncompressed video (1 min., 76 megabytes) failed to load. This result confirmed that our compression procedure aided not only with downloading but also with streaming capabilities in low-bandwidth settings. This procedure will ultimately allow our program to be available to other communities with limited internet access in the future.

As a failsafe, we created a zip folder containing all video content. We allow facilitators to download the zip folder onto the fifteen computers in advance, thereby saving class time. In the case of a video lagging or not playing on the website, the students can access the downloaded video content on the computer's hard drive and continue to follow along with the website's instructions. We also added this zip folder to Google Drive to be shared with future WPI IQP teams. This folder will be shared through our contact with Joe Doiron, who is a key stakeholder in P.A.Y.'s partnership with the Namibia IQP project site.

With initial delivery timelines for the VEX IQ kits on site in Namibia unclear, our team advanced the usability of the curriculum through VEXcode VR, the virtual alternative to VEX IQ, and interactive challenges that do not require any tangible kits. These substitutes for the tangible VEX IQ kit are available to the students through the curriculum website. We recognized the inherent differences in the physical and virtual kits, but understand that the skills required to instruct them are complimentary. For students using VEXcode VR, the assembly videos for the

VEX IQ kits have acted as a supplemental visual tool. When the IQ kits arrived, students were already familiar with assembly and programming in the VR landscape, mitigating potential confusion during the construction process. On the website, students are informed which lessons require the tangible VEX IQ kits and which lessons they can skip if they do not have one. VEXcode VR has afforded students the opportunity to instruct the robot through coding in the same manner they would instruct the tangible VEX IQ robot.

In conversation with Mr. Kleopas, he requested more lessons that did not require the VEX IQ kits. This is due to the short nature of their classes, as students work for 45 minutes per day on technology topics. The constant use of VEX IQ kits during this time would be too strenuous for students and faculty, as there would not be enough time to build, program, test and disassemble the kits each day. With this understanding, we integrated VEXcode VR lessons into the intermediate and advanced levels to allow students to use their new programming knowledge to test robots on a virtual game field. The VR software uses virtual mechanisms and sensors that the students must program and run to complete certain tasks. With an expansive library of challenges ranging in difficulty, VEXcode VR offers facilitators the option to learn the fundamentals of programming and sensor integration in a fully virtual space. The addition of VEXcode VR into the intermediate and advanced levels allowed for a more accessible curriculum for students who do not have access to the VEX IQ kits.

To continue learning the curriculum in a hands-on manner without the VEX IQ kits, we updated the curriculum with interactive challenges to reinforce the conceptual content using only commonplace objects or none at all. We provided these interactive challenges to Mr. Kleopas, with the intention of implementing them with the different target age groups while the VEX IQ kits were in transit. The structure of these interactive activities can be found in Appendix E.

After initial onsite testing, we obtained feedback from the students via an online form. We asked students to rate their enjoyment, information comprehension, and give feedback on the lessons. This feedback informed further modifications to challenge content.

4.7. Summary

To accomplish these four objectives, we segmented our effort into two concrete deliverables: a revised curriculum structure and new active-learning material. We executed our first deliverable by restructuring the curriculum to be more suitable for the target age ranges and incorporating high-quality media to replace existing visuals on the website. The respondents to our surveys validated our decision to use videos as an additional form of content delivery. Also, the survey respondents reinforced our restructuring of the program, as they agreed it would be suitable for the intended age ranges. We executed our second deliverable by creating conceptual review lessons, interactive activities that are independent of the VEX IQ kits, multiple-choice quizzes, and collaborative challenges that are dependent on the VEX IQ kits. This active-learning material improves learner retention and fosters a collaborative learning environment both with and without the VEX IQ kits. In conversation with Mr. Kleopas and the students at P.A.Y., we learned that the students enjoy the active-learning material and remain more engaged in comparison to lecture-based content delivery. Our team presented these two deliverables to P.A.Y. to further enhance the existing robotics curriculum and to inspire students to undertake a project-based learning approach. Given the positive feedback from our survey respondents and contacts at P.A.Y., the deliverables that we presented satisfied our project goal of creating a scalable robotics curriculum.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

OVERVIEW

5.1 SUMMARY OF FINDINGS AND DELIVERABLES

5.2 RECOMMENDATIONS

5. Conclusions and Recommendations

Overview

This chapter summarizes our team's key findings and deliverables, as well as our recommendations. Our team worked with Physically Active Youth (P.A.Y.) to renovate and enhance an educational robotics curriculum originally developed by a previous WPI team. Our goal was to enhance and cultivate a scalable educational robotics curriculum to further promote STEM to Namibian youth. Throughout our work on this project, we focused on two main sectors of our deliverables: renovated video and website content, and the respective challenges.

5.1. Summary of Findings and Deliverables

In conversations with our sponsors at P.A.Y. and the 2020 WPI IQP team, both groups advised us to enhance the quality and material of the current curriculum content. As a team, we discussed the efficacy of the original curriculum with WPI Robotics Engineering Department Professors to gain insight on the gaps we could bridge. Through these discussions, we created four objectives to tackle: obtain feedback on current curriculum and learning environment preferences, renovate existing content and implement more elaborate lessons and video content, develop a challenge at the end of each level to test cumulative knowledge, and tailor the program to meet P.A.Y.'s needs and plan for global expansion.

We surveyed Worcester youth to gain insight on learning delivery mode preferences. With the help of the WPI Pre-Collegiate Outreach office, we distributed learning preference surveys to about 1,000 Worcester families. This survey consisted of questions regarding preferences of learning delivery mode. The qualitative data obtained confirmed that students far prefer learning through hands-on activities and videos. By obtaining these key findings, we could cater the program to the direct preferences of youth. We did this by implementing the interactive activities, collaborative challenges, and videos to satisfy the student preferences. Our team developed independent and collaborative activities and renovated videos as deliverables to give to P.A.Y.

Summary of Deliverables

The 2020 team used videos outsourced from YouTube to give learners an overview of STEM, engineering, and robotics. They used low-quality photographs of the VEX IQ kits to demonstrate simple machines and basic building instructions. To address this, we developed a series of instructional videos that guided learners through the building steps of the components such as the Lever Simple Machine and the Chassis, along with others. After we completed the videos, we compressed the file size to about 50 megabytes to account for P.A.Y.'s limited bandwidth. As a failsafe, we put all instructional videos in a zip folder that members at P.A.Y. can download onto the hard drives of the computers in their classroom. We upgraded all photos and videos from last year's team to higher resolutions and frame rates. The enhanced visuals gave learners clarity when constructing the VEX IQ kits and improved the delivery of scientific concepts.

To ensure that each student fully comprehends each section of the curriculum, we developed a series of post-lesson activities at the end of each section: beginner, intermediate and advanced. These activities consist of review lessons, interactive activities, comprehension quizzes, and collaborative challenges. Each of these four sections aid the learners with retention and give facilitators confirmation that the learners are prepared to move on to the next level. The "Let's Review" section works as a quick review of the level that students can use to recognize any key points. We designed the interactive activities for students to do without the use of the

VEX IQ kits. Students will complete short activities with everyday classroom items to give parallels to the STEM topics they learned in the lessons. We developed the comprehension quizzes to serve two purposes: to help students retain the material and for facilitators to ensure that students are comprehending material. These quizzes consist of 5 to 10 multiple-choice or short-answer questions which facilitators can access. Lastly, the collaborative challenges bring fun and competition into applied STEM topics. The collaborative challenges test students to be creative and work in a team to complete a given task. These collaborative challenges streamline students to be prepared to compete on P.A.Y.'s competitive robotics team.

5.2. Recommendations

Towards the end of the project, our team created recommendations to address further developments to the project that were not attainable during our timeline. We segmented the recommendations to target the different components of this multifaceted project.

The recommendations relate to:

1. Improvement of the web-based curriculum content,
2. Future development of challenge material,
3. Curriculum integration and global expansion, and
4. Guidance for Educators.

Recommendation 1: Expand Content and Spread Over More Lessons

The current website does a great job of teaching students the basic knowledge for succeeding in STEM. Though the content is a thorough and coherent educational tool, there is room for future expansion to the curriculum. We recommend that a group of students who is continuing this project expands the content being taught and spreads it out over more lessons. With the material spaced out and presented more thoroughly, students will have better content comprehension. Facilitators at P.A.Y. have limited time each day to teach robotics lessons to the students, so the lesson structure should reflect this limited classroom time. Lessons should go more in depth on the relevant content, especially in the higher age levels. With shorter, more in depth lessons, students and facilitators can be efficient with their limited classroom time. More difficult material offers students the space to challenge and immerse themselves in their education. We know that P.A.Y. 's goals for the robotics program are to have students learn and retain STEM concepts, engage in healthy competition, and foster creativity in the classroom. Further projects should keep these goals at the forefront when addressing future changes.

Recommendation 2: Continue Developing Collaborative Challenge Material

Facilitators at P.A.Y. expressed their excitement about the new challenge material that we developed. We recommend that a future project team add additional interactive activities and collaborative challenges to improve knowledge retainment and student interaction. Feedback on the interactive activities showed that the content kept students engaged and active in the classroom. Activities such as these help to maintain order and control in an otherwise animated classroom environment. In addition, the activities offered a much-needed break for students from their computer screens and created a fun learning environment. We recommend the addition of two interactive challenges in each level to keep students engaged with the content and offer activities to push the students' critical thinking skills. More of P.A.Y.'s onsite resources can be integrated into these interactive activities to take advantage of the assets that P.A.Y. offers as a learning institution. This will be possible, as future IQP project groups will have the opportunity to travel to Namibia and assess the onsite resources at P.A.Y. We also recommend the expansion of the collaborative challenge sections within the curriculum. Current challenges offer excellent competitive opportunities and the continued development of these challenges only benefits the students. Each section currently offers one competitive challenge. This can be expanded to offer a challenge at the completion of each lesson level. A suggested structure for future expansions is illustrated in Table 4 below:

Table 4: Proposed structure for future curriculum content additions.

Level 1	Level 2	Level 3
- Lesson 1 - Lesson 2 - Interactive Activity - Lesson 3 - Lesson 4 - Cumulative Challenge	- Lesson 1 - Lesson 2 - Interactive Activity - Lesson 3 - Lesson 4 - Cumulative Challenge	- Lesson 1 - Lesson 2 - Interactive Activity - Lesson 3 - Lesson 4 - Cumulative Challenge

Table 4 shows the progression through a proposed Beginner section on the website. Additional levels, interactive activities, and competitive challenges allow students to engage with the content in different ways and supports all styles of learners.

<u>Recommendation 3: Planning for Global Expansion</u>

The accessibility of the current curriculum allows for integration at other youth programs in different communities globally. If a future IQP team were to adapt the contents of this project at another location, we can provide recommendations for them specifically. We recommend that future teams begin by assessing the resources in the new community. By analyzing the access to STEM resources, the future IQP team can infer the necessary changes to the curriculum. A future team would also have to assess the need for additional fundraising for the purchase of VEX IQ kits. Since the website was designed to be shared with multiple audiences, project teams should use our curriculum as a resource. We recommend that a future team makes modifications to the curriculum content to best fit the culture and learning style of the new location. This can be done by incorporating relevant local examples into lessons. Current content uses the example of bicycles in many lessons because we know that students at P.A.Y. have an advanced level of knowledge and exposure to bicycles. We recommend that similar local references be used as educational tools. Future teams will also need to account for adjusting the pace of content to fit the prior knowledge and skill level of the new learners. With the current content focusing around the VEX IQ kit resource, integration at new sites without these kits will prove difficult. There are many schools and programs local to the Worcester area who already have VEX IQ kits who would benefit from the curriculum as a resource in the classroom. As a team, we sought out local summer programs where the curriculum could be used. Though we did not have time to fully integrate the curriculum into one of these programs, we see this as an accessible task for a future team.

Recommendation 4: Reference the Facilitator Manual when Using the Curriculum

By creating the curriculum on the WIX website platform, it can be shared easily to benefit many audiences. We updated the facilitator manual with the purpose of guiding educators through the lessons, activities and challenges. The facilitator manual serves as a vital resource to facilitators whether they are experienced teachers or not. Other facilitator resources should be taken advantage of to the fullest extent and are located on the resources tab of the website. For other organizations planning to use the curriculum, we recommend following the facilitator guide to fully understand the intent behind each component of the curriculum. Facilitators must also adjust the lessons to best fit the needs of their learners. This includes relating examples to their life and culture, adjusting the pacing based on their prior experience with robotics, and presenting the material in such a way that best engages students. We also highly recommended that in a classroom setting, facilitators present the material to the class as a group when possible. We recommend that students work on teams of 2-3 members, discuss guiding questions, and brainstorm ideas among themselves often.

Conclusion

Over the past two years, WPI IQP teams have developed an extensive educational robotics curriculum at P.A.Y. Our team worked to achieve the goal of making this a scalable curriculum to enhance STEM education for Namibian youth. This robotics curriculum has the potential to be implemented worldwide to students with various backgrounds. The comprehensive website allows students with a variety of backgrounds to become comfortable with STEM topics. As a team, we hope to inspire Namibian youth to pursue STEM opportunities inside and outside of the classroom. In the creation of this curriculum, we fostered P.A.Y.'s mission to create a more equal and knowledge-based Namibia. Although we created this project for the application at Physically Active Youth, the versatility of the content allows the curriculum to be applied globally for organizations and students interested in educational robotics.

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7. Appendices

7.1. Appendix A: Questionnaire for American Youth

Questionnaire for American youth to gain insight into learning habits and effects of virtual learning:

1. What is your age?
    - *a. Open answer*
2. What gender do you identify with?
    - a. Female
    - b. Male
    - c. Other: *open answer*
    - d. Prefer not to say
3. Is it easier to learn from activities or lectures?
    - a. Activities
    - b. Lectures
4. How do you like to work?
    - a. Alone
    - b. With one other person
    - c. In a small group
5. What is the best mode of information delivery?
    - a. Videos
    - b. Slideshow
    - c. Textbook
    - d. Worksheet
    - e. Lecture
    - f. Other (fill in)
6. How do you prefer to be assessed on learned material?
    - a. Test or Exam
    - b. Group Project
    - c. Independent Project
    - d. Presentation

   e. Other (fill in)

7. When you struggle with a task how do you prefer to work through it?
   a. Ask teacher for help
   b. Watch video to explain it
   c. Work through it independently
   d. Ask classmate
   e. Other (fill in)
8. How do you prefer to study?
   a. Flashcards
   b. Reading Notes
   c. Re-writing Notes
   d. Watching videos
   e. Completing Review Assignments/Practice Tests
9. What is your *least* favorite part of group work?
   a. Open answer
10. What is your favorite part of group work?
   a. Open answer

7.2 Appendix B: Questionnaire during Educational Robotics Program

Questionnaire embedded within each lesson of the educational robotics program to elicit opinions on the layout and difficulty:

1. How difficult was this lesson?
    a. Easy
    b. Medium - challenging, but still able to complete
    c. Hard - got stuck multiple times
2. Did you understand the language and examples in this lesson?
    a. Yes
    b. No
3. What did you like about this lesson, and how could it be improved?
    a. Open Answer

7.3. Appendix C: Questionnaire for Feedback at the end of each Level

Questionnaire located at the end of each level to elicit opinions on the level overall and to remove any impediments within the level:

1. How would you describe the questions at this level?
    a. I understood all of them
    b. I understood most of them
    c. I understood some of them
    d. I understood none of the questions
        i. If so, which lesson were they in? *Open Answer*
2. How difficult was this level?
    a. Easy- I had no problem at all
    b. Medium - challenging, but still able to complete
    c. Hard - got stuck multiple times
3. Which lesson was your least favorite, and why?
    a. Open Answer
4. Which lesson was your favorite, and why?
    a. Open Answer
5. What are three things you learned from this lesson?
    *a. Open Answer**
    *b. Open Answer**
    *c. Open Answer**
6. How could this level be improved?
    a. Open Answer
7. How much did you learn in this level?
    a. 1: Nothing, I already knew this.
    b. 2: Some things, but I knew most of this.
    c. 3: Average, but I knew a good amount beforehand.
    d. 4: A lot, but I knew some of it beforehand.
    e. 5: All of this was new.

7.4. Appendix D: WPI Engineering Ambassadors Video Feedback

Survey sent to WPI Engineering Ambassadors to obtain video feedback.

1. On a scale from 1-5, how comprehensive would you rate these videos?
    a. 1 (difficult to understand)
    b. 2 (15-18 y.o. could understand)
    c. 3 (average, 10-14 y.o. Could understand)
    d. 4 (7-9 y.o. could understand)
    e. 5 (easy to understand, a 6 y.o. could understand)

2. On a scale of 1-5, how would you rate audio and visuals?
    a. 1 (unclear/distracting)
    b. 2
    c. 3 (average)
    d. 4
    e. 5 (did well to demonstrate topic)

3. What could be done to improve videos overall?

7.5 Appendix E: Activities and Challenges located in the Facilitator Manual

Activities and challenges to be implemented with the purpose of developing critical thinking skills and assessing the students' comprehension of the curriculum concepts.

Beginner (ages 6-10 recommended):

Simple Machine Challenge

<u>Instructions:</u>

1. With the selected *heavy object*, have the students each try and pick it up normally.
2. Then, set up a pulley-system and attach the same *heavy object* to the string or rope used in the pulley-system.
3. Next, have each student try and pick up the *heavy object* using the rope and pulley.
4. After each student has had a chance to pick up both, ask if it was easier or harder to pick it up using the pulley-system.
5. Discuss with students that this is a simple *mechanical* machine, and when they utilize *mechanical systems* to make tasks easier, they are using *mechanical advantage*.

Programming Challenge:

<u>Instructions</u>:

1. Students need to split into teams of two.
2. Have one student write down exact instructions to have their teammate go from one point in the classroom to the one point in another classroom.
3. Give students very limited instructions, this is to have them realize that they need to be specific. The only instructions they are allowed to give are start, go straight, turn left, turn right, stop.
4. Allow the students to attempt this activity once before reminding them to include *distance* in their instructions (for example, go straight *for 10 steps*).

5. After students have all completed this exercise, successfully getting from point A to point B, discuss with the students the importance of giving *specific instructions* and how this activity connects to Scratch and programming.

Intermediate (ages 11-14 recommended):

Programming Challenge:

Key: *VEX robot* = the person acting as the VEX robot

VEX brain = the person acting as the VEX brain

Instructions:

1. Organize the class into groups of two and provide a material to use as a blindfold for one person in each group. If both participants are uncomfortable using a blindfold, they may cover their eyes with their hands or simply keep them shut completely.

2. Assign a role to each member; one person is the VEX robot and the other person is the VEX brain. The *VEX brain* will stand behind the *VEX robot* and tell the *VEX robot* how to travel through the classroom to a random location that the *VEX brain* decides at the beginning of the activity without telling the *VEX robot*. The *VEX robot* should hold their arms straight in front of them while executing the instructions from the *VEX brain*. The *VEX robot* will execute one instruction at a time, continuously, until they walk into an obstacle. At this point, the *VEX brain* will give another instruction to be executed continuously in the same way.

3. Once the *VEX brain* successfully instructs the *VEX robot* to arrive at the chosen location, the two students should discuss how this activity is comparable to the bumper sensor on Robbie the robot.

4. In the same groups, translate the instructions that the *VEX brain* gave to the *VEX robot* into Scratch code.

Advanced (ages 15-18 recommended):

Mechanical Activity:

Instructions:

1. Organize the students into teams of 2-3.
2. Have each group of students construct a plow, scoop, and friction grabber using only the objects available to them in the room. The intent of this activity is to work around the functional fixedness of certain objects and have the students think critically to create these object manipulators.
3. If the students succeed in this activity, have them also construct a rotating joining, linkage, and elevator lifting mechanism.
4. If any students struggle to construct any of these items, give them small hints to help them complete the construction.