Curriculum Design and Evaluation for the XRP Robot Platform

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ABSTRACT

STEM education has become a focal point of educational development across the world with many projects being conceived to help spread STEM education to those without access. One such project is the Experiential Robotics Project (XRP) which provides a wealth of robotics knowledge at an affordable price. This IQP focuses on the development and subsequent measuring of curricular content for the XRP kit. We sought to develop a curriculum centered around student engagement and teacher usability in the hopes of democratizing STEM education. We then transitioned to developing surveys to collect feedback on how we could further improve the curriculum for future years. Through this work, we hope to have answered our research question: "What changes should be made to further maximize student engagement (as perceived by teachers) and teacher usability in a curriculum that we developed?"

ACKNOWLEDGEMENTS

We would like to acknowledge the work in the XRP community that made this IQP project possible. This work includes contributions from sponsors like WPI, SparkFun, and DEKA, who were responsible for creating the XRP kit for which we developed curriculum. We would also like to thank other members of the XRP team (namely Frank Grossman, Kevin Siegall, and Ansel Chang) who were directly responsible for creating the custom IDE and developing software libraries for the XRP kit. Furthermore, we would like to recognize the work that previous WPI students did when developing the first set of curricular content. Finally, we would like to thank our advisors, Brad Miller and Mia Dubosarsky, whose guidance was paramount to the success of this IQP.

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EXECUTIVE SUMMARY

Introduction

STEM (Science, Technology, Engineering, and Math) education equips students with vital problem-solving skills for real-world applications. Recognizing its significance, educators often attempt to leverage robotics as an engaging medium, aiming to inspire younger students to pursue STEM education and to further develop skills such as open-ended problem solving, critical thinking, and teamwork. Many of these classes use robotics platforms like the XRP project. Collaboratively developed by DEKA, WPI, SparkFun, and Raspberry Pi, the XRP project aims to democratize STEM education. This IQP specifically focuses on curriculum development and assesses student engagement and teacher usability in the developed curriculum. The research questions this IQP hopes to answer is: "What changes should be made to further maximize student engagement (as perceived by teachers) and teacher usability in a curriculum that we developed?"

Background

The democratization of STEM education will be paramount as the world continues to develop into the digital age. The benefits of a STEM education are shown in a qualitative sense where students have been proven to have an increased aptitude for skills like problem-solving, collaboration, and critical thinking. However, benefits also extend to a quantitative and practical sense where students pursuing STEM careers have a lower unemployment rate and are met with higher levels of financial success.

Despite the benefits of a STEM education, a lack of volume and lack of diversity have become prevalent issues. The volume of students interested in STEM education is still less than half of the STEM-educated workers required by the US labor force. Thus, many researchers have sought ways to mitigate this disparity by developing engaging gateways to STEM-education for younger students. Robotics has since been proven to be one such gateway platform due to its ability to engage students of all age ranges and experience levels and its inherent project-based nature.

Students interested in pursuing robotics in high school often participate in robotics competitions or study robotics using educational robotics kits. FRC (*FIRST* Robotics Competition), developed by the *FIRST* organization, has been shown to be incredibly successful in combatting the issues that currently exist in STEM education. However, FRC currently presents its own barriers to entry such as its high financial investment, extracurricular nature, and limited international availability which have prevented thousands of prospective roboticists from joining. Thus, the XRP project was introduced as an educational robotics kit that solves these problems by being affordable, incorporating robotics into formal education, and being readily available internationally.

The XRP project is the culmination of the work done by sponsors such as SparkFun, DEKA, WPI, and Raspberry Pi as well as previous WPI students who have all contributed to the development of the XRP kit and providing curriculum in the hopes of guiding students and teachers as they use their XRP's. However, the previous set of curricular content presented itself as a user guide rather than a fully encompassing curriculum. Thus, the focus of this IQP is to iterate upon the previous set of curricula to increase the efficacy of the XRP to be more engaging for students and more usable for teachers; also, we hope to be able to gather data and provide recommendations for future work. Thus, through our work, we hope to answer our research question: “What changes should be made to further maximize student engagement (as perceived by teachers) and teacher usability in a curriculum that we developed?”

We also acknowledge the importance of aligning curricular content with national educational standards to ensure that the curriculum encompasses topics that are thought to be important by experts in the field. By including such standards, we hope to foster confidence in educators that by teaching according to the XRP’s curriculum, their students are receiving a proper education.

Methodology

In this section, we outline the changes we made to the curriculum and the steps we took when developing surveys so that we could obtain the maximum amount of high-quality information from teachers.

To maximize student engagement, the team:

- Included more hands-on activities to increase the interactivity of the curriculum
- Included a diverse array of real-world examples outside of robotics to engage students with varied interests
- Incorporated Blockly (a Scratch-based, ‘drag & drop’ programming language) for beginner-level programming students

To improve teacher usability, the team:

- Included a plethora of video, code, and pictures that teachers can reference throughout the curriculum
- Restructured the curricular content such that every lecture period had its own lesson page for information to be easily accessible for both teachers and students
- Designed module-based standards pages that refer to standards outlined by the NGSS and CSTA for teacher reference

The team then transitioned to developing feedback surveys to inform the next revision of the curriculum, with these key questions in mind:

- How engaging was the material for the students?
- What was the perceived quality of the material by the teachers?
- How easy was the material to deliver having only seen it for a limited time?
- Did the timing work out such that each module was able to fill a class session?
- How well did the XRP hardware and software perform?

To then obtain the maximum amount of information from teachers, the team:

- Asked multiple choice questions such that it would be quick for teachers to provide answers and allow us to analyze responses numerically.
- Included short-response questions to give teachers a platform through which they could elaborate upon their responses to multiple-choice questions.

- To simplify the experience of the survey participants as well as our process for analyzing the results, we combined all module surveys into one Qualtrics survey.
- Pilot tested the surveys to improve clarity and gauge survey-completion times and other quantitative metrics.
- Incorporated learnings from pre-notification surveys to try and maximize the number of responses we would gather from our surveys

The team also hosted interviews with high school teachers in the Massachusetts area. For these interviews, a very similar approach was taken as the surveys since the goal remained of obtaining high quality information from teachers who have used the XRP.

Findings / Analysis

In this section, we report on qualitative and quantitative analysis conducted on the survey responses; furthermore, we elaborate upon the limitations of our data and findings.

We must first acknowledge that all data related to student engagement is reported from a teacher's perspective, as opposed to being directly from students, and therefore represents *perceived* student engagement:

- Teachers perceived that ~50% of their students were engaged in course material
- The difficulty of a module had an inverse relationship with student engagement.

As another measure of student engagement, we collected and analyzed data related to student learning with the assumption that there is a direct relationship between student engagement and learning:

- Nearly half of students were not able to fully understand lesson content

- Students with a pre-existing interest in robotics were shown to be more likely to succeed with our current curriculum.

For our analysis of teacher usability, we chose to break it down into two categories: content quality and content quantity. When measuring content quality, we wanted to see how easy it is for teachers to grasp the core concepts of the content to start teaching it quickly:

- Teachers mentioned having difficulties when explaining more complex topics.
- Teachers found textual and coding components of each module to be useful
- Teachers found adequate background information in majority of lessons
- Teachers also mentioned that lesson-specific images and videos were useful

When gathering answers to questions about content quantity, we wanted to know how well we met our goal of having each module occupy one class session worth of time. When analyzing teacher responses, we found a strong consensus that modules were not presenting enough information to fully cover a class period. This, combined with previous findings of only half of the students understanding lesson content signaled to us that there was not enough information in each lesson.

We then transitioned to acknowledging limitations that our group faced during our project; the rationale for this section is to highlight confounding factors that may impact the data that we gathered:

- There are existing hardware and software issues that may influence a classroom's experience with the XRP robot kit. One example of this was a class that could not continue due to software issues they encountered with the XRP.

- Due to XRP kits being shipped late and only a few teachers using the curriculum this semester, teachers were not able to fully cover the curriculum.

- Due to these limitations, we were unable to gather many responses. One issue that this presented was a high standard deviation between survey responses, meaning that our data might look different if the sample size was larger.

Conclusion / Final Recommendations

From our findings, we then curated the following lists of recommendations for future work. We begin by elaborating upon recommendations for the curriculum:

- Add more information to each lesson such that it spans a 45-60-minute class period. Furthermore, this information should be iterated upon using feedback from a pilot group without previous experience with the XRP
- It would be useful to have a "Frequently Asked Questions" (FAQ) section for each module that covers common issues teachers may run into.
- A network of support (staff or other resources) should be set up such that they can provide guidance to any teachers who encounter difficulties
- It would be very useful to include photos and/or videos in all modules, as this could have impacts on engagement as well as usability.

We have also outlined the following recommendations for XRP hardware and software developments:

- More testing should be done to ensure that the software is fully functional, especially on school-managed devices.

- More testing should be done with the robot to ensure repeatability of experimental code to ensure that every XRP behaves the same way.

Conclusion

This IQP started as an effort to improve library code for the XRP robot kit, a robot kit developed by WPI. Based on the project's needs, this became a project in developing updates to curriculum modules to maximize student engagement and teacher usability. We hope that the information we have presented will be useful in future work done by the XRP team and other students working on similar projects.

INTRODUCTION

“Fostering students’ competence in applying interdisciplinary knowledge to solve problems has been recognized as an important and challenging issue globally” (Darmawansah et al., 2023, p. 1). These are the insights of Prof. Darmawansah and his STEM education research group at the National Taiwan University of Science and Technology. Much like Prof. Darmawansah, numerous researchers and practitioners of STEM education consider it the optimal medium through which students can apply their problem-solving skills to address real-world problems.

Consequently, many nations have begun "integrating STEM education into both formal and informal educational settings" to nurture the competence emphasized by Darmawansah and his team (Akcan et al., 2023, p. 2). A prominent approach adopted by educators is the utilization of robotics platforms as an introductory gateway to STEM education for younger students due to their inherently engaging nature. The XRP robot project is one such platform which is the conception of collaborative efforts from partners including DEKA, WPI, SparkFun, and Raspberry Pi. At its core, the project strives to serve as an accessible gateway that hopes to democratize STEM education.

While the XRP project encompasses a plethora of components, this IQP focuses on curriculum development, as well as measuring the student's engagement and teacher usability. Through our work, the research question that we hope to have answered through our work is: “What changes should be made to further maximize student engagement (as perceived by teachers) and teacher usability in a curriculum that we developed?”

BACKGROUND

To meet this project's goal of developing and ascertaining feedback on curriculum for the XRP robot kit, this chapter provides foundational background information necessary in understanding the importance of the XRP kit. We begin by elaborating on the importance of STEM education and its current issues. We then discuss robotics as a gateway into STEM while also acknowledging current barriers to entry that exist in current robotics competitions, specifically FRC. Subsequently, we introduce the XRP project as a solution to the issues prevalent in current robotics competitions as well as provide contextual information about the XRP. Finally, we discuss the importance of national educational standards and why we have chosen to include them when developing curriculum for the XRP.

The Importance of STEM Education

STEM education is a diverse subject and is defined by the California Department of Education to encompass the processes of critical thinking, analysis, and collaboration (CADOE, 2022). In our project, we adopted a definition similar to James Madison University, noting that "STEM Education is an interdisciplinary approach to learning and teaching practices, where students have opportunities to practice the integration of the knowledge and skills of science, engineering, mathematics, and technology" (Cresawn, nd, p.1).

However, the benefits of a STEM education expand beyond the confines of these attributes. The University of Texas at Austin wrote about how STEM education increases innovative thinking, curiosity, and ingenuity in young students (Marshall & Harron, 2018). Furthermore, students attain collaborative, communication, teamwork-oriented, and leadership skills that benefit students long into their careers.

As mentioned, building these skills can become a vital component of a student's future successes. A study from the Firat University in Turkey also found statistically significant increases in academic performance from students that underwent a STEM-based education (Kazu & YalÇIn, 2021). Due to these benefits, the US National Science Foundation (NSF) has drafted their vision for the future of STEM education to begin combatting the prevalent scarcity of STEM education around the world (NSF, 2020).

Furthermore, in August 2021 the NSF presented a report elaborating upon practical benefits to a STEM-centric career. The report found that "Unemployment was lower among the STEM labor force (2%) compared to the non-STEM labor force (4%) in 2019, and this pattern persisted even during the COVID-19 pandemic" (Okrent & Burke, 2021, p.1). In addition, the report noted that "STEM workers had higher median earnings ($55,000) than non-STEM workers ($33,000)".

Current Issues in STEM Education

While STEM education offers many advantages, its current challenges have been shown to manifest in insufficient representation and diversity within the labor force. Furthermore, other research groups have analyzed possible solutions to combat these issues and have found that it may be optimal to do so on an individual level. In this subsection, we elaborate on these issues and discuss why developing an engaging gateway to STEM education is the promising solution to combatting current issues in STEM education.

Researchers from the University of Virginia School of Engineering and Applied Science found that in 2012, over 60% of jobs in the United States require a post-secondary degree with STEM literacy skills. Despite the demand, the same group found that less than 25 percent of college students pursuing STEM careers (Jones & Morescu, 2018). These findings are corroborated by the August 2021 report provided by the NSF which notes that "the STEM workforce represented 23% of the total U.S. workforce in 2019" which emphasizes the disparity between the demand and supply of STEM professionals. Furthermore, researchers at the University of Illinois System found that a large majority of STEM students were identified as White and Male or Asian even though other groups such as Women, Hispanic, Black, etc. are projected to form a larger percentage of the United States population (Palid et al., 2023). Once again, the NSF found similar results and they noted that "Although Blacks or African Americans, Hispanics or Latinos, and American Indians or Alaska Natives represent 30% of the employed U.S. population, they are 23% of the STEM workforce due to underrepresentation of these groups among STEM workers with a bachelor's degree" (NSF, 2021, p. 1).

In light of these issues, researchers from the University of Michigan, Ann Arbor and the University of California, Davis found that an engaging gateway to STEM education might be the answer to combatting these issues on the individual level (Xie et al., 2015). Their findings showed that "Interest in math/science or aspirations for a STEM-type career are strongly predictive of STEM educational outcomes" (ibid, p. 9). Thus, the researchers noted that when trying to increase interest in STEM education at the individual level, one should do so through an engaging gateway to maximize the amount of interest in younger students. And by doing so, society can maximize the number and diversity of students interested in STEM education.

Robotics as a Gateway to STEM

Considering the need for an engaging gateway for STEM education, some have turned towards robotics for a multitude of reasons. Robotics engages students of all age ranges and experience levels and is inherently based on project-based learning which has been shown to be incredibly successful in educational settings (Hughes-Roberts et al., 2019).

When considering how to teach students with special needs, a project funded by the EU Commission Lifelong Learning Programme employed robotics as a teaching tool in the hopes that it would engage a wide array of young students. Through this project, researchers from Nottingham Trent University found robotics encourages student engagement, even for students with intellectual disabilities (ibid). Furthermore, they found that robotics was a successful educational medium when considering a wide array of individual learner characteristics. This work was corroborated by researchers from Boise State University who found that robotics could be incorporated into formal education to create “interactive and engaging learning environments to develop computational thinking (CT) in K-12 learners” (Ching & Hsu, 2023, p. 1). The work done at BSU further emphasizes the plethora of age groups and experience levels that robotics can engage, specifically depicted by how robotics was able to aid in the development of computational thinking in both kindergarteners and high schoolers.

Furthermore, robotics is an inherently project-based learning approach to STEM education, making it an extremely powerful and inviting introduction to STEM education. Beyond the commonly known benefits of students collaborating effectively towards a common goal, researchers have found many other benefits resulting from project-based learning. To highlight an example, Dr. Condliffe led a group of researchers where they found that students learning in a project-based environment were shown to become better problems solvers and also retain more information when compared to their peers (Condliffe, 2017). Also, the University of Southern California and Michigan State University found that project-based learning helps students outside of the classroom by refining skills such as critical thinking, collaboration, problem solving (Saavedra et al., 2021).

High School Robotics Competitions

For many students interested in pursuing robotics in high school, they often participate in robotics competitions or follow lessons in educational robotics kits. In this section, we discuss how robotics competitions have been shown to combat the current issues present in STEM education. However, we also acknowledge the current barriers to entry related to high school robotics competitions which are the inherent expensive and extra-curricular nature of such competitions. For this subsection, we focus on the FIRST Robotics Competition (FRC). While we acknowledge that there are many other competitions like the VEX Robotics Competition, the FIRST organization reaches the widest audience when compared to its competitors and thus affects the highest number of students, reaching “2.5 million+ student participants impacted in more than 100 countries since 1989” (*FIRST*, 2023, p. 1).

FRC was started by For Inspiration and Recognition of Science and Technology (FIRST) for high school students to learn about robotics in a fun, high-paced environment alongside other, like-minded students. The annual FRC calendar is broken into three portions: build season, competition season, and off-season. Build season starts in January when the annual competition is released, and students are given 2 months to build their robots before competition season. Then, competition season runs from February to April where students iterate upon their robot's design using learnings gathered from their experiences at competitions. After competitions end, teams then transition into the off-season where new student leaders are chosen, auxiliary projects are pursued, and new members are trained until next January where the cycle repeats.

Beyond growing students' technical skills, FRC has been shown by researchers at Brandeis University to directly combat the issues with STEM education discussed earlier in this paper (Meschede et al., 2021). Brandeis researchers highlight that *FIRST* participants continue to show positive impacts on STEM-related interests seven years after joining. Furthermore, they showed that these results were especially pronounced for young female *FIRST* alumni, directly combatting current issues related to diversity in STEM. FIRST alumni were also shown to be more likely to pursue STEM-related fields in college and display a higher aptitude on "STEM-related attitudes" such as collaboration, problem-solving, and critical thinking.

Current Barriers to Robotics Competitions

Despite these benefits, FRC has inherent flaws that act as barriers to entry; specifically shown in its large financial investment, extracurricular nature, and lack of international availability. The first issue many students cannot overcome is the financial commitment they must make when joining FRC. The registration fee for a rookie team is $6,000 and does not cover costs such as travel or auxiliary components which can cost hundreds of dollars (*FIRST*). For teams with less resources, these costs can present a financial barrier of entry as they do not have the same resources as larger teams with more school support. The issue of cost has been shown to be an incredibly challenging problem for students by researchers at the National Taiwan University of Science and Technology who found that a low-cost robotics platform was much more successful when engaging with younger students (Darmawansah et al., 2023). Furthermore, FRC's inherently extracurricular nature presents a barrier to entry for students who cannot put in time outside of the classroom to pursue their interests. While participating in extra-curricular activities is extremely beneficial for high school students, Prudence Carter, a Professor of Sociology at Brown University, wrote of how students from minority groups often do not have access to extracurricular activities due to a myriad of financial, societal, and structural barriers (Carter, 2012).

These issues are only further exacerbated for international teams where competitions like FRC have just sprouted and there is no pre-existing *FIRST* infrastructure to build around. For example, FRC Team Gart (team 6520) is the first and only FRC team in Vietnam. While an extremely impressive accomplishment, this presents the team a multitude of challenges like needing to travel to Australia just to participate in FRC competitions. While this is an extreme example, many international teams face similar challenges when attempting to participate in robotics competitions like FRC. Due to these barriers to entry, many students turn to educational robotics kits when pursuing robotics in high school.

The XRP Project

The XRP project started in 2021 to combat the flaws in current robotics competitions and to increase the prevalence of STEM education by reducing the financial investment, incorporating robotics into formal education, and by being available internationally. The project has since included partners such as SparkFun, DEKA, WPI, and Raspberry Pi that have all contributed to materializing the XRP. Furthermore, many WPI students have worked on documentation to help support the XRP's effectiveness as a platform to teach robotics. This documentation is meant to serve as a guide for both academic and self-taught settings where both teachers and hobbyists could refer to the documentation for help and lessons using the XRP kit. If you are interested in seeing the curriculum, please follow this link: https://introtoroboticsv2.readthedocs.io/en/latest/course/course_info/index.html

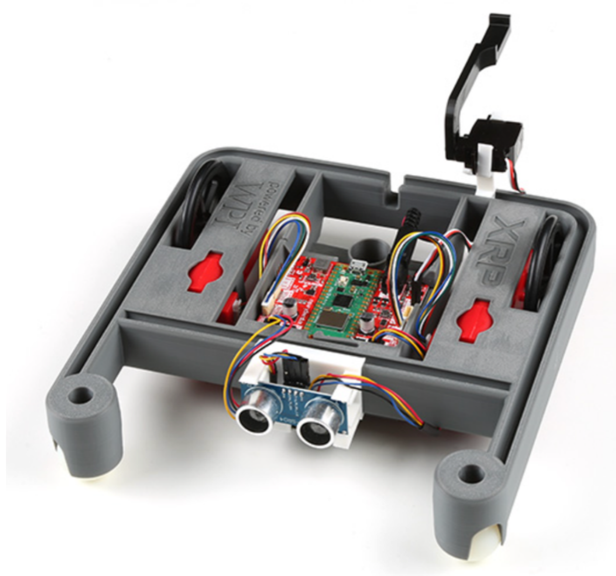

Figure 1 - A Photo of the Fully Assembled XRP Robot Kit (image credit SparkFun)

For some technical context, the XRP (see figure 1) includes a controller board, chassis, and a host of sensors that all contribute to creating an extremely capable robot. Also, due to technological progress made by the XRP team, schools can now purchase the XRP for only $65 each while individual roboticists can purchase them for $115 from SparkFun. The XRP has a no-tool assembly, sensors, and extensive software libraries. The only attribute yet to be refined was a set of curricular content to aid the effectiveness of the XRP.

While WPI students in the past had worked on developing curriculum, the outcome of their work was an unfinished set of documents that operated as a user guide rather than a proper curriculum. Furthermore, the previous documentation would often overwhelm students with technical material, rather than using project-based learning as a method to increase student engagement. In addition, the previous documentation lacked proper standards alignment which is useful to teachers when assessing the content of the curriculum that they are teaching. The curriculum has been split into 8 sections: Course Information, Introduction to the XRP, Robot Driving, Measuring Distances, Robot Control, Sensing and Following Lines, Manipulation, and the Final project, the Delivery Challenge (XRP, 2023). Each of these modules has sub-sections which cover material related to specific lessons. For example, under the Sensing and Following Lines module, Lesson 1 covers the innerworkings of how line (reflectivity) sensors work.

The initial goal of this project was to develop a refined set of curricular materials for the XRP kit before the start of the academic year. After the start of school, the project's focus shifted to data collection where we as a team assessed the successes and inadequacies of our work as well as looking into the future in terms of what could be improved to enhance the XRP curriculum. Thus, through our work, we hope to answer our research question: "How engaging to students (as perceived by teachers) and usable to teachers is the curriculum that we developed?"

Before refining the curriculum, however, we would like to convey the importance of properly incorporating educational standards for this curriculum to be applicable in academic settings.

Importance of Standards Alignment

Aligning curricular content with engineering standards is key when attempting to provide a fully encompassing education. Engineering standards have been iterated upon by experts in their respective fields since 1918 by the American Engineering Standards Committee (AESC) and have only become more encompassing of a proper educational experience (NASA, 2007).

While the responsibility of standardizing engineering curriculum has shifted to the American National Standards Institute (ANSI), the intent behind providing student a well-rounded educational experience has withstood the test of time. Furthermore, engineering standards and educational research findings are shared annually at conferences such as the ASEE Annual Conference and Exposition where academics congregate from around the world to forward developments in engineering curriculum. For the XRP curriculum, we chose to draw from standards outlined by the NGSS (Next Generation Science Standards) and CSTA (Computer Science Teacher Association) due to their national prevalence and because they cover the topics of engineering and computer science that the XRP curriculum addresses. The NGSS was first proposed in 2011 and then were released in 2013 after much refinement by groups of experts such as the NRC (National Research Council), NSTA (National Science Teachers Association), and the AAAS (American Association for the Advancement of Science). These standards have now been adopted in 21 states and many other states have since followed suit by iterating upon standards from the NGSS to form their own (TNSG). The CSTA was founded as an organization for Computer Science teachers to provide community, professional development, a platform for advocacy, and standards for K-12 computer science education. Like the NGSS, it is also nationally prevalent, shown by how skills presented by the CSTA have been shown to be adopted by 73% of states (ACM, 2010).

Due to the effectiveness of educational standards in validating curricular content, we have come to understand that they will become a key component of the XRP curriculum. Thus, due to the lack of standards alignment in the previous documentation, the future documentation encompasses engineering curriculum standards to ensure that students using the XRP are receiving a well-rounded education.

METHODOLOGY

Our project has two primary goals, the first of which is to enhance an existing robotics curriculum. The other goal of our project is to develop an answer to our research question: "What changes should be made to further maximize student engagement (as perceived by teachers) and teacher usability in a curriculum that we developed?" To achieve this second goal, we set subgoals of identifying teachers we could work with to test our changes, soliciting teacher feedback through surveys, conducting interviews, and analyzing the collected data. To discuss the project's methodology, we first expand on the updates we made to the existing curriculum. Next, we discuss the process of identifying and working with pilot teachers to test the updated curriculum. We then discuss the process of defining research objectives and developing surveys for pilot teachers who have already been testing prior versions of the XRP kits, including how we developed questions to form a preliminary understanding of our research question. Finally, we discuss our plan to work with two Massachusetts area teachers to collect more targeted feedback on the curriculum and reinforce survey results using this data.

Curriculum Updates

This sub-section delves into the iterative process undertaken to enhance the XRP curriculum and specifically addresses the inherent flaws present in the previous version of the XRP documentation. Thus, the rest of the section will elaborate on the following, key improvements made to the curriculum: increasing the number of hands-on activities, diversifying the curriculum content to branch outside of the realm of robotics, improving upon the flexibility of the curriculum to meet a plethora of student and teacher needs, splitting lesson plans into 45-60 minute blocks to aid teachers, and aligning curricular content with national engineering standards.

When first approached by the XRP team with the previous documentation, the primary flaw was the overwhelming focus on technical content and the lack of hands-on activities. One example was the previous Driving module, where the curriculum would attempt to explain concepts like “effort” without providing any intuitive explanation or hands-on activity to foster student understanding. Thus, the first step to making the content more engaging and approachable for students was to shift the paradigm that robotics curriculum needed to be packed with technically challenging content. Despite the potential drawback of not developing the skill of reading technical documentation, our priority is to elevate student interest in STEM through project-centered learning and supplementary materials like videos and example code. Thus, we made the necessary change of greatly increasing, by almost five times, the number of hands-on activities throughout the curriculum. One example of such an activity occurs in Module 2, Lesson 8 where students are guided through the completion of the Parking Garage Activity after just learning how to control their XRP. The Parking Garage activity has students navigate an artificial parking garage with occupied parking spaces; the goal of the activity is that the robot should be able to “park” itself in an empty space without ever colliding with an obstacle.

Furthermore, the previous version of the curriculum mostly hyper-focused on robotics content, without any regard for the broad interests of students outside of the world of robotics. Thus, to better encompass a plethora of student interests; one example of which occurs in Module 3, Lesson 1 where range-finder sensors are likened to bats’ echolocation. Through this change, we hope to have captured the broad variety of interesting concepts from fields outside the realm of robotics as a means of increasing student engagement.

Another major concern with the previous documentation was the high barrier of entry for both student and teachers, where we previously expected experience with Python. However, we felt as though this was unreasonable for high school students and for teachers without programming experience. Thus, we expanded the curriculum to include Blockly, where even beginner programmers without any experience can pick up and start programming their XRP. Blockly is a Strach-based, ‘drag & drop’ programming language that is incredibly intuitive to use. Also, for advanced classes with more experienced students, we included bonus activities like the “Parking Garage” activity so that they could be properly challenged in this course. The Parking Garage activity has been noted as challenging due to its requirement of a multi-step process, use of many sensors, and high precision needed from a successful robot.

From a teacher usability point of view, beyond including example solutions throughout the curriculum, we also split each 45–60-minute lesson into its own page. The point of this change was to craft a smooth teacher experience where, for each lesson, they would simply have to open a page, review that content, and then teach the content they just reviewed. This eliminates difficulty with skipping between lesson pages or trying to piece together content from different areas of the curriculum and hopefully increases teacher usability of the curriculum.

To align the curriculum with national standards from the Next Generation Science Standards (NGSS) and Computer Science Teachers Association (CSTA), we took great care in incorporating lessons that meet such standards. This was done to ensure that we were providing students with a fully encompassing curriculum with nationally recognized engineering and computer science concepts and skills. One such example was Module 4, Lesson 3, "Introduction to Proportional Control", which introduces the proportional control algorithm. Through the integration of this lesson, we were able to meet standard 3B-AP-10 which tasks students to "Use and adapt classic algorithms to solve computational problems" (CSTA, 2017). Furthermore, we included module-based standards alignment pages (all of which are included in **Appendix D**) which elaborate upon what specific standards are met in each module. This addition can help teachers reference the validity of the curriculum they are teaching students, thus increasing its usability.

This myriad of changes was made to greatly improve upon the previous documentation and was completed before the start of the academic year in order to provide this new set of curricular content to teachers. The following sections will focus on identifying pilot teachers and developing our surveys for measuring our updated curriculum's success.

Defining Research Objectives

Our research question focuses on two tenets of a curriculum: student engagement and teacher usability. To evaluate the updated curriculum for performance in these areas, it is first important to expand each of these tenets into a set of measurable objectives that can be studied. For student engagement, we chose to break the concept into three components:

engagement and attentiveness to each lesson, ability to demonstrate understanding, and ability to complete the lesson's material. The first component is somewhat reciprocal to the overarching tenet of student engagement, but we felt it was important to allow surveyed teachers to use their judgement when assessing the engagement levels of their students. The remaining two components are shown to be effective measures of student engagement in various studies (Kay & Knaack, 2009).

To understand teacher usability, we were primarily focused on the pacing and quality of the material. A design goal of the curriculum is that each module provides exactly enough content to fill a single class session, so this is something that our research must measure. In terms of content quality, this can be divided into sufficiency of background information provided by each module, perceived quality of multimedia content such as images, videos, and code samples, as well as specific questions tailored to each module's content. Finally, the content of the curriculum should be able to be integrated into any teacher's lesson plan without substantial restructuring.

Identifying Pilot Teachers

To answer our research question, we needed to collect data about how usable and engaging the curriculum modules were. While testing was being done at WPI during and after our updates, this was not sufficient for our analysis as this testing was not done in a high-school classroom setting with teachers seeing the material for the first time. Thus, we worked with our project advisors to identify several groups of high-school pilot teachers. The first group of pilot teachers identified were a subset of Engineering 4 Us All (e4usa) affiliated teachers receiving grant money from Arizona State University to test XRP kits. These teachers had already been testing previous iterations of the XRP robots and thus had some background experience, although they had not been using the version of the curriculum we worked on. The second group of teachers identified were found by various outreach efforts of our advisors to many Massachusetts (and surrounding) area teachers. Of the group contacted, two teachers were able to work within our timeline and were eager to get started with the kits as soon as possible. Due to the timeline of our project, with the curriculum development efforts taking place over the summer, the tests needed to be done in the winter months towards the end of the year. This timing placed significant constraints on the amount of time we had to collect data, with many teachers responding that they'd be interested in using the kits but would not be able to start until the following year. Ultimately, this constraint led to us only having two pilot teachers to test the curriculum with. To complement our survey data, we made agreements with the Massachusetts area teachers to conduct additional interviews and discussions on top of the surveys that all teachers completed. The Massachusetts area teachers are both male and teach robotics classes at different schools in MA. One of the teachers also teaches AP Computer Science.

Survey Development

Purpose and Design of the Survey

The development of our survey aimed to satisfy several objectives. First, the survey had to provide an answer (or at least the beginning of an answer) to our research question, meaning we needed to ask questions about the quality and quantity of the content, as well as questions which assess student engagement. Second, we had an opportunity to collect additional feedback about other aspects of the XRP, such as the hardware, software, programming tools, and user guide. Since these are all resources that need to function properly for our curriculum to be effective in satisfying its goals, getting this additional feedback could prove invaluable to the rest of the XRP development team. To address the project goals, we developed further questions to be answered by the teachers:

1. How engaging was the material for the students while they were completing each module?
2. What was the perceived quality of the material by the teachers?
3. How easy was the material to deliver having only seen it for a limited time?
4. Did the timing work out such that each module was able to fill a class session?
5. How well did the XRP hardware and software perform while completing the modules?

The first question directly aligns with the student engagement aspect of our research question, while the remaining four questions cover the aspects of teacher usability that we were interested in measuring.

Ethical Considerations

Ethical considerations are vital when making surveys of any kind. If surveys are collecting sensitive, personally identifying information, making sure the data is stored securely and that the study is run ethically is crucial to maintaining the trust placed in the researchers by the participants. Since our primary goal is to collect data about the quality of the curriculum, we did not consider it important to be able to identify which teachers provided which responses. In addition, we decided early in the process that we were not interested in surveying students directly, since teachers are the ultimate users of the curriculum. While a student perspective would be an interesting study, for our purposes we are more interested in student engagement as perceived by teachers. For these reasons, we ultimately decided on a fully anonymous survey answered only by teachers. With these restrictions, as well as clear disclaimers that the survey is anonymous with all questions optional included in both the prenotification and the survey introduction itself, we were able to get the survey approved by WPI's IRB as "exempt" meaning that our survey does not collect personal information and therefore is exempt from a full board review.

Question Development Process

While developing specific survey questions, we kept the set of broad, key questions in mind and treated them as core design tenets of the survey. We carefully considered each question we came up with to ensure that an answer to it would provide a partial answer to at least one of our key questions. The updated XRP curriculum consists of 7 units, with each unit containing between 3 and 9 modules. In addition, there is a final project module called the "Delivery Challenge" which is meant to take several class periods. When initially planning our survey's development, we recognized that each module is unique and may require individual questions. On the other hand, a common set of questions asked for each module would be useful so that we can perform analysis across modules to see which need the most improvement and collect average results for the entire curriculum. To satisfy these requirements, we developed a set of questions for each module tailored to the module's content, and a common question block which would be asked afterwards for each module. To develop the tailored questions, we repeated our process of determining a key set of questions that we wanted answered, only this time considering only within the scope of a single module's content. The full set of questions is available in **Appendix A**.

Question Types and Structure

Once a refined set of guiding questions were developed for each module and the common block, we began writing the actual questions. Our research question implies a need for qualitative responses, meaning using open ended text response questions in the survey.

However, this approach discourages participation in the survey as it takes longer to complete (Cook et al., 2000), and it does not give us an easy way to do quantitative analysis on the data. To solve these problems, we decided that most of our survey questions should be multiple choice. As an example, if we wanted to know how useful a certain concept in one of the modules was, we would add a multiple-choice question with five response options:

1. Not at all useful
2. Slightly useful
3. Moderately useful
4. Very useful
5. Extremely useful

This specific style of response is known as a “Likert scale” (Bhandari, 2023), and gives us a data point that can be analyzed numerically without the survey participant thinking about the response numerically as they would with, for example, a 1-5 scale. To balance out the qualitative data potentially lost with this approach, we provided an open-ended free response question at the beginning of the common question block where participants can share any ways they think the module can be improved. This question was deliberately placed before the rest of the common questions to increase the odds of participants responding to it, instead of skipping past it as the last question. For certain questions, such as those asking about specific issues encountered with a module, we added optional open response text questions that would appear if specific choices were selected. The research approach combining quantitative and qualitative methods is known as “mixed methods” (George, 2023)

As a general principle, we avoided matrix style questions, as these have been shown to be discouraging to survey participants and cause early terminations of survey sessions (Liu &

Cernat, 2018). An example of a question where a matrix may have been typically used is our general question about student engagement. In this question, we ask teachers to estimate how many of their students were engaged with the lesson, able to demonstrate understanding of the material, and able to get their robot to do the task laid out in the curriculum module. In a matrix style question, there may have been options on the horizontal axis ranging from “none” to “all” with each question on the vertical axis. While this would have given us the data we needed, it would be visually busy and confusing to participants, which could lead to an early termination. Instead, we asked the participants to estimate percentages of their students which met each goal using draggable sliders. To restrict answers to a reasonable level, since it is not expected that teachers will maintain exact counts of their students in each respect, we restricted the sliders to move in increments of 20% at a time.

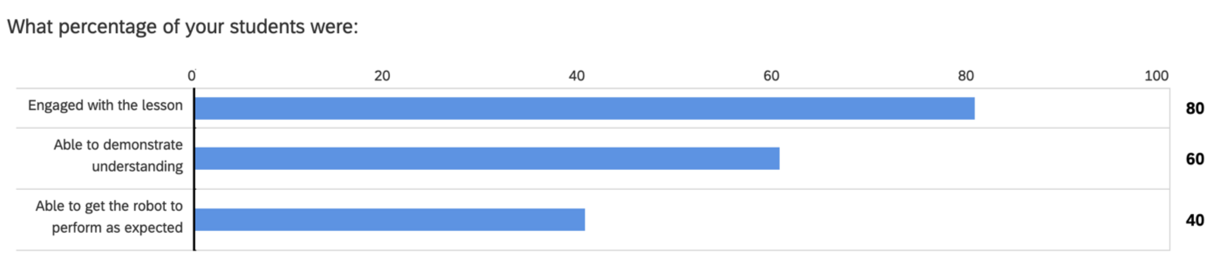

Figure 2 - Survey question with draggable sliders for reporting student engagement

To simplify the experience of the survey participants as well as our process for analyzing the results, we combined all the module surveys into a single Qualtrics survey. This allowed us to send out a single link to the participants and gave us a single dashboard where we could view the response data. When taking the survey, participants are first asked which units and modules they want to provide feedback on, and then the Qualtrics flow configuration appropriately shows the correct question blocks for their selection while hiding irrelevant question blocks. The full flow of a user's interaction with a survey session is as follows:

1. General information screen about the survey, with our contact information listed.
2. Unit and module selection pages
3. Module intro screen
4. Module specific questions
5. Common questions

Each step of the participant's interaction with the survey appeared on its own empty page to not overwhelm the participant with content. If the user selected multiple modules, the last two steps of the interaction would repeat until all selected modules are answered. Taking into account teachers' time constraints, and to maximize input, we designed the survey to accommodate their availability. Some teachers may wish to provide feedback immediately after each module while others may not have time and wish to provide feedback on, for example, a week's worth of modules. While this choice made the data analysis slightly more complex, it ended up being used effectively by most of our participants. The full, final set of questions is shown in **Appendix A.**

Pilot Testing

Once the completed survey was developed in Qualtrics, we ran some brief pilot tests of the unpublished survey with our peers at WPI. We started by selecting a few curriculum modules for our peers to review, and then had them take the survey while we observed. The goal of the pilot testing was to measure response times, as we wanted to ensure that a single module's questions could be completed in an average time of 5 minutes. The outcome of this testing was that our common question set was a good length, but some of our module specific questions were taking too long to answer. We used this feedback to shorten our set of module specific questions, leaving us with an average of about two specific, multiple-choice questions per module.

Distribution

To start collecting survey results, we needed to distribute the survey to our pilot teachers. We distributed the survey to both sets of our pilot teachers, with the first wave being to a set of Engineering for US All (e4usa) who had already been testing prior revisions of the XRP hardware, software, and curriculum. The second wave was to our two selected Massachusetts area teachers. In both cases, we waited to send the surveys to the teachers in each group until we had confirmed that they had already been introduced to the new curriculum and the XRP kits. In the case of the selected Massachusetts area teachers, this meant pointing them to the XRP users guide, programming software, and conducting an informal training session to introduce the teachers to the basics of using the XRP in a classroom setting. In addition to these prerequisites, we also prenotified both groups of teachers about the survey. Studies have shown that prenotification of web surveys is an effective way to increase response rates, likely because it assures the participants in advance that the completion of the surveys will not be a major time commitment (Sheehan, 2001). The e4usa teachers were prenotified by us during a recurring bi-weekly Zoom meeting, while the Massachusetts area teachers were prenotified via email. After prenotification, we followed up after receiving WPI Institutional Review Board (IRB) approval of our survey questions with a link to our finished survey.

FINDINGS / ANALYSIS

Our research focused on two main facets of the curriculum design: student engagement and teacher usability. To evaluate the effectiveness of the curriculum in these areas, we employed a combination of anonymous surveys sent to teachers running pilot programs with the XRP kits, as well as focused interviews with selected Massachusetts area teachers. Our surveys combined questions tailored to each module with a common set of questions asked for all curriculum modules and were designed to be answered quickly by the participating teachers. Using the responses to the qualitative and quantitative questions in the surveys, we formulate a baseline answer to each of the aspects of our research question. We will then reinforce these answers with answers to the focused interview questions. We also acknowledge and delve into the limitations of our data and findings, including hardware issues, teacher unavailability, and issues getting survey responses from the teachers.

Tables 1 and 2 provide a summary of the survey responses received. Since the survey was anonymous, we do not know which of our pilot teachers responded, though we estimate that a total of 6 teachers completed the surveys based on the geolocation information provided by Qualtrics. Due to the small number of pilot teachers and the limited time they had to use the curriculum, the data is limited in scope and not all responses provide enough data to do statistical analysis. We expand on these limitations in detail in the limitations section of our report.

Module Number	**Number of responses**
2.2 “What is a robot?”	2

3.3 “Getting the Robot Moving”	1
3.4 “Driving a Distance”	1
3.5 “The Encoders”	1
3.6 “Helpful Drivetrain Functions”	1
8 “Delivery Challenge” (final project)	1

Table 1 - Summary of survey response counts by curriculum module

Question	**Research Objective**	**Number of Responses**
How useful did you find the text, images/videos, and code samples in the module?	Teacher Usability: Content Quality	26
Did the module provide enough background information?	Teacher Usability: Content Quality	8
Did this module provide too little or too much content to be delivered in a single class session?	Teacher Usability: Pacing	8
What percentage of students were engaged with the lesson?	Student Engagement	8
What percentage of students were able to demonstrate understanding?	Student Engagement: Understanding	8
What percentage of students were able to get the robot to perform as expected?	Student Engagement: Activity Completion	8

Table 2 - Summary of survey response counts by research objective

Student Engagement

Student engagement when completing the curriculum modules is highly dependent on the quality of the activities within them; if the structure and pacing of the activities are not understandable and interesting, student engagement suffers. Since we surveyed and interviewed teachers, our data reflects *perceived* student engagement, as observed by responding teachers. It may be difficult for teachers to objectively determine if a student is or is not engaged, but we chose to defer to their expertise to make this determination instead of providing more specific behaviors we were looking for in response to the modules. To establish a baseline metric for engagement, we simply asked the following question inside the common question block on the survey: “What percentage of your students were engaged with the lesson?” As we mentioned in the survey design section of the report, the responses to this question were restricted to intervals of 20%. We took the mean of all responses to establish an average score of engagement across all modules:

Question	**Average Score (%)**	**St. Dev. (%)**	**N**
What percentage of your students were engaged with the lesson?	57.5%	19.8%	8

Table 3 - Average score of student engagement across all curriculum modules

Our data indicates that slightly over half of the students that used the modules were engaged with the lessons during their class sessions. The standard deviation of almost 20% makes sense for this dataset since that was the increment size of the slider in our survey, but also indicates that there was a high amount of variance in the samples. The relatively low number of samples is likely partially responsible for this.

While averaging across all modules gives us a basic understanding of engagement of the curriculum, it is not useful on its own since each module is different in terms of content and activities. By simply averaging our data across modules, we are also ignoring the fact that the modules become more difficult as they progress. For example, unit 6 modules cover implementing line following algorithms on the robot, and using proportional control, a topic many students aren't introduced to until college courses. Meanwhile, unit 3 modules cover basic robot driving functions, and while this is still expected to be challenging to the students, it is considered by the developers to be less challenging than the following modules. On the flipside, students are expected to build and develop their skills and knowledge level as they progress through the curriculum. In an ideal world, the rate which the curriculum's difficulty increases would exactly match the rate at which all students learn the material. All students learn at different rates, and even ignoring this it would be incredibly difficult to match the curriculum to even the average learning rate across all students given the amount of material that must be introduced in a short timeframe. To assess how close we came to this ideal rate of difficulty increase, we plotted the average engagement percentage score of each module in increasing order of lesson number, along with the trendline of the data.

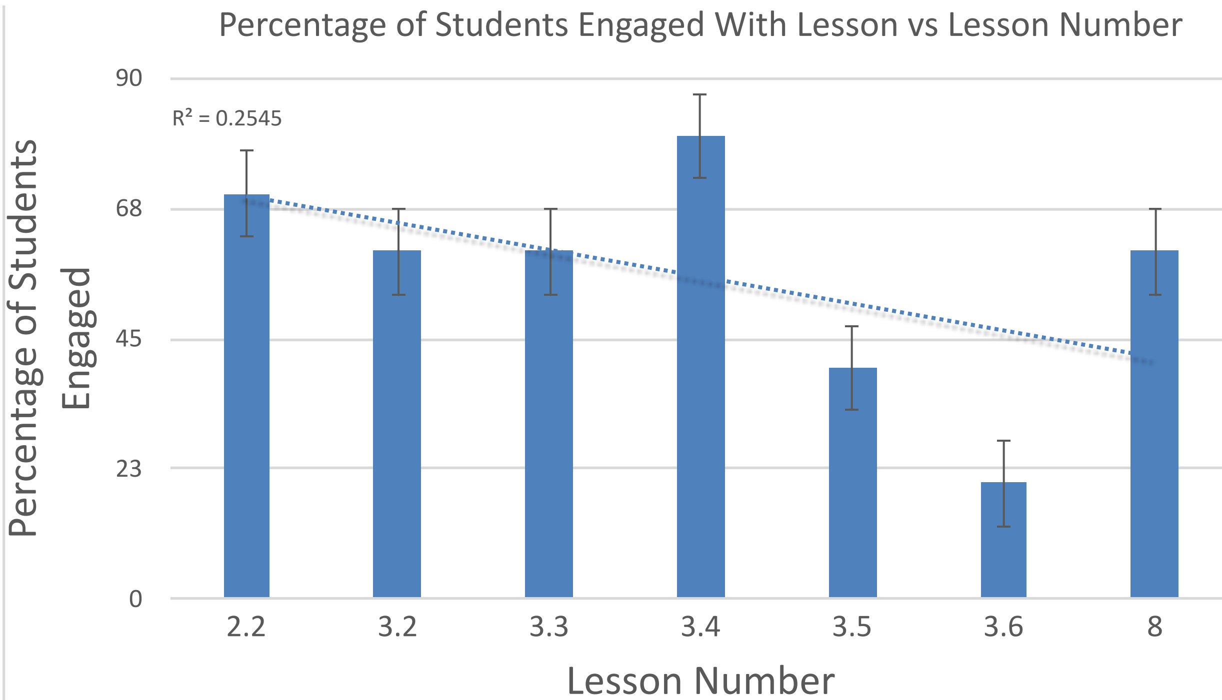

Figure 3 - Chart displaying student engagement percentages by curriculum module in ascending order

An initial observation of this graph confirms what we expected to see, with the trend of engagement decreasing as the lessons progress. Interpreting the data this way, unit 3.4 ("Driving a distance") is an unexpected outlier. Looking at the content of this module, it is the first module where students are introduced to functions and given a software design problem, so it is possible that this created a spike of engagement. It is also unsurprising that unit 8 has higher engagement, as this is the final project module and may have been completed over multiple class sessions. If we consider 3.4 to be an outlier with unusually high engagement, the data can be interpreted in a different way, where 60-70% should be considered the "target" engagement level. Looking at the data through this lens, modules 3.5 and 3.6 are underperforming and deficient in terms of engagement and may need to be restructured. Looking specifically at module 3.5, which introduces the encoders on the XRP's wheels that allow the software to track how far the wheels have rolled and how fast they are moving, we find that the module is rather math heavy, asking students to convert wheel rotations into linear distances. Additionally, the only activity in this module is for the students to rotate the XRP's wheels by hand and observe the encoder value changing, which is not as interactive of an activity as other modules provide. To dive in further, we look at a response to an open-ended question from this module's survey results: "Were there any specific concepts in this module that you found particularly hard to teach?" One teacher responded:

> "*What the encoder is doing. These are freshmen/sophomore boys, they are not going to RTFM. This is not a problem with the unit itself. Possibly video content might help, probably we will have to live with it*"

In this case, the teacher's students struggled to understand the purpose of the XRP's encoders. Since encoders are a foundational concept within our curriculum, it is expected that we provide content explaining their purpose. The teacher suggests video content could help, of which there is very little in this unit. At the very least, the data seems to indicate that this module should be revisited to make it more interactive, and it is also likely that other foundational modules which we do not have data for could be improved in similar ways. It is important to note that the correlation coefficient (number describing proximity of each datapoint to the trendline) of our trendline is very poor, indicating that we should not try to draw statistical conclusions based on the trendline, hence the multiple interpretations of the data.

In addition to directly asking about student engagement, we also collected data in the survey about percentages of students who were able to demonstrate understanding and proficiency with the material, as well as percentages of students who were able to get the XRP robot to do the tasks laid out in the activities.

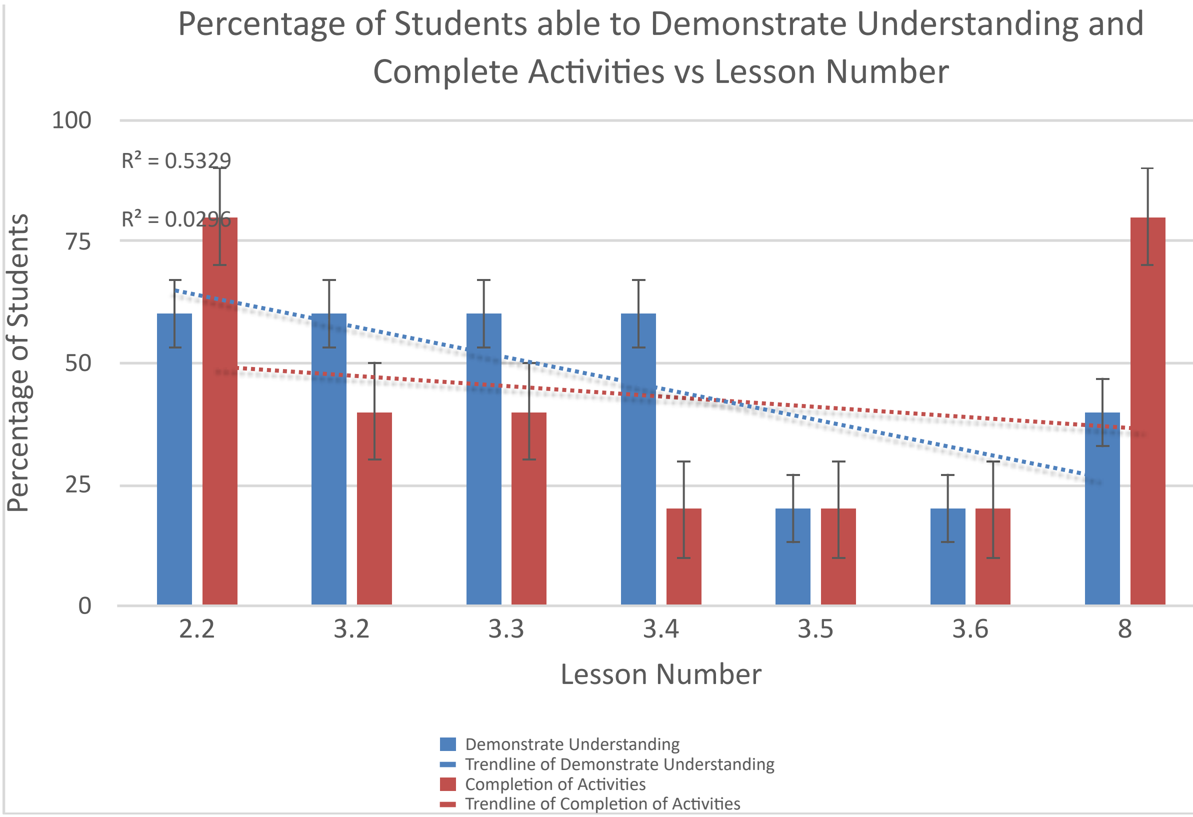

Figure 4 - Chart showing percentages of students able to demonstrate understanding and complete module activities by module in ascending order

In both cases, we saw the same average score of less than 50% of students meeting the criteria. While we were intentionally vague on the definition of demonstrating understanding, again choosing to defer to teacher expertise on this matter, the results of the second question are unambiguous: less than half of the students were on average able to get their robots working. In fact, only one response on one module reported having 100% of students able to complete the activity.

Overall, the results are mixed on student engagement, as it seems that overall engagement is lower than we would like it to be across the board. To gain some clarity, we can look at a response from an interview with one of our selected Massachusetts area teachers. In one of our teacher interviews, we asked: "Did you notice any changes in student engagement or interest in STEM subjects after using the curriculum?" The teacher responded:

> "I would say so. The kids that were waiting for the FRC kickoff and they were like, you know, looking at the robot, but it was, had no batteries and it wasn't moving. This was an instant, tangible, concrete way for them to make sense of what they were going to be doing and also what was possible, so it was a great appetizer for much deeper learning materials. So for them, it was a great hook to show them that this is a small scale version of everything that's possible. So [the curriculum] definitely helps."

They then followed up with:

> "Post COVID, I've noticed that students need something to catch their interest. They'll lose interest very quickly. And this is just, it fit the bill for them. gratifying, it was interesting. Yeah, I would say that it was probably the best thing that I've offered in a long time for the kids that really kept interest."

It seems that the teacher and their students had a different experience to the average respondents to our survey in terms of student engagement. There are several possible reasons for this: for one, the teacher delivered this curriculum to prospective FRC team members, who are likely to be more passionately interested in robotics going into the modules than the average student since they chose to be part of an extracurricular robotics team. Another possibility is that the teacher's responses to us were biased since they are aware that we are the ones that made the curriculum, so he may not have been as candid with the veil of anonymity provided by the surveys being removed. Overall, the tone of the teacher's interview was very positive. In the case of student engagement, this tells us that students who have a pre-existing interest in robotics are more likely to succeed with our current curriculum, while for the average student it will be necessary to make further adjustments to raise engagement.

One final metric for student engagement is how many questions students asked the teachers. To measure this, in modules where it made sense, we asked questions about how many questions students asked the teachers about various module specific topics. For these survey questions, we gave the teachers five response choices:

1. None at all
2. A few
3. A moderate amount
4. A lot
5. A great deal

We planned to analyze these responses numerically like the others, but we only received two responses to these questions. The average response can best be described as “a few to a moderate amount” of questions. While there is not enough data here to draw any concrete conclusions, this data does help support the conclusion that engagement is lower than we would have liked.

Teacher Usability

As mentioned previously, we chose to break teacher usability down into two categories: content quality and content quantity. When looking at content quality, we want to see how easy it is for teachers to grasp the core concepts of the content to start teaching it quickly. For content quantity, we are looking at how well we met our goal of having each module occupy one class session worth of time. We asked specific survey questions aimed at answering each of these questions.

A good curriculum consists of more than just blocks of text and activities for students to complete. Images, videos, and in our case, code samples play a big role in the perceived quality of a curriculum and have effects on both teacher and student usability. To this end, the XRP curriculum contains all three, however not all modules contain all three elements. We asked teachers to rank the usefulness of each on a scale of 1 to 5, with 1 being "not at all useful" and 5 being "extremely useful."

Question	Average	Minimum	Maximum	N
How useful did you find the following components of the module? - Text	3.625 "Moderately to Very Useful"	3	5	7
How useful did you find the following components of the module? - Code Samples	3.444 "Moderately To Very Useful"	2	5	8
How useful did you find the following components of the module? - Images and Videos	2.889 "Slightly to Moderately Useful"	1	5	8

Table 4 - Average scores of content quality and usefulness survey questions

From this data, photos and videos are consistently less useful in the XRP curriculum than the code samples and text. 25% of the responses indicated that the photos and videos were "not at all useful." These responses were for modules 3.3 ("Getting the robot moving") and 3.4 ("Driving a distance"), both of which do not have any photos or videos. Ignoring the responses for these modules, the average score increases to roughly 3.5, putting this question in the same bracket as the other two. Interestingly, these two modules scored average scores in the engagement data, suggesting this may not have a student-facing impact. However, it seems that it would be a good standard to try to include photos and/or videos in all modules, as this could have impacts on engagement as well as usability. Of note, responses for the final project module indicated all three categories as "moderately useful." With the final project being the module that ties the entire curriculum together, future writers may wish to focus on this area particularly.

Another important factor of the curriculum's content as it pertains to teacher usability is background information. It is not reasonable to expect that teachers delivering this content are robotics experts, much less experts on the specifics of the XRP. Thus, it is up to the curriculum to fill in these gaps and provide appropriate background information to bring teachers up to speed quickly on what they are teaching in each module. Since the XRP is a simple robotics kit, this should be an achievable goal. To measure the curriculum's performance in this regard, we asked teachers if each module provided enough background information.

Question	Average Score (% Yes)	St. Dev. (% Yes)	N
Did the module provide enough background information for teachers?	77.78%	44.1%	9

Table 5 - Average percentage of modules which provided enough background information for teachers

From this data we can conclude that on average there is enough background information provided. One of the modules which did not provide enough background information was module 3.3 "Getting the robot moving" in which students are expected to drive their robot for the first time using a simple one line of code. Looking at the open-ended free response for the "No" response to the question:

> "We ran into motor issues, it wasn't clear if this was hardware or software related. Some debugging hints when it talks about the motors not behaving perfectly would be useful, maybe discuss hardware and hardware/software interaction in a general way to make this useful learning (perhaps this is covered elsewhere)"

We can see that this respondent had hardware or software issues with the motors, and that there is not enough information in the module about the hardware and software interaction. While writing this module, we thought this was the simplest module we could possibly write, so seeing this result is somewhat confusing, perhaps indicating that future curriculum writers need to reframe their reference in terms of user knowledge level to an even higher degree than we did.

In addition to content quality, we also want to ensure that we are pacing content in a way that works for most teachers. This is important so that teachers do not need to spend a lot of time restructuring the modules to fit them to their schedule. When updating the curriculum structure, we set a goal that each curriculum module should occupy one class session. To measure the curriculum's performance in this regard, we asked teachers if each module provided enough content to fill a class. We gave the teachers 5 options, ranging from far too little content to far too much content for a single class.

Question	**Average Score**	**St. Dev.**	**N**
Did this module provide too little or too much content to be delivered in a single class session?	2 "Slightly too little"	1.2	8

Table 6 - Average score of content pacing as perceived by teachers

From this response data, we can see that on average the modules provided too little content. In addition, 50% of responses said modules provided "far too little" content. This result is not entirely surprising, as we noted while working with the initial curriculum that we were given that many modules were incredibly short, only having the students do a single "test" style activity with their robot. The original curriculum was not designed with this pacing in mind, and we were not able to completely align to this new pacing with our updates. To get more insight, we asked one of our Massachusetts area teachers in our interview if there were any ways that we could restructure the modules to increase usability. The teacher responded:

> "I like the modules a lot. I've come from a world of using projects either way for a long time. And the way that the modules are set up are really organized […] The only thing I would wonder about, it's probably difficult, is like a way for students to answer or interact with the online part, which I don't think would be possible, but it would be neat for them to have like a companion notebook or like something that kind of summarizes the units for them. I mean, a teacher could do that too, but I almost feel like at the end of the module, the units would be neat to have the kids like, okay, now in your own words, try this sample."

Interactive modules were something we discussed during our curriculum updates, but it was deemed too difficult to accomplish with the current curriculum platform. Based on our data about amount of content, however, this seems like something that may be necessary to provide more content for teachers. If teachers could allow students to use interactive components of the modules, it could mean less materials that they need to prepare themselves.

Limitations

XRP Hardware

The XRP is a new product that is bound to have issues, both hardware and software. Issues with the hardware and software had a profound impact on our ability to collect data. From the survey results, several teachers reported that the kits had broken or missing parts. This is an example of data we wanted to collect in the survey that was not curriculum related but was instead useful to others working on the XRP development, which was another one of our project goals. In conversations with one of our Massachusetts area teachers, the teacher reported issues with the XRP programming software used on student laptops "frequently disconnecting" from the XRP robots, which inhibited their ability to complete the modules. We also observed these issues with the teacher's laptop during our professional development session with them. As a result, some degree of frustration likely comes off in their responses to curriculum related survey questions, which may artificially lower scores of areas that are not related to the hardware and software. In the teacher's case, the issues were so significant that they were only able to get through a single class session with students before running out of patience with the hardware and software.

Availability of Teachers

Our project took place over the summer of 2023 and extended fully into the winter months, which is the timeframe when we started working with teachers. While we were in initial contact with both the e4usa teachers and the Massachusetts area teachers by the end of the summer, we did not have the surveys prepared until after this time. Our surveys were completed in accordance with our project timeline, but the timeline did not leave adequate time for teachers to pre-read the curriculum, test the kits, and prepare to deliver the material. As a result, this time had to be taken from the time we planned teachers to already be started with the kits which greatly reduced the overall time our teachers had to test our modules. This meant that we did not collect any data for modules past those which used the XRP's drivetrain, i.e. no data for line following, the ultrasonic sensor, or the manipulator arm modules. These modules are substantially more complex than the drivetrain modules, so the lack of data impacts our ability to draw conclusions and generalize recommendations, as it may not be a correct assumption to extrapolate data collected from the robot drivetrain modules to these more advanced topics.

Since our data collection was done during the winter months, scheduling with teachers was challenging due to limited availability. In the end, the teachers only had a few weeks with the kits in hand. We also had difficulty finding times for both teachers to do professional development sessions. Ultimately, we were only able to do a session with one of the Massachusetts area teachers, and we had to rely on the other's robotics background in place of this. Ultimately, this worked out since the other teacher had a very positive experience with the kits. Finally, we had a lot of scheduling issues with our interviews, so much so that we were unable to secure an interview with one of the teachers despite agreeing on it in advance.

Survey Responses

Convincing participants to volunteer their time answering surveys can be challenging. While we made efforts to make our survey as easy and approachable as we could, with up front estimates of how long it would take participants to complete, we still had many issues with getting enough responses. We sent two reminders to the e4usa teachers as response rates frequently stagnated, despite the expectation that those teachers had been and were continuing to be actively testing the XRP kits. From our Massachusetts area teachers, while we have no way of knowing for certain, from email communications with the teachers it appears that each only filled out the survey once. This would not have been an issue if we were able to secure interviews with both teachers, but as mentioned before we were not able to interview one of them, so we are missing a large amount of data about their negative experience.

As a result of all the previous factors, we got 11 total recorded responses on Qualtrics for our survey. Upon downloading and looking at the results, 5 of these responses were completely empty. This left us with 6 responses that contained data. Within the 6 survey responses, some participants answered multiple modules which is what allowed us to see up to 9 datapoints in some of our numerical averages. Even with this, 9 datapoints is not enough to do effective statistics, so our ability to do deep analysis into these results was greatly limited.

Numerical averages from this data are likely not reliable, and there are many sources of bias that we are unable to correct for with this set of participants. To execute a truly data driven curriculum development process, more pilot teachers would be needed, and the study would need to be run over a much longer period.

CONCLUSION / FINAL RECOMMENDATIONS

Since this study measured results about curriculum development that we did ourselves as opposed to work that we did with a third party, we will direct our recommendations to any future authors of XRP curriculum material, as well as to anyone who may run a study in the future using the XRP and curriculum. We will also pose some recommendations to the XRP software and hardware development team based on the data we have collected in those areas.

Future Curriculum Development

Our study has identified several major gaps in the existing XRP curriculum, even after our updates. As we were fundamentally working on revisions to an existing structure, the changes we could make were limited, and we had limited time and headcount to make updates. Based on the data we gathered, it seems that the largest issue with the curriculum today is modules with not enough content. Our average score for this datapoint was consistently low, and looking back at the modules referenced by the survey participants the issues can be clearly seen, with many of these modules having only a single, very simple activity. More thought needs to be put into module pacing. Students to test the curriculum were only available towards the end of our update process, and the testing they did was split between code samples provided by us and tests provided by the XRP software team. Additionally, these were volunteer college students, so the timing data from them is likely not accurate to average high school classes. A better data-driven process would have a pilot group involved during the development to test new ideas as they came up. While this was not something we were able to do given our constraints, a new project could define this as a requirement from the start.

Another issue our data identified is that most of the modules do not have sufficient (or any) images and videos. While the usefulness of this to teachers is less apparent, it is vital if students are expected to view the modules. An entire project could be formed out of ensuring that all pages have descriptive images and/or videos that align with the current content. This is especially important for sections such as the final project. At the time of writing of this report, the final project module is a single page with one picture, and that picture does not show an actual playing area or any of the elements used in the final project. The final project module itself is also lacking in information, instead only showing various point values that are scored. There is a general lack of guided walkthroughs for teachers in the curriculum, with the final project being only one example of where this is missing. Another example is the page which explains the encoders, which was directly pointed out by one of our pilot teachers as being insufficient to explain the concept.

For any group who wishes to run a study using the XRP and curriculum, contact should be established early and often with the teachers or students in the study. Critically, the researchers should take care to ensure the XRP hardware is functional, and that the XRP software works in the environment of the subjects. Ideally, the study would be conducted with the researchers in the room with the teachers or students, but this is understandably difficult to achieve in a school environment.

XRP Hardware and Software

Our set of recommendations to the XRP hardware and software teams are brief. Overall, more attention needs to be put into ensuring that the software is functional even on school managed devices. As an example, the process to update the XRP's onboard software was not possible to do on one of the teacher's computer since it blocked USB storage devices, and part of the update process requires the XRP to appear to the laptop as a USB flash drive. Because this failed, the entire update process was stuck in an intermediate state that could no longer be recovered even by a non-school owned computer. In general, it seems there are several cases like this where the XRP software does not behave as expected, and while we are unable to provide specific guidance as to what these issues were since it was out of our project's scope to research them further, it feels like more testing is required before this product is ready for mass teacher use. Thus, we would heavily recommend that the XRP team sets up a network of support staff or resources that can guide teachers through any problems they may encounter.

Conclusion

This IQP started as an effort to improve library code for the XRP robot kit, a robot kit developed by WPI. Based on the project's needs, this became a project doing updates to curriculum modules targeted at high school teachers and students. In addition to updating existing content to fill gaps, we also restructured the pages to reorder material into a more sensible order for delivery to students who had no exposure to this kind of curriculum. After doing these updates, we communicated with pilot teachers and developed a survey to collect data about our updated curriculum. We worked with teachers from an organization, e4usa, as well as selected teachers in Massachusetts to get survey results and interview data. Ultimately, while we were not able to collect the amount of data we hoped for, we were able to draw some concrete conclusions from the data we did collect, and we were able to take lessons away from the data (and lack thereof) that we can pass along as recommendations to future groups who may work on this or similar projects.

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APPENDIX A: SURVEY QUESTIONS

XRP Introduction to Robotics Curriculum Survey

Start of Block: Introduction

IntroductionText Welcome to the XRP Introduction to Robotics Curriculum Survey.

This survey is intended to give WPI feedback on how to improve the XRP curriculum going forward. We look forward to your candid feedback about our course. Please remember that your responses are **completely anonymous** and will have no impact on your continued access to XRP curriculum and training. Participating in the survey is **voluntary**, and all questions are **optional**. You can stop taking the survey at any time.

This survey includes questions for each module of the curriculum. We estimate that each module's questions will take between 5-7 minutes.

If you have any questions about the survey, please reach out to **Error! Hyperlink reference not valid.** and/or **Error! Hyperlink reference not valid.**

End of Block: Introduction

Start of Block: Unit Selection

SelectionInfo You will be asked to select one or more curriculum units. For each unit you select, you will be asked to select which modules from that unit you want to provide feedback on. The questions will be in the order of the listed units and modules in the curriculum. Each set of questions will be labeled with the unit and module it is referencing.

Page Break

UnitSelection Which units(s) would you like to provide feedback on today?

- Unit 2: Introduction to the XRP (1)
- Unit 3: Robot Driving (2)
- Unit 4: Measuring Distances (3)
- Unit 5: Robot Control (4)
- Unit 6: Sensing & Following Lines (5)
- Unit 7: Manipulation (6)
- Unit 8: Delivery Challenge (7)

End of Block: Unit Selection

Start of Block: Unit 2 Module Selection

Unit2Selection Which modules from unit 2 ("Introduction to the XRP") would you like to provide feedback on?

- 2.2 What is a robot? (1)
- 2.3 Building the XRP Robot (2)
- 2.4 Installing the Programming Tools (3)

End of Block: Unit 2 Module Selection

Start of Block: 2.2 Questions

2.2Intro The following questions are for **Error! Hyperlink reference not valid.**

Page Break

2.2Q1 How clearly did you find the example robots (and not robots) we provided in module 2.2 matched (or did not match) our definition of a robot:

In this course we talk about robots as devices that can: Sense their environment Think and perceive what is happening around the robot Carry out actions using actuators (motors)

	Radio Controlled Airplane (1)	Drone (2)	Vacuum Cleaner (3)	Autonomous Vacuum Cleaner (4)	Self-driving car (5)
Extremely unclear (1)					
Somewhat unclear (2)					
Neither clear nor unclear (3)					
Somewhat clear (4)					
Extremely clear (5)					

2.2Q2 Did you find that this module provided useful background information about robotics that a majority of your students did not already have?

- ◯ Yes (1)
- ◯ No (2)

End of Block: 2.2 Questions

Start of Block: Lesson Module Common Questions

OpenEnded How do you think this module could this module be improved?

____

____

Page Break

Q1 How useful did you find the following components of the module?

	Not at all useful (1)	Slightly useful (2)	Moderately useful (3)	Very useful (4)	Extremely useful (5)
Text (1)					
Code Samples (2)					
Images and Videos (3)					

Q2 Did the module provide enough background information?

- Yes (1)
- No (please elaborate) (2) ____

Q3 How clear were the objectives of the module?

- Extremely clear (1)
- Somewhat clear (2)
- Neither clear nor unclear (3)
- Somewhat unclear (4)
- Extremely unclear (5)

Q4 Were there any specific concepts in this module that you found particularly hard to teach?

- No (1)
- Yes (please specify) (2) ____

Q5 Did this module provide too little or too much content to be delivered in a single class session?

- Far too little (1)
- Slightly too little (2)
- Neither too much nor too little (3)
- Slightly too much (4)
- Far too much (5)

Q6 What percentage of your students were:

	0	20	40	60	80	100
Engaged with the lesson (1)						
Able to demonstrate understanding (2)						
Able to get the robot to perform as expected (3)						

End of Block: Lesson Module Common Questions

Start of Block: 2.3 Questions

2.3Intro The following questions are for **Error! Hyperlink reference not valid.**

Page Break

2.3Q1 How easy were the XRP assembly instructions for **you** to follow?

- Extremely easy (1)
- Somewhat easy (2)
- Neither easy nor difficult (3)
- Somewhat difficult (4)
- Extremely difficult (5)

2.3Q2 How easy were the XRP assembly instructions for **your students** to follow?

- Extremely easy (1)
- Somewhat easy (2)
- Neither easy nor difficult (3)
- Somewhat difficult (4)
- Extremely difficult (5)

2.3Q3 How many of your students were able to assemble the XRP robot using the instructions without assistance?

- A great deal (1)
- A lot (2)
- A moderate amount (3)
- A little (4)
- None at all (5)

2.3Q4 Did you or your students run into any issues while assembling the XRP kits, such as broken or missing parts?

- ▢ Missing parts (1)
- ▢ Broken parts (2)
- ▢ Parts broke during assembly (3)
- ▢ Other (please specify) (4) ____

End of Block: 2.3 Questions

Start of Block: 2.4 Questions

2.4Intro The following questions are for **Error! Hyperlink reference not valid.**

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Page Break

2.4Q1 Which supported programming language(s) are you planning on using with your students?

☐ Python (1)

☐ Blockly (2)

2.4Q2 How many of your students were able to get the sample code running on their XRP without assistance?

○ A great deal (1)

○ A lot (2)

○ A moderate amount (3)

○ A little (4)

○ None at all (5)

2.4Q3 Did you or your students run into any issues while using the programming tools?

☐ Tools didn't load (1)

☐ Couldn't load code onto robot (2)

☐ Tool instructions were unclear (3)

☐ Other (please specify) (4) ____

End of Block: 2.4 Questions

Start of Block: Unit 3 Module selection

Unit3Selection Which modules from unit 3 ("Robot Driving") would you like to provide feedback on?

- ▢ 3.2 Understanding Your Robot's Drivetrain (1)
- ▢ 3.3 Getting the Robot Moving (2)
- ▢ 3.4 Driving a Distance (3)
- ▢ 3.5 The Encoders (4)
- ▢ 3.6 Helpful Drivetrain Functions (5)
- ▢ 3.7 Driving with Geometry (6)
- ▢ 3.8 Waiting for Button Input (7)
- ▢ 3.9 Parking Challenge (9)
- ▢ 3.10 Advanced: Circles and Differential Steering (10)

End of Block: Unit 3 Module selection

Start of Block: 3.2 Questions

3.2Intro The following questions are for **Error! Hyperlink reference not valid.**

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3.2Q1 How clear do you find the term "differential drivetrain" is when describing how the XRP drives?

- ◯ Extremely unclear (1)
- ◯ Somewhat unclear (2)
- ◯ Neither clear nor unclear (3)
- ◯ Somewhat clear (4)
- ◯ Extremely clear (5)

3.2Q2 How challenging was it to convey the concept of effort to students using the definition provided in the module?

- ◯ Not challenging at all (1)
- ◯ Slightly challenging (2)
- ◯ Moderately challenging (3)
- ◯ Very challenging (4)
- ◯ Extremely challenging (5)

3.2Q3 This module is the first time students run their own program on their robot. Did students have any issues with this process that you couldn't help them solve?

- ◯ No (1)
- ◯ Yes (please specify) (2) ____

End of Block: 3.2 Questions

Start of Block: 3.3 Questions

3.3Intro The following questions are for **Error! Hyperlink reference not valid.**

End of Block: 3.3 Questions

Start of Block: 3.4 Questions

3.4Intro The following questions are for **Error! Hyperlink reference not valid.**

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3.4Q1 How familiar are your students already with the concept of dimensional analysis?

- Extremely familiar (1)
- Very familiar (2)
- Moderately familiar (3)
- Slightly familiar (4)
- Not familiar at all (5)

3.4Q2 Was our explanation of dimensional analysis clear enough to give your students the background they needed to solve for the time needed to drive a distance?

- No (1)
- Yes (2)

3.4Q3 How many questions did you receive from students about how writing functions in Python or Blockly?

- None at all (1)
- A few (2)
- A moderate amount (3)
- A lot (4)
- A great deal (5)

End of Block: 3.4 Questions

Start of Block: 3.5 Questions

3.5Intro The following questions are for **Error! Hyperlink reference not valid.**

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3.5Q1 Do you think that introducing the fundamentals of how an encoder works (disk, light source, etc.) is useful information for the students?

- Definitely not (1)
- Probably not (2)
- Probably yes (3)
- Definitely yes (4)

3.5Q2 This lesson assumes a fundamental geometry background to rotate the robot to a given direction. Did the module provide enough information for most of your students to be able to do this on their own?

- Yes (1)
- No (2)

End of Block: 3.5 Questions

Start of Block: 3.6 Questions

3.6Intro The following questions are for **Error! Hyperlink reference not valid.**

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3.6Q1 The functions introduced in this module make driving the robot much easier. Do you think it would be better to introduce these functions at the start of the course so that students can get the robot driving sooner?

- Yes, introduce the content at the start of the course (1)
- No, students must understand the background theory before using the easy functions (2)

3.6Q2 How many of your students had questions about function parameters?

- None at all (1)
- A few (2)
- A moderate amount (3)
- A lot (4)
- A great deal (5)

End of Block: 3.6 Questions

Start of Block: 3.7 Questions

3.7Intro The following questions are for **Error! Hyperlink reference not valid.**

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3.7Q1 This module assumes a moderate geometry background to compute the interior and exterior angles of the different shapes. Was the information we provided clear enough for most of your students to be able to do this?

- Yes (1)
- No (2)

3.7Q2 Were there any accuracy issues with student robots that made drawing shapes difficult or discouraging, even when the students wrote correct code?

- None at all (1)
- A few (2)
- A moderate amount (3)
- A lot (4)
- A great deal (5)

End of Block: 3.7 Questions

Start of Block: 3.8 Questions

3.8Intro The following questions are for **Error! Hyperlink reference not valid.**

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3.8Q1 Would this section be more useful if it was moved to the start of the course so that students can use the button in all of their code?

- Yes (1)
- No (2)

3.8Q2 Would it be better if the XRP automatically waited for button input before starting any program?

- Yes (1)
- No (2)

3.8Q3 This activity is very simple. Was this enough to fill one class or did you combine it with another lesson?

- Enough to fill one class (1)
- Combined with another lesson (2)

End of Block: 3.8 Questions

Start of Block: 3.9 Questions

3.9Intro The following questions are for module 3.9: "Parking Challenge"

This is a project module. Questions will focus on how effectively students were able to complete the project.

End of Block: 3.9 Questions

Start of Block: 3.10 Questions

3.10Intro The following questions are for **Error! Hyperlink reference not valid.**

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3.10Q1 How clear did **you** find the math in this module?

- Extremely unclear (1)
- Somewhat unclear (2)
- Neither clear nor unclear (3)
- Somewhat clear (4)
- Extremely clear (5)

3.10Q2 How clear did **your students** find the math in this module?

- Extremely unclear (1)
- Somewhat unclear (2)
- Neither clear nor unclear (3)
- Somewhat clear (4)
- Extremely clear (5)

3.10Q3 How useful were the pictures and video in this module?

- Not at all useful (1)
- Slightly useful (2)
- Moderately useful (3)
- Very useful (4)
- Extremely useful (5)

End of Block: 3.10 Questions

Start of Block: Unit 4 Module selection

Unit4Selection Which modules from unit 4 ("Measuring Distances") would you like to provide feedback on?

- ▢ 4.2 Measuring Distances (1)
- ▢ 4.3 Obstacle Avoidance (2)
- ▢ 4.4 Locating a Nearby Object (3)

End of Block: Unit 4 Module selection

Start of Block: 4.2 Questions

4.2Intro The following questions are for **Error! Hyperlink reference not valid.**

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4.2Q1 How clear was the analogy of a bat's sonar to the ultrasonic rangefinder on the XRP to your students?

- Extremely clear (1)
- Somewhat clear (2)
- Neither clear nor unclear (3)
- Somewhat unclear (4)
- Extremely unclear (5)

4.2Q2 Was this module enough content for a single class, or should there be more activities in this module?

- Enough content (1)
- More activities (2)

End of Block: 4.2 Questions

Start of Block: 4.3 Questions

4.3Intro The following questions are for **Error! Hyperlink reference not valid.**

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4.3Q1 This module introduces a complex programming task. Do you think the module gives not enough or too much information for the students to write their own code without just copying and pasting?

- Far too little (1)
- Slightly too little (2)
- Neither too much nor too little (3)
- Slightly too much (4)
- Far too much (5)

End of Block: 4.3 Questions

Start of Block: 4.4 Questions

4.4Intro The following questions are for module 4.4: "Locating a Nearby Object"

4.4Q1 An activity similar to the one in this module is used as part of a project in an introduction to robotics course at WPI, and many students have accuracy problems when using the ultrasonic sensor that make it almost impossible to accurately drive towards a detected object. Were most of your students able to have their XRP accurately drive towards detected objects (i.e. aimed at the center?)

- No (1)
- Yes (2)

4.4Q2 This module provides large amounts of sample code that essentially give the answer to the problem. How difficult was it for you to adapt this module to a form where students are gradually introduced to the concepts?

- Extremely difficult (1)
- Somewhat difficult (2)
- Neither easy nor difficult (3)
- Somewhat easy (4)
- Extremely easy (5)

4.4Q3 This is the first module where students use the IMU. Do you think it needs more of an introduction earlier in the course?

- Yes (1)
- No (2)

End of Block: 4.4 Questions

Start of Block: Unit 5 Module selection

Unit5Selection Which modules from unit 5 ("Robot Control") would you like to provide feedback on?

- 5.2 Controlling Behavior: Introduction (1)
- 5.3 Distance Tracking (2)
- 5.4 Introduction to Proportional Control (3)
- 5.5 Implementing a Proportional Controller (4)
- 5.6 Introduction to Wall Following (5)

End of Block: Unit 5 Module selection

Start of Block: 5.2 Questions

5.2Intro The following questions are for module 5.2: "Controlling Behavior: Introduction"

5.2Q1 How useful did you find the examples of open and closed loop controllers (oven, self driving car) for explaining the concept to your students?

- Not at all useful (1)
- Slightly useful (2)
- Moderately useful (3)
- Very useful (4)
- Extremely useful (5)

5.2Q2 This module does not provide an activity for students. Were you able to come up with an activity or should one be provided?

- I was able to come up with an activity (feel free to share) (1) ____
- One should be provided (2)
- I taught this module as a lecture with no activity (3)

End of Block: 5.2 Questions

Start of Block: 5.3 Questions

5.3Intro The following questions are for module 5.3: "Distance Tracking"

5.3Q1 How well were your students able to recall the previous work they did with the rangefinder when completing this activity?

- ◯ Extremely well (1)
- ◯ Very well (2)
- ◯ Moderately well (3)
- ◯ Slightly well (4)
- ◯ Not well at all (5)

5.3Q2 Do you think the curriculum provided enough background information on what a "deadband" is?

- ◯ No (1)
- ◯ Yes (2)

End of Block: 5.3 Questions

Start of Block: 5.4 Questions

5.4Intro The following questions are for module 5.4: "Introduction to Proportional Control"

5.4Q1 This module uses college level terminology for control systems: **process variable, gain, proportional, underdamped,** and **overdamped**. Did you find it easy to teach these terms to your students, or would you rather the curriculum choose different terminology that is suitable for a lower level of understanding?

- ◯ Yes, it was easy to teach (1)
- ◯ No, I would rather the curriculum used simpler terminology (2)

5.4Q2 How easy was it for you to explain the relationship between the Kp value and the way a system responds?

- Extremely difficult (1)
- Somewhat difficult (2)
- Neither easy nor difficult (3)
- Somewhat easy (4)
- Extremely easy (5)

End of Block: 5.4 Questions

Start of Block: 5.5 Questions

5.5Intro The following questions are for module 5.5: "Implementing a Proportional Controller"

5.5Q1 Would you have preferred if this module was combined with the one before it which introduces the concept of proportional control?

- Yes (1)
- No (2)

5.5Q2 Did you find that students had a difficult time tuning the Kp value for their robot?

- Extremely difficult (1)
- Somewhat difficult (2)
- Neither easy nor difficult (3)
- Somewhat easy (4)
- Extremely easy (5)

End of Block: 5.5 Questions

Start of Block: 5.6 Questions

5.6Intro The following questions are for module 5.6: "Introduction to Wall Following"

5.6Q1 Did you find that the sample code in this module was explained adequately?

- Definitely not (1)
- Probably not (2)
- Might or might not (3)
- Probably yes (4)
- Definitely yes (5)

5.6Q2 Did you find that this module provided enough material to turn into a full lesson, or did you treat it as a project?

- Enough material for a full lesson (1)
- Treated it as a project (2)

5.6Q3 Do you think adding more explanatory graphics to this page would make it easier to teach?

- Yes (1)
- No (2)

End of Block: 5.6 Questions

Start of Block: Unit 6 Module selection

Unit6Selection Which modules from unit 6 ("Sensing & Following Lines") would you like to provide feedback on?

- ▢ 6.2 Understanding the Line Sensor (1)
- ▢ 6.3 Stopping at a Line (2)
- ▢ 6.4 Staying in the Circle (3)
- ▢ 6.5 Challenge: Sumo-Bots! (4)
- ▢ 6.6 Following the Line: On/Off Control (5)
- ▢ 6.7 Following the Line: Proportional Control (6)
- ▢ 6.8 Following the Line: Proportional Control with Both Sensors (7)
- ▢ 6.9 Stopping at an Intersection (8)
- ▢ 6.10 Parking Garage Challenge (9)

End of Block: Unit 6 Module selection

Start of Block: 6.2 Questions

6.2Intro The following questions are for module 6.2: "Understanding the line sensor"

6.2Q1 How clear did you find the definition of a "threshold" value in this module?

- ○ Extremely unclear (1)
- ○ Somewhat unclear (2)
- ○ Neither clear nor unclear (3)
- ○ Somewhat clear (4)
- ○ Extremely clear (5)

6.2Q2 How clear did you find the explanations of the data reported by the sensor in this module?

- Extremely unclear (1)
- Somewhat unclear (2)
- Neither clear nor unclear (3)
- Somewhat clear (4)
- Extremely clear (5)

6.2Q3 How many of your students were able to successfully write the function to detect if the robot is over the line?

- None at all (1)
- A few (2)
- A moderate amount (3)
- A lot (4)
- A great deal (5)

End of Block: 6.2 Questions

Start of Block: 6.3 Questions

6.3Intro The following questions are for module 6.3: "Stopping at a line"

6.3Q1 How clear did you find the explanation of "inverting" logic in Python or Blockly in this module?

- ◯ Extremely unclear (1)
- ◯ Somewhat unclear (2)
- ◯ Neither clear nor unclear (3)
- ◯ Somewhat clear (4)
- ◯ Extremely clear (5)

6.3Q2 How many of your students attempted the challenge activity?

- ◯ None at all (1)
- ◯ A few (2)
- ◯ A moderate amount (3)
- ◯ A lot (4)
- ◯ A great deal (5)

6.3Q3 Did you find that the challenge activity section provided enough hints to deal with the special requirements (starting on a line) of driving over multiple lines?

- ◯ Yes (1)
- ◯ No (2)

End of Block: 6.3 Questions

Start of Block: 6.4 Questions

6.4Intro The following questions are for module 6.4: "Staying in the circle"

6.4Q1 How useful was breaking down the problem into a series of steps before introducing the content?

- Not at all useful (1)
- Slightly useful (2)
- Moderately useful (3)
- Very useful (4)
- Extremely useful (5)

6.4Q2 Would you prefer if all modules broke down challenge problems into a series of steps before introducing content?

- Yes (1)
- No (2)

6.4Q3 How many of your students were able to use prior experience from the course to piece together a solution to this problem without example code provided?

- None at all (1)
- A few (2)
- A moderate amount (3)
- A lot (4)
- A great deal (5)

End of Block: 6.4 Questions

Start of Block: 6.5 Questions

6.5Intro The following questions are for module 6.5: "Challenge: Sumo-Bots!"
This is a project module.

6.5Q1 Was a "fun" class-wide activity like this more engaging to your students than the activities they have been doing as part of the regular modules?

◯ None at all (1)

◯ A little (2)

◯ A moderate amount (3)

◯ A lot (4)

◯ A great deal (5)

6.5Q2 Was the content presented in the previous modules enough for students to implement the Sumo-Bots functionality on their own?

◯ Yes (1)

◯ No (please share anything you found missing) (2) ____

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*

6.5Q3 How many class sessions did you give students to prepare for the activity?

____

End of Block: 6.5 Questions

Start of Block: 6.6 Questions

6.6Intro The following questions are for module 6.6: "Following the Line: On/Off Control"

6.6Q1 How clear did you find the explanation of why the robot needs to follow the edge of a line?

- Extremely clear (1)
- Somewhat clear (2)
- Neither clear nor unclear (3)
- Somewhat unclear (4)
- Extremely unclear (5)

6.6Q2 How easy was it to teach students about the conditional logic (if/else) using this module?

- Extremely difficult (1)
- Somewhat difficult (2)
- Neither easy nor difficult (3)
- Somewhat easy (4)
- Extremely easy (5)

6.6Q3 How many of your students were able to effectively reuse the code they had written in previous modules to help with this lesson?

- None at all (1)
- A few (2)
- A moderate amount (3)
- A lot (4)
- A great deal (5)

End of Block: 6.6 Questions

Start of Block: 6.7 Questions

6.7Intro The following questions are for module 6.7: "Following the Line: Proportional Control"

6.7Q1 How clear was the concept of using the line sensor to compute an error value?

- Extremely unclear (1)
- Somewhat unclear (2)
- Neither clear nor unclear (3)
- Somewhat clear (4)
- Extremely clear (5)

6.7Q2 Did you find the graphics in this module to be useful in visualizing what the line sensor sees?

- Not at all useful (1)
- Slightly useful (2)
- Moderately useful (3)
- Very useful (4)
- Extremely useful (5)

End of Block: 6.7 Questions

Start of Block: 6.8 Questions

6.8Intro The following questions are for module 6.8: "Following the Line: Proportional Control with Both Sensors"

6.8Q1 How useful were the graphics showing both sensors on the line in understanding what the sensors see?

- Not at all useful (1)
- Slightly useful (2)
- Moderately useful (3)
- Very useful (4)
- Extremely useful (5)

6.8Q2 How challenging did students find it to tune the proportional controller to reliably follow the line?

- Not challenging at all (1)
- Slightly challenging (2)
- Moderately challenging (3)
- Very challenging (4)
- Extremely challenging (5)

End of Block: 6.8 Questions

Start of Block: 6.9 Questions

6.9Intro The following questions are for module 6.9: "Stopping at an Intersection"

6.9Q1 How useful were the graphics showing both sensors on the line in understanding what the sensors see?

- Not at all useful (1)
- Slightly useful (2)
- Moderately useful (3)
- Very useful (4)
- Extremely useful (5)

6.9Q2 How challenging was it for your students to measure the new threshold values using both sensors?

- Not challenging at all (1)
- Slightly challenging (2)
- Moderately challenging (3)
- Very challenging (4)
- Extremely challenging (5)

6.9Q3 How challenging was it for your students to write the functions required in this module without sample code being provided?

- Not challenging at all (1)
- Slightly challenging (2)
- Moderately challenging (3)
- Very challenging (4)
- Extremely challenging (5)

6.9Q4 How many of your students were able to complete the challenge activity?

- ◯ None at all (1)
- ◯ A few (2)
- ◯ A moderate amount (3)
- ◯ A lot (4)
- ◯ A great deal (5)

End of Block: 6.9 Questions

Start of Block: 6.10 Questions

6.10Intro The following questions are for module 6.10: "Parking Garage Challenge".
This is a project module.

6.10Q1 How clear did you find the description of this project?

- ◯ Extremely unclear (1)
- ◯ Somewhat unclear (2)
- ◯ Neither clear nor unclear (3)
- ◯ Somewhat clear (4)
- ◯ Extremely clear (5)

6.10Q2 How difficult did you find it to set up a space for students to run their robots in for this project given the project description in the module?

- Extremely difficult (1)
- Somewhat difficult (2)
- Neither easy nor difficult (3)
- Somewhat easy (4)
- Extremely easy (5)

6.10Q3 Did the project description provide enough context (without sample code) for most students to complete the project?

- No (1)
- Yes (2)

End of Block: 6.10 Questions

Start of Block: Unit 7 Module selection

Unit7Selection Which modules from unit 7 ("Manipulation") would you like to provide feedback on?

- 7.2 Introduction to Manipulation (1)
- 7.3 Picking up a Basket (2)
- 7.4 Intersection into Drop Off (3)

End of Block: Unit 7 Module selection

Start of Block: 7.2 Questions

7.2Intro The following questions are for module 7.2: "Introduction to Manipulation"

7.2Q1 How clear was the concept of a "DOF" given the description provided in the module?

- Extremely unclear (1)
- Somewhat unclear (2)
- Neither clear nor unclear (3)
- Somewhat clear (4)
- Extremely clear (5)

7.2Q2 Did you find that this module was enough to fill a class session, or was it too short?

- Enough to fill a class session (1)
- Too short (2)

End of Block: 7.2 Questions

Start of Block: 7.3 Questions

7.3Intro The following questions are for module 7.3: "Picking up a Basket"

7.3Q1 How clear was the description of this activity to follow without sample code provided?

- Extremely unclear (1)
- Somewhat unclear (2)
- Neither clear nor unclear (3)
- Somewhat clear (4)
- Extremely clear (5)

End of Block: 7.3 Questions

Start of Block: 7.4 Questions

7.4Intro The following questions are for module 7.4: "Intersection into Drop Off"

7.4Q1 How easy were the activity instructions on this page to understand?

- Extremely difficult (1)
- Somewhat difficult (2)
- Neither easy nor difficult (3)
- Somewhat easy (4)
- Extremely easy (5)

7.4Q2 How easy was it for your students to complete this activity with no sample code provided?

- Extremely difficult (1)
- Somewhat difficult (2)
- Neither easy nor difficult (3)
- Somewhat easy (4)
- Extremely easy (5)

End of Block: 7.4 Questions

Start of Block: Delivery Challenge Questions

8Intro The following questions are for module 8: "Delivery Challenge".
This is the final project module.

8Q1 How clear did you find the specifications of the project?

- Extremely unclear (1)
- Somewhat unclear (2)
- Neither clear nor unclear (3)
- Somewhat clear (4)
- Extremely clear (5)

8Q2 Do you think students will be able to complete this project in a reasonable amount of time?

- Definitely not (1)
- Probably not (2)
- Might or might not (3)
- Probably yes (4)
- Definitely yes (5)

8Q3 How clear did you find the scoring system to be for this project?

- Extremely unclear (1)
- Somewhat unclear (2)
- Neither clear nor unclear (3)
- Somewhat clear (4)
- Extremely clear (5)

End of Block: Delivery Challenge Questions

APPENDIX B: SURVEY RESPONSES

Module	Question	Responses
2.2	Did you find that this module provided useful background information about robotics that a majority of your students did not already have?	Yes
2.2	How do you think this module could this module be improved?	I don't think it can be. The youtube video is fantastic and let's kids build the kit at their own pace.
2.2	How useful did you find the following components of the module? - Text	Moderately useful
		Extremely useful
2.2	How useful did you find the following components of the module? - Code Samples	Moderately useful
		Extremely useful
		Slightly useful
2.2	How useful did you find the following components of the module? - Images and Videos	Very useful
		Extremely useful
		Very useful
2.2	Did the module provide enough background information? - Selected Choice	Yes
		Yes
		No
2.2	How clear were the objectives of the module?	Somewhat clear
		Extremely clear
2.2	Were there any specific concepts in this module that you found particularly hard to teach? - Selected Choice	No
		No
2.2	Did this module provide too little or too much content to be delivered in a single class session?	Neither too much nor too little
		Neither too much nor too little
2.2	What percentage of your students were: - Engaged with the lesson	80
		60
2.2	What percentage of your students were: - Able to demonstrate understanding	60
		60
2.2	What percentage of your students were: - Able to get the robot to perform as expected	100
		60
2.3	How easy were the XRP assembly instructions for you to follow?	Extremely easy
		Somewhat easy
2.3	How easy were the XRP assembly instructions	Somewhat easy

	for your students to follow?	Somewhat easy
2.3	How many of your students were able to assemble the XRP robot using the instructions without assistance?	A great deal A moderate amount
2.3	Did you or your students run into any issues while assembling the XRP kits, such as broken or missing parts? - Selected Choice	Missing parts,Parts broke during assembly
3.2	How clear do you find the term "differential drivetrain" is when describing how the XRP drives?	Somewhat clear Somewhat clear
3.2	How challenging was it to convey the concept of effort to students using the definition provided in the module?	Slightly challenging Not challenging at all
3.2	This module is the first time students run their own program on their robot. Did students have any issues with this process that you couldn't help them solve? - Selected Choice	Yes (please specify)
3.2	This module is the first time students run their own program on their robot. Did students have any issues with this process that you couldn't help them solve? - Yes (please specify) - Text	There were frequent disconnections of the XRP from the IDE, no obvious pattern but it happened to everyone, generally several times. The motors sometimes seemed to not respond or only respond briefly, I believe rebooting/refreshing fixed this eventually.
3.2	How do you think this module could this module be improved?	Being able to flip between Blockly and Python in the code examples is a nice feature from other units.
3.2	How useful did you find the following components of the module? - Text	Very useful
3.2	How useful did you find the following components of the module? - Code Samples	Very useful
3.2	How useful did you find the following components of the module? - Images and Videos	Moderately useful
3.2	Did the module provide enough background information? - Selected Choice	Yes
3.2	How clear were the objectives of the module?	Somewhat clear

3.2	Were there any specific concepts in this module that you found particularly hard to teach? - Selected Choice	No
3.2	Did this module provide too little or too much content to be delivered in a single class session?	Far too little
3.2	What percentage of your students were: - Engaged with the lesson	60
3.2	What percentage of your students were: - Able to demonstrate understanding	60
3.2	What percentage of your students were: - Able to get the robot to perform as expected	40
3.3	How do you think this module could this module be improved?	Navigation buttons on bottom of page are nice (general comment)
3.3	How useful did you find the following components of the module? - Text	Moderately useful
3.3	How useful did you find the following components of the module? - Code Samples	Moderately useful
3.3	How useful did you find the following components of the module? - Images and Videos	Not at all useful
3.3	Did the module provide enough background information? - Selected Choice	No (please elaborate)
3.3	Did the module provide enough background information? - No (please elaborate) - Text	We ran into motor issues, it wasn't clear if this was hardware or software related. Some debugging hints when it talks about the motors not behaving perfectly would be useful, maybe discuss hardware and hardware/software interaction in a general way to make this useful learning (perhaps this is covered elsewhere)
3.3	How clear were the objectives of the module?	Neither clear nor unclear

3.3	Were there any specific concepts in this module that you found particularly hard to teach? - Selected Choice	No
3.3	Did this module provide too little or too much content to be delivered in a single class session?	Far too little
3.3	What percentage of your students were: - Engaged with the lesson	60
3.3	What percentage of your students were: - Able to demonstrate understanding	60
3.3	What percentage of your students were: - Able to get the robot to perform as expected	
3.4	How familiar are your students already with the concept of dimensional analysis?	Moderately familiar
		Slightly familiar
3.4	Was our explanation of dimensional analysis clear enough to give your students the background they needed to solve for the time needed to drive a distance?	Yes
		Yes
3.4	How many questions did you receive from students about how writing functions in Python or Blockly?	A moderate amount
		A few

3.4	How do you think this module could this module be improved?	The major issues we had came to a head here: 1. the Python code generated from Blockly frequently didn't match the python code on the webpage. This may be a versioning issue; a common issue was that the module that used to be called "drivetrain" is being translated as "differential_drive" in the blockly conversion, this is what the github 1.21 XRPLib code calls it; I installed 1.20 from the IDE at home (our school managed devices can't mount drives). One student's IDE seemed to want to reinstall 1.20 at one point, but we couldn't and nothing happened. 2. The XRP would frequently disconnect from the IDE, multiple hard and soft reboots, un/plugging the USB, eventually fixed it, no obvious pattern but it happened frequently. 3. The motor commands generally didn't act as anticipated, this may have been related to the software issue, but there wasn't time to debug thoroughly.
3.4	How useful did you find the following components of the module? - Text	Very useful
3.4	How useful did you find the following components of the module? - Code Samples	Very useful
3.4	How useful did you find the following components of the module? - Images and Videos	Not at all useful
3.4	Did the module provide enough background information? - Selected Choice	Yes
3.4	How clear were the objectives of the module?	Somewhat clear
3.4	Were there any specific concepts in this module that you found particularly hard to teach? - Selected Choice	No

3.4	Did this module provide too little or too much content to be delivered in a single class session?	Slightly too little
3.4	What percentage of your students were: - Engaged with the lesson	80
3.4	What percentage of your students were: - Able to demonstrate understanding	60
3.4	What percentage of your students were: - Able to get the robot to perform as expected	20
3.5	Do you think that introducing the fundamentals of how an encoder works (disk, light source, etc.) is useful information for the students?	Definitely yes
3.5	This lesson assumes a fundamental geometry background to rotate the robot to a given direction. Did the module provide enough information for most of your students to be able to do this on their own?	Yes
3.5	How do you think this module could this module be improved?	The code at the very end of the module doesn't render correctly, we see: Python .. code-block:: python def turn(target): global rotations differentialDrive.reset_encoder_position() rotations = (target * 15.5) / (360 * 6) if target > 0: differentialDrive.set_effort((-0.3), 0.3) else: differentialDrive.set_effort(0.3, (-0.3)) while not math.fabs(motor1.get_position()) >= math.fabs(rotations): differentialDrive.stop() Some kind of unclosed tag or syntax error I'd guess.
3.5	How useful did you find the following components of the module? - Text	Very useful

3.5	How useful did you find the following components of the module? - Code Samples	Very useful
3.5	How useful did you find the following components of the module? - Images and Videos	Very useful
3.5	Did the module provide enough background information? - Selected Choice	Yes
3.5	How clear were the objectives of the module?	Somewhat clear
3.5	Were there any specific concepts in this module that you found particularly hard to teach? - Selected Choice	Yes (please specify)
3.5	Were there any specific concepts in this module that you found particularly hard to teach? - Yes (please specify) - Text	What the encoder is doing. These are freshmen/sophomore boys, they are not going to RTFM. This is not a problem with the unit itself. Possibly video content might help, probably we will have to live with it
3.5	Did this module provide too little or too much content to be delivered in a single class session?	Far too little
3.5	What percentage of your students were: - Engaged with the lesson	40
3.5	What percentage of your students were: - Able to demonstrate understanding	20
3.5	What percentage of your students were: - Able to get the robot to perform as expected	20
3.6	The functions introduced in this module make driving the robot much easier. Do you think it would be better to introduce these functions at the start of the course so that students can get the robot driving sooner?	No, students must understand the background theory before using the easy functions
3.6	How many of your students had questions about function parameters?	A moderate amount

3.6	How do you think this module could this module be improved?	The XRPLib versioning issue (or whatever the underlying problem was) with the Python functions was a big issue; at least in some cases the python code derived from Blockly in the IDE would work while the python code in the web page would not. There may have been other issues here: disconnection problems continued, and motor response was sometimes puzzling, I wasn't able to trace anything back to a definitive cause or causes.
3.6	How useful did you find the following components of the module? - Text	Moderately useful
3.6	How useful did you find the following components of the module? - Code Samples	How useful did you find the following components of the module? - Code Samples
3.6	How useful did you find the following components of the module? - Images and Videos	Not at all useful
3.6	Did the module provide enough background information? - Selected Choice	Yes
3.6	How clear were the objectives of the module?	Somewhat clear
3.6	Were there any specific concepts in this module that you found particularly hard to teach? - Selected Choice	No
3.6	Did this module provide too little or too much content to be delivered in a single class session?	Far too little
3.6	What percentage of your students were: - Engaged with the lesson	20
3.6	What percentage of your students were: - Able to demonstrate understanding	20

3.6	What percentage of your students were: - Able to get the robot to perform as expected	20
4.2	How clear was the analogy of a bat's sonar to the ultrasonic rangefinder on the XRP to your students?	Somewhat clear
4.2	Was this module enough content for a single class, or should there be more activities in this module?	Enough content
8	How clear did you find the specifications of the project?	Somewhat clear
8	Do you think students will be able to complete this project in a reasonable amount of time?	Might or might not
8	How clear did you find the scoring system to be for this project?	Somewhat clear
8	How do you think this module could this module be improved?	Would like to see a cool robust game with remote control!
8	How useful did you find the following components of the module? - Text	Moderately useful
8	How useful did you find the following components of the module? - Code Samples	Moderately useful
8	How useful did you find the following components of the module? - Images and Videos	Moderately useful
8	Did the module provide enough background information? - Selected Choice	Yes
8	How clear were the objectives of the module?	Somewhat clear
8	Were there any specific concepts in this module that you found particularly hard to teach? - Selected Choice	No

8	Did this module provide too little or too much content to be delivered in a single class session?	Slightly too much
8	What percentage of your students were: - Engaged with the lesson	60
8	What percentage of your students were: - Able to demonstrate understanding	40
8	What percentage of your students were: - Able to get the robot to perform as expected	80

APPENDIX C: TEACHER INTERVIEW TRANSCRIPT

How did the setup go? And it sounds like that went pretty well. Were there any specific issues you were having with the hardware during the setup of the kits with any of the groups?

No, they didn't have any issues. The only thing that they were concerned about was they were afraid to snap. the plastic while they were putting it together. So as they put the board into the chassis, they were like, I know it's gonna snap into place and everything's gonna be fine, but up until that happens, I'm really worried I'm gonna break it. But that was it. It wasn't a logical worry, but they were just cautious and that they had a great time. And then they help each other. It was a good collaborative project for them to work on. Cool. They especially loved the sticker pack that came in it. So.

Well, I'm glad to hear that.

So I guess like so for you were doing this as part of an FRC sort of team like training exercise at most so it may be that this question is not as Might not make as much sense as it would to like you doing in the class but like how well I guess were you able to integrate these modules into your Sort of training for the team

Yeah, so it we didn't get too far into it because of our meeting time just happened that we got hung up with the holidays but The classes were like our FRC meetings were meant to get the kids accustomed to the meeting schedule and then each other before we actually had the kickoff. And so this was a great activity for them to kind of have like a, a dry run of FRC. They knew what they were going to be working on a little bit. It, as far as problem solving and collaborating. And I think for them, they felt. better about what they're going to be doing later on because they felt more like they could wrap their head around what the bigger FRC stuff would be. So this was really helpful to them. They're actually some really good conversations. Kids who'd been in the FRC for a couple of years were going through the modules and they were, I think I was, I'd mentioned over email, they were discussing the types of turning and there were a lot of interesting ideas and debates and kids had come up with extensions on their own about trying different things. But it was, it was a lot of fun. for them to preview some higher level material through something that was totally accessible. Yeah. Okay.

And so like, I think like when Mia reached out to you first, she mentioned that there was basically, there were the two modules we were really interested in, which were the driving and the one after that, which I think sounds like you got through what we needed there.

So for the, based on like the ones you did, was there one that was like particularly effective? With them, I guess, like, does maybe the driving one is the answer to that. But like, was there one that you found to be particularly like resonating with them?

I think the driving one was a lot of fun. The driving. But then they were, they were discussing too about the driving velocity and how that could help it turn smoothly. Uh, and the students who had been in FRC were referencing past challenges and how at certain points their robot would get hung up or it would be. too aggressive in its motion. And so they were talking about how what they had learned in the modules would have been useful for them to know at that time because they were like, we didn't really think about changing, the velocity of the motor so that they would turn smoother or they would turn with like a gradual kind of a sweep. They were like, everything was kind of sudden and jerky and this is really cool how it works. But then they talked about the merits, like the pros and cons of each style of turning. Um, yeah, I think for them, they, they really know deep on how, because there were some students who were like, well, that style is just not, you know, it's not useful when we can use it. And someone would say, well, you could. And then they would bring up an older scenario. And I think for them, that was a, that was a good one. They, they found use in everything in there. Um, and they really found different ways to reapply it and move around. It was, I enjoyed listening to them. Cool. Was there one that was like the most challenging for them to do? I don't know if there was anything that was too challenging. I think all of it was a pretty good steady pace. They didn't really seem to get hung up in any one particular thing, but they had a lot of fun doing it. So I think no matter where the struggles were, they always found some solution and then felt a lot of accomplishment. So I didn't really see them see them get hung up on any one particular point though.

Okay. Cool, so yeah, so it sounds like overall it integrated pretty well with what you were trying to get out of it then.

Oh, it's awesome. The students who are new and the students who are familiar with that kind of material, they all got something out of it, which is as a teacher, when I bring something to my students, you're gonna have the high achieving and the lower achieving students and finding something that meets all their needs is rare. And that was really cool.

Yeah. Okay.

So I guess like, I'm going to go a little off my script here, but let's say you were to be using this in a, in an actual like day class type of scenario, right? Like what do you think this fits best into? As like, what type of class would this be a good fit for?

So next semester I have an intro to robotics class, and meeting kids around the school. I have a couple of kids who have no experience. computer science or robotics or engineering or anything technical, but they wanted to take the class because they were curious about it. And I think this would be a great way for them to experience that. My plan is to use some, and we have so many resources to draw from. I did use, I signed up to use a CoderZ curriculum just to start because it's block based and it kind of gives them some virtual environments to mess around with and see it. It's what I hope a lot of different like. to get some exposure to a lot of different scenarios. But my hope is that as soon as they're really rocketed and rolling into that, to move over to the XRP kits and have them reapply that into the physical world. And I'm hoping that students who are kind of on the fence, a little curious about what robotics are like, with a deeper understanding that they'll have that stage set so if they wanna come back and do FRC, they've covered a lot of material, but they're also. they're seeded for that bigger show. So that's where I'm going to go with it. My plan is partway through this next semester that my kids in that class will be using the kids.

Yeah. So based on that, this is something we worked on internally, but it's not published with the actual documentation. But we did work a little bit on standards alignment with identifying, what was it, N something, NGST standards or something.

Oh, next generation science, yeah. In GSS.

Yeah, so like Nikhil was the one who did most of this work, but like how important as a teacher to you if you were integrating this into a class, like how important is it to you that there are a list of standards that the modules are aligned with?

So I would say as a teacher, it is important because everything that we do is more relevant if we can show what we're. we're teaching and sometimes your administrators, they can come in and say, wow, this looks great. But their administrators, the people who would manage our MCAT scores are looking at the standards and for them to see how what we're teaching connects to what they're responsible for, having those linked to the standards is incredibly important. So the bigger answer to your question is, I try not to teach to a test, but the reality is we all have to.

Okay. Yeah, that's kind of what our advisors told us too, is like, And we weren't really sure if that mattered or not, but it sounded like that, like for higher up reasons, that's important. So that's something that like probably the people after us will work on sort of tying in more.

It definitely justifies the material by showing what it does. And I would say like the NGSS standards, and then if you had like the computer science standards, like the DLCS standards for Massachusetts, those would be great to tie into. A lot of times curriculum like this would- You can tie it into both of those but I would say in my personal opinion as teachers for the better Because if people don't need it, they won't reference it. But if they do it's Like life or death it justifies a lot of classes to exist if you can say hey We're complementing these standards that are taught on, you know, or that are tested on then caps

Okay, makes sense

Okay, so I have a section here on student engagement. I think you've already answered my first question, which is just how did your students respond? So we can go past that. So you mentioned in your emails that these were sort of newer students that you were starting this out with. Did you notice an engage... So, okay, on FRC teams for me in the past, we've had a lot of issues with engaging software students, and it's kind of boring for them or whatever, they kind of lose them halfway through. Was this able to sort of make a positive impact in their engagement in a pretty noticeable way?

I would say so. The kids that were waiting for the FRC kickoff and they were like, you know, looking at the robot, but it was, had no batteries and it wasn't moving. This was an instant, tangible, concrete way for them to make sense of what they were going to be doing and also what was possible. So it was a great appetizer. for like that much deeper learning materials. So for them, it was a great hook to show them that this is a small scale version of everything that's possible. So definitely helps. I mean, kids, and it's hard too, because I think that now, especially post COVID, I've noticed that students need something to catch their interest. They'll lose interest very quickly. And this is just, it fit the bill for them. gratifying, it was interesting. Yeah, I would say that it was probably the best thing that I've offered in a long time for the kids that really kept interest.

Well, glad to hear that.

So the, I guess like, would you say that most of the students you had coming into this had essentially no programming background?

Most don't. I would say half of them do, and it would be, I'd say a quarter of them had higher level. They've. taken classes at school, they've been on the FRC team. A quarter of them have taken an intro class with JavaScript. And then I'd say the other half of the students are just, they're fresh, they haven't taken anything, they just were interested in the club. Okay.

Uhhh... Let's see here. So I'm going to skip past most of my, I have three questions here about usability. But again, I think you've given us a lot of detail about that. So the big one I want to get answered is are there any changes that you would like to see in the way we structure the modules?

I like the modules a lot. I've come from a world of using projects either way for a long time. And the way that the modules are set up are really organized and they make me think of projects either way. The only thing I would wonder about, it's probably difficult, is like a way for students to answer or like to interact with the online part, which I don't think would be possible, but it would be neat for them to have like a companion notebook or like something that kind of summarizes the units for them. I mean, a teacher could do that too, but I almost feel like at the end of the module, the units would be neat to have the kids like, okay, now in your own words, describe a war, you know. try this sample or something like that. Just as like, you know, I usually go for formative assessments and when students are working and kind of checking to see what they are like myself, I mean, informal assessments is what I meant to say, but so something like that, I don't know. I mean, not how difficult that is, but sometimes I feel like it gives kids some ownership over that and lets them know that they're responding and interacting with it so that they can answer some questions. But that's just my wishlist idea.

I mean, that's kind of something we had talked about at the beginning of this. I mean, that was out of scope for our project, but like long-term, I think Read the Docs is not the right platform for this type of curriculum, and we need to sort of do something more interactive.

But I guess project lead the way is like, they have tons of money for stuff like that, and people pay tons of money to use it, so there's a reciprocal part there that just kind of funds itself, but yeah.

I guess sort of following up. off of that. Oh, I had something I had forgotten. It just escaped me. Oh, okay. Yeah. So as it's built right now, the target audience of it is kind of a hybrid between students and teachers, right? We only have this one sort of thing that like is designed so that either group can look at it. How useful to you would it be if instead of that we had sort of a separate, like teacher version that had worked examples? like that we have tested and we know like if you just put this on here it will work and then a student version that is not that.

I think it would be for me I always find that really useful the teacher versions. I think in the tech realm like this there can probably be lots of solutions to a problem but having a baseline recommendation of what could be possible helps me as the teacher kind of work off of that and show it to the students. I'm usually okay, but I've been doing this for a while and I feel comfortable not knowing and working to find the answer. But I've worked with a lot of teachers who were interested to teach something like this and I feel like just like students, they'll kind of shy away from it as soon as it gets a little unknown and a little risky. So I feel like for the success of the program, giving teachers access to material like that would make teachers feel more successful and keep them using it.

Yeah, I mean, that's another thing we talked about. The challenge for us is this whole thing is open source. So we don't have a way to hide that from anybody, right? So I don't like that. Yeah. So we're not teachers, right? I mean, we have been high school students. We know how easy it is to look things up, right? But I guess how big of a factor, if that existed for you, is it that would be something public? For the way you're delivering this, is it? Are they engaged enough to where they're not gonna try and go searching for that? And that's not something we should worry about or do we need to sort of brainstorm a better solution?

Yeah, you're totally right about students looking it up. I would say if the class was set up as a higher stakes class, the likelihood of them going to look forward also increases. But I feel like for an elective, they probably would. It's so tricky. I feel this also opens up for me, like the whole idea of like reads and what grades are to students. And I feel like the motivating factor for them would be I need to get a high grade if you won't look up the internet for it. So, um, but for me personally, I mean, I wouldn't, I would, I would look to make assessments that they couldn't find any answers to if it was out there. Um, I would just, you know, make my own version. So I mean, If they went out and they found the solution to Flashword, that's great and maybe that helps them because in the back of a textbook, you would find the answers to like, you know, the odd or the even numbered math problems and that's not a secret. So I don't know, it's kind of a toss up. I feel like. it's better not to share with students, but in reality I wonder if they actually access it. Yeah. I don't know. My thought too is, and I don't know if this is possible, I've used other curriculums. They're not a professor there anymore, but I don't know, do you take intro to computer science at WPI at all, maybe?

I think, we probably both tested out of it.

Oh, okay. But there's a curriculum that's bootstrapped. and they teach on the WeSkeme environment or the pirate environment. There was a professor there at WPI who was using it. However, their website had teacher solutions. They're also open source out of round, but they just had one page in the website that was password protected. And that solved the problem. It did not allow my students access to it. So I don't know if there's a quick fix like that for you.

Yeah, that's something that someone else is like. like Brad will need to think about that. But I guess like we had this Canvas page as well that was supposed to be like the teachers and yeah, that wasn't updated correctly. It was a whole mess. But yeah, like that's something we had talked about. It's good to hear like a teacher perspective on that because we truly had no idea like what people wanted in that respect.

Yeah, and I feel like if Exquisite answers to solutions are out on the internet, they're gonna find it. And even if they're not, kids are gonna find it. They're gonna find some way to do it. Yeah, and I would say that it's an it's an important thought but also realistically it's like trying to hold water in a basket

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Okay Let's see here. I'm realizing as we're doing this that my sort of planned questions were kind of repetitive. So I guess which. Okay, here's one. Here's what I can go off of. So we talked a little bit before about using this in a traditional class. So as a, you know, you have a technical background, right? So like for you, it's pretty easy to see how this stuff works for like, let's say like a high school physics teacher that does not have a lot of software experience. As it stands right now, do you think we're giving enough background information to suit their needs?

I think so. I like that in a lot of the modules, in the examples, there's a sample code and it even acknowledged you can copy and paste this and try it that way. And I think that kind of bridges the gap of who would have trouble understanding it because once they see it work, I think they can reasonably go from there. So I would vote for the physics teacher as somebody who's like, you know, I'm going to try this. But I don't have a ton of background. They can use what's there to build their knowledge. And I mean, too, high school students can be working through this and be expected to learn from it. My hope is that a reasonable teacher could do the same thing. But I like the way that it was set up. I found it to be really thoughtful and professional. The freshmen can learn the best. So I think so.

OK. Yeah,

I guess. The last. One else sort of ask. Is like what if in its current state today what recommendations would you give to other teachers that wanted to use this?

Oh, I would tell them to totally contact you, contact me, and do anything you can to get a kid, because it's awesome. I mean, really, for teachers who would be on the fence and not so sure about it, it gives kids like a reasonable entry point, but it opens up so many opportunities to them afterwards. Like, as I'm going through this, I would love to have kids finish the module and then. ask them afterwards, you know, like do a pre and post test and find out their knowledge of what they've picked up. But my expectation is that when they finish this class, they're going to be excited for the future and feel accomplished for where they've already gotten to. But I think that the tricky part is giving it to kids at a reasonably spot where they're going to stay invested and don't want to quit. I think this is a great curriculum. great book, like it has a great setup, link kids, something interesting, something fun, something rigorous, but it doesn't baby them, and it doesn't push them to the edge. It's a great sweet spot for anybody who's curious to try robotics.

Okay, cool. Yeah, I think that's pretty much all I've got. So yeah, I mean, I assume you did fill out the survey, I think, I don't have any way of knowing if you did or not, because it's anonymous, but assuming you did. I think I did. Okay, cool. Yeah, so like we've already started pulling that data, so like we've got some information there, but I think this was really helpful. Yeah. To like fill in with this.

APPENDIX D: MODULE-SPECIFIC STANDARDS

Module 2:

3A-AP-16 Design and iteratively develop computational artifacts for practical intent, personal expression, or to address a societal issue by using events to initiate instructions.

3A-AP-17 Decompose problems into smaller components through systematic analysis, using constructs such as procedures, modules, and/or objects.

3B-AP-15 Analyze a ~~large-scale~~ computational problem and identify generalizable patterns that can be applied to a solution.

3B-AP-16 Demonstrate code reuse by creating programming solutions using libraries and APIs.

Module 3:

HS-ETS1-2. Break a complex real-world problem into smaller, more manageable problems that each can be solved using scientific and engineering principles.

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability~~, aesthetics, and maintenance, as well as social, cultural, and environmental impacts.~~

3A-AP-16 Design and iteratively develop computational artifacts for practical intent, personal expression, or to address a societal issue by using events to initiate instructions.

3A-AP-17 Decompose problems into smaller components through systematic analysis, using constructs such as procedures, modules, and/or objects.

3B-CS-02 Illustrate ways computing systems implement logic, input, and output through hardware components.

3B-AP-15 Analyze a large-scale computational problem and identify generalizable patterns that can be applied to a solution.

3B-AP-16 Demonstrate code reuse by creating programming solutions using libraries and APIs.

Module 4:

HS-ETS1-2. Break a complex real-world problem into smaller, more manageable problems that each can be solved using scientific and engineering principles.

3A-AP-15 Justify the selection of specific control structures when tradeoffs involve implementation, readability, and program performance, and explain the benefits and drawbacks of choices made.

3A-AP-16 Design and iteratively develop computational artifacts for practical intent, personal expression, or to address a societal issue by using events to initiate instructions.

3A-AP-17 Decompose problems into smaller components through systematic analysis, using constructs such as procedures, modules, and/or objects.

3B-AP-10 Use and adapt classic algorithms to solve computational problems.

3B-AP-11 Evaluate algorithms in terms of their efficiency, correctness, and clarity.

3B-AP-15 Analyze a large-scale computational problem and identify generalizable patterns that can be applied to a solution.

3B-AP-16 Demonstrate code reuse by creating programming solutions using libraries and APIs.

Module 5:

HS-ETS1-2. Break a complex real-world problem into smaller, more manageable problems that each can be solved using scientific and engineering principles.

3A-AP-15 Justify the selection of specific control structures when tradeoffs involve implementation, readability, and program performance, and explain the benefits and drawbacks of choices made.

3A-AP-16 Design and iteratively develop computational artifacts for practical intent, personal expression, or to address a societal issue by using events to initiate instructions.

3A-AP-17 Decompose problems into smaller components through systematic analysis, using constructs such as procedures, modules, and/or objects.

3B-CS-02 Illustrate ways computing systems implement logic, input, and output through hardware components.

3B-AP-10 Use and adapt classic algorithms to solve computational problems.

3B-AP-11 Evaluate algorithms in terms of their efficiency, correctness, and clarity.

3B-AP-15 Analyze a large-scale computational problem and identify generalizable patterns that can be applied to a solution.

3B-AP-16 Demonstrate code reuse by creating programming solutions using libraries and APIs.

Module 6:

HS-ETS1-2. Break a complex real-world problem into smaller, more manageable problems that each can be solved using scientific and engineering principles.

3A-AP-16 Design and iteratively develop computational artifacts for practical intent, personal expression, or to address a societal issue by using events to initiate instructions.

3A-AP-17 Decompose problems into smaller components through systematic analysis, using constructs such as procedures, modules, and/or objects.

3B-CS-02 Illustrate ways computing systems implement logic, input, and output through hardware components.

3B-AP-10 Use and adapt classic algorithms to solve computational problems.

3B-AP-11 Evaluate algorithms in terms of their efficiency, correctness, and clarity.

3B-AP-15 Analyze a large-scale computational problem and identify generalizable patterns that can be applied to a solution.

3B-AP-16 Demonstrate code reuse by creating programming solutions using libraries and APIs.

Module 7:

HS-ETS1-2. Break a complex real-world problem into smaller, more manageable problems that each can be solved using scientific and engineering principles.

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, aesthetics, and maintenance, as well as social, cultural, and environmental impacts.

3A-AP-16 Design and iteratively develop computational artifacts for practical intent, personal expression, or to address a societal issue by using events to initiate instructions.

3A-AP-17 Decompose problems into smaller components through systematic analysis, using constructs such as procedures, modules, and/or objects.

3B-CS-02 Illustrate ways computing systems implement logic, input, and output through hardware components.

3B-AP-10 Use and adapt classic algorithms to solve computational problems.

3B-AP-11 Evaluate algorithms in terms of their efficiency, correctness, and clarity.

3B-AP-15 Analyze a large-scale computational problem and identify generalizable patterns that can be applied to a solution.

3B-AP-16 Demonstrate code reuse by creating programming solutions using libraries and APIs.