VEX Robotics Competition STEM Summer Camp for High School Students: An Engineering Approach

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Abstract– **Although the VEX Robotics Competition provides a very challenging STEAM engineering challenge for students all over the world. However, many teams lack the knowledge, experience, or resources necessary to compete efficiently and effectively. In many cases, the instructor placed in charge of the teams does not have a background in engineering or have the knowledge necessary to teach students the information needed. Consequently, students in these teams are faced with even greater difficulty as they would need to allocate most of the limited time to learn what is necessary to compete. This creates a major problem as many teams start at the beginning of the school year where tournaments are only two months away, giving them very limited time to prepare. As a result of this, many students perceive the engineering and STEAM-related fields of VEX Robotics Competition as too difficult and challenging.**

This project assesses the development of a STEM summer camp structure for high school students using an integrated engineering approach. In following an engineering approach, the program is developed to focus only on Robotics (Mechatronic) Engineering introductory core course topics. By doing so, this program was developed around introducing high school students to robotics engineering with a primary common goal of competing in the VEX Robotics Competition. The VEX Robotics International Competition, presented by the Robotics Engineering and Competition (REC) Foundation, works to provide pre-college students with an engineering challenge in STEM Education. The goal of this competition is to promote STEM to students and learning communities internationally and aid in the development of skills such as teamwork, communication, leadership, and presentation.

The paper is designed to focus on the Content, Assessment, and Pedagogy of the summer camp program through an integrated engineering education design approach. The concept portion of the paper discusses the target domain, target content, and a pre-defined structure of course outcomes. The section also focuses on analyzing the salient characteristics of intended learners and the intersection of knowledge-centered and learner-centered pedagogical approaches. The Assessment section of the project focuses on the methods of assessment used in the summer camp following the Anderson and Krathwohl Taxonomy approach as well as the Authentic Assessment Criteria by Edmund Hansen. Finally, the pedagogy section of the paper focuses on the course syllabus and individual lesson plan development. The development of the pedagogical methods will be done with the structure of teaching and learning in the book, "Making Learning Whole," by David Perkins.

Keywords—VEX Robotics, Engineering Education, Content, Assessment, Pedagogy, Mechatronic, Robotics

I. INTRODUCTION

The VEX Robotics Competition summer camp is an eight-week STEM program focused on preparing high school students for the Overclock Robotics team. The Overclock Robotics Team is based in Flushing, New York at KG Computech Inc, an afterschool organization specializing in the development of computer skill sets uniquely designed for teenagers. This includes tools for immediate career and higher educational advancements in industries such as engineering, computer science, and graphic design. At the start, the organization provided training programs for middle and high school students in certification programs including CompTIA A+, Network+, and Security+.

In 2017, the organization changed direction focusing on STEAM education and providing students with the knowledge and tools necessary to succeed in engineering and other STEAM-related fields. To achieve this, the VEX Robotics Competition team, 16099 Overclock, was established in the summer of 2017 to achieve this new mission and goal. The name "Overclock" was chosen given the background of KG Computech Inc. which originally focused on the development of computer skill sets uniquely designed for teenagers. At the start, the mission of the Overclock team was to create an afterschool program providing students with the opportunity to engage in STEM education as well as cultivate their passions in engineering. The Overclock robotics team in total consists of three high school teams (16099 Overclock) and two middle school teams (16699 Overclock M.S.).

In total the course will cover 15 topics providing students with the relevant pre-requisite knowledge to successfully compete in the competition. These topics will be covered over a duration of eight weeks between July and August. The reason for this is that the class is designed for the students to meet three days a week for 3-hour sessions. During the second week, students are introduced to veteran team members of Overclock and enrolled in the mentorship portion of the summer program. Students are assigned to a current team and will work with the team members who are preparing for the upcoming competition season in brainstorming, Computer-

Aided Design (CAD) modeling, building, and programming. The mentorship initiative is a very important section of the summer program as it provides students with hands-on experience in the design process of Overclock teams, teamwork skills, and overall reinforces topics covered in class. Furthermore, the purpose of the mentorship is to create a team bond between the veteran members and new members as well as allow instructors to evaluate the teamwork, communication, and leadership skills of students enrolled in the summer program.

The curriculum project will be the prerequisite summer program that is required for all students who are interested in competing on the team. The program is designed specifically for high school students who have minimal experience in STEM and engineering. It is implemented in after-school institutions but can be adapted to work in a school setting. It can be implemented by any educators who wish to create a robotics program or course for their high school.

1.1.2. Important contextual issues and external constraints

An important contextual constraint that must be considered is the total number of topics and information that would need to be taught and practiced in the eight-week program. In this given time, students will meet with each other five days a week and with an instructor three days a week, for three hours each day. Given that these students are high school students, they would need to be introduced to mechanical, electrical, and computer engineering concepts and principles. Furthermore, students would also need to learn technical writing, presentation, and interview skills that come with the competition.

Another constraint that is important in this project is the constraint of time. Students are given lecture courses three days a week during this program for three-hour sessions. The students are then provided with a three-hour laboratory session to apply these concepts and principles learned in class on actual robot projects that provide them with experiential learning to make the curriculum effective. A third constraint of the curriculum is the incorporation of the students into the competition team environment. To develop teamwork within the students, the new students will need to be given opportunities to work with members who have had experience in VEX Robotics Competition and continuing for the upcoming season.

Furthermore, the curriculum should be based on the engineering challenge that is provided by the competition. This is very similar to the common engineering challenge in which the engineer must fulfill the needs and requirements provided by a client or company in the development of a product or service. They should be able to define the constraints of the challenge and develop solutions that can efficiently and effectively solve the problem. The last constraint in this project would be the introduction of advanced engineering course concepts such as basic control systems, mathematics, engineering mechanics, electronic circuits, and physics to high school students. To create a successful team, students must be able to apply engineering principles to robot design and programming in an effective manner.

1.2 Motivation for the Project

Although the VEX Robotics Competition provides a very challenging STEAM engineering challenge for students all over the world. However, many teams lack the knowledge, experience, or resources necessary to compete efficiently and effectively. In many cases, the instructor placed in charge of the teams do not have a background in engineering or have the knowledge necessary to teach students the information needed. Consequently, students in these teams are faced with even greater difficulty as they would need to allocate most of the limited time to learning what is necessary to compete. This create a major problem as many teams start at the beginning of the school year where tournaments are only two months away, giving them very limited time to prepare. As a result of this, many students perceive engineering and STEAM related fields of VEX Robotics Competition as too difficult and challenging.

1.2.1. Personal Expertise in the Target Domain

My personal experience as a VEX Robotics Competition University division and Unmanned Aerial Vehicle (UAV) competition participant provides me with knowledge and a strong background in engineering competitions. In my undergraduate studies in Mechatronic Engineering, I was exposed to mechanical, electrical, computer, and control engineering courses that were the key components in Robotics Engineering. During my undergraduate studies, I was a member of the Vaughn College of Aeronautics and Technology robotics team. During my sophomore year, I continued to become a co-founder of the Vaughn College UAV team who competed in competitions such as the Vertical Flight Society Micro Air Vehicle Competition.

After graduating, I was given a job as a adjunct laboratory instructor teaching Mechatronic Engineering courses such as Introduction to robotics and Mechatronics II. In addition, I was assigned as a faculty advisor for both the robotics and drone teams at Vaughn College. In 2018, I was also hired as the head coach of the Overclock Robotics team at KG Computech Inc. As a result of my experience, I have developed a strong sense in teaching engineering courses and STEM courses in a competition style environment.

2. CONTENT

2.1. Project Domain

2.1.1. Big Ideas of the Target Domain

In this curriculum students will be learning about the VEX Robotics Competition, how a competition team works, and the STEAM and engineering concepts and principles necessary to develop a robot for the competition. The curriculum will integrate the engineering, math, and physics concepts that are necessary to complete the engineering and STEM challenge provided by the VEX Robotics Competition. A big idea is for the students to be able to learn and implement engineering through the competition. Another major idea for the project is for the students to learn the key concepts of teamwork and develop ethical practices for working in a team-oriented environment. A third big idea for the project is to introduce advanced and normally difficult engineering concepts and principles to high school level students with no prior experience and knowledge in pre-requisite courses needed to understand them.

2.1.2. Guiding Concepts of the Target Domain

The guiding concepts that are used in the development of the curriculum are robotics engineering design, teamwork skills, project management, and the engineering design process. Students will be learning about the different topics, concepts, and principles that govern robotics engineering in a competition setting. Furthermore, as a team competition, students will be learning how to function as a member of a professional team and the work and communication ethics that are needed. Given the limited time and pace of the competition season, students will also need to understand and utilize project management. Finally, the engineering design process of define, learn, plan, and test would be emphasized so that students are able to effectively and efficiently develop competition robots that can succeed in the VEX Robotics Competition.

2.1.3. Essential Questions for your Target Content

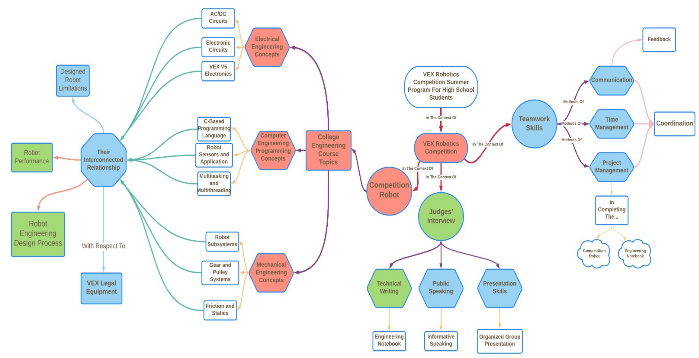
Given the scope of the project, there are several essential questions that are critical to its success. Once question that is essential is how to implement the engineering design process into the design of the robot in a fast-paced competition schedule. Another essential question would be what the best method is to approach the engineering challenge provided by VEX Robotics. A third essential question is how to apply the concepts and theories of different engineering major topics to the design and build of the competition robot. The last essential question would be how to create the most effect team using project management to ensure that deadlines are met for the competition season.

2.2. Course Outcomes

2.2.1 Enduring Outcomes

The enduring outcomes of the summer program reflect the critical core requirements needed for a student to effectively meet the challenges and requirements of the VEX Robotics Competition. In the enduring outcomes, the goal is to fulfill the many positions that will be required for a team to compete at a tournament effectively and efficiently with a high rate of success in placing in the top ranks. These enduring outcomes are as follows:

1. How to design and build a robot that can best meet the requirements of the competition challenge.
2. How to develop program codes and autonomous paths that can achieve high scores in the demanding and intensive season schedule.
3. Effective methods in creating a technical engineering



notebook that is presented in a manner that can be understood by anyone new to VEX Robotics Competition.
4. Development of a strong understanding in concepts and theories in the mechanical, programming, and electrical systems of the robot.
   a. In electrical systems, students will be able to understand and explain concepts in AC/DC circuits and electronic systems.
   b. In mechanical systems, the student will be able to understand and explain concepts in robot subsystems, gear and pulley systems, friction, and engineering mechanics (statics).
   c. In computer engineering, students will be able to understand and implement c based programming language skills, understand robot sensors and their implementation, and multitasking/multithreading.
5. How to effectively explain the engineering design process in a method that can be understood by anyone without prior experience.
6. How to function and be a productive member of a professional design team.

2.2.2 Important to Know Outcomes

In the summer program, there are also several outcomes that are considered important to know. The outcomes listed below are considered good to know as these are outcomes that will be

1. How to use the engineering design process in designing, building, and programming a competition grade robot.

2. Develop an understanding of how different robot subsystems impact the overall performance of the robot.
3. How to develop an engineering notebook that documents the design process and team's path to success.
4. What are the important components and skills necessary for a successful judges' interview?

2.2.3 Good-to-be-familiar-with Outcomes

1. What are good presentation and interview skills for the judging portion of the competition.
2. Become familiar with VEX Robotics products that are available and legal for use in the design process of the robot.
3. Develop a basic understanding of the concepts, principles, and limitations of other robot systems.
4. What are core teamwork skills that are necessary in a team environment and what is their importance.

Figure 1. Concept Map of Curriculum Outcomes and Relationships

2.4.1 Concept Map Explanation

The concept above shows the relationships among the guiding concepts that are listed in the previous section. The map starts by illustrating that the summer program has been designed in the context of the requirements and major sections of the VEX Robotics Competition and the necessary components to compete at a VEX tournament. As seen in Figure 1, the three main components that are required in a VEX Robotics Competition is a competition robot, teamwork skills, and the requirements to participate in the judges' interview. It is important to note that each of these three core sections are heavily dependent on one another.

The concept map highlights in red the components that are reflective of the enduring outcomes of the course. The section is divided into three core sections that illustrate robotics engineering. As robotics engineering has also been termed as Mechatronic Engineering, the course follows the three core engineering disciplines of this engineering major. As a result, the concept map highlights electrical, mechanical, and computer engineering. In understanding all three disciplines, students will be able to combine the knowledge to design a competition robot.

The green highlighted shapes represent concepts and learning outcomes that are important to know. This includes methods of utilizing the engineering design process in designing, building, and programming a competition grade robot based on the individual topics covered in the section of the college engineering course topics. In essence, this learning outcome is dependent on the knowledge that is gained through understanding the enduring outcome of the different topics in Mechatronic Engineering. Furthermore, we see from the concept map that there is a relationship between the engineering concepts and the understanding of how the different subsystems of the robot impact its overall performance. As judging is a key component of the VEX Robotics concept, it is important to know how to develop an engineering notebook that meets the rubric of the VEX Robotics Competition. Similarly, it is also important to know how to complete a successful judges' interview. This is important as it also reinforces the students' understanding of all topics that the engineering notebook development is dependent on. Finally, the good to know outcomes of the concept map are highlighted in blue. This includes the core teamwork skills that are necessary for an effective team. Furthermore, it also highlights the outcome of understanding vex legal components and presentation skills for a successful judges' interview.

In the concept map, the dark red lines represent the center purpose and basis of the summer program curriculum. The purple lines represent the different key topics of the overall three main parts of a successful VEX Robotics Competition team. The yellow lines represent the subtopics that are important to each of the key topics that are important to the overall course goal. Finally, the green lines represent items that are interdependent for the success of different outcomes of the course.

2.4. Salient Characteristics of the Intended Learners

2.4.1. Prior Knowledge of the Target Domain

The prior knowledge domain of the learners in this project curriculum and high school students who have minimal to zero knowledge in STEAM education topics and VEX Robotics Competition. The learners range from students who are entering their freshman year of high school to senior level students understand high school physics and mathematics courses such as geometry and trigonometry. Furthermore, most students in the curriculum may not be familiar with working in a team environment and project management. A final issue would be that students may potentially have not been introduced to the engineering design process prior.

2.4.2. Age and Developmental Level

The students in this program would be high school students between the ages of 13 and 18 years of age. The students should have taken algebra and middle school level mathematics. In the project, there are no emotional, neurological, or physical challenges.

2.4.3. Emotional Factors

There are not emotional factors that may affect learning for this curriculum project. The program curriculum is defined in that students who experience no major difficulties would be able to learn as expected.

2.4.4. Other Consideration Factors

Since the program covers students who are entering their freshman year of high school to seniors who have completed most high school level courses, there is a large gap in knowledge difference. There will be differences in the performance of students for different topics depending on the difficulty of that topic. Other factors of consideration is how knowledgeable students are in using a computer and working with electronics. From past experiences, there has been students who are very skilled in operating a computer and those who are unable to use basic software. The curriculum should consider this factor in providing detailed information when introducing new software programs such as Computer Aided Design (CAD) design software and programming environments.

2.4. Intersection for Knowledge-Centered and Learner-Centered

2.4.1. Difficult Concepts and Misconceptions

Given the scope of the VEX Robotics Competition and the topics that will be covered in the summer program, students may have several difficult concepts. A difficult concept that I have identified in the target domain is the difficulty of learning to program in general. Programming has been argued to be a difficult skill to master and commonly viewed as something complex. (Jenkins, 2002) Another difficult concept that that has been identified for the target domain of this program is that of control systems. Control systems and PID Theory are considered difficult topics due to the requirement for an understanding in advanced mathematic courses such as calculus and differential equations. The last difficult concept that has been identified for the curriculum is the engineering design process. Many students may find the engineering process difficult to follow and implement due to the specific requirements and integration of various components.

2.4.2. Difficult Concepts Explained and the Theory of Difficulty

In many studies, it has been observed that some issues in relation to difficulty in learning program stem from the fact that programming is a structure of skills that form a hierarchy. However, research has shown that this difficulty can be resolved by choosing a language that is pedagogically suitable for the target group. Furthermore, programming courses should be designed to be flexible allowing students to learn in different ways. The author continues to state that the two main factors of difficulty in programming may be learning style and motivation. Each student requires a particular style of motivation and learning. As a result, most students are unable to comprehend and master programming through one common teaching method (Jenkins, 2002). As a result, many perceive programming as a difficult task to master and generally tend to avoid the topic.

The engineering design process may be perceived as difficult for many students to follow due to the complexity and various variables that would need to be considered. In many cases, student difficulty may be the result of the complexity of the techniques and theories behind engineering concepts. Another reason the engineering design process can be identified as a difficult concept to comprehend is the result of general difficulty for novice engineers to translate systems into mathematical models as well as generate relationships between components or aspects that belong in different domains of analysis (Ermer,G. E. & College, C., 2012). This difficulty can be overcome with the incorporation of engineering constraints and requirements that should be created during the initial phases of the design process.

2.4.2. Evidence-Based Rationale for Curricular Design Decisions

There are several evidence-based rationales for the curricular design decisions that I had made in the development of this summer program. After thorough search, there were little literature and prior courses that were very similar to the curriculum design in this project. However, one program that shared some similarity was a STEM summer robotics camp that introduced robotics to elementary and middle school students. The course followed a similar design in which students would be introduced to science and engineering disciplines through a competition designed approach to provide the real world applications of the coursework. (Stansbury, R.S. et. al, 2012).

However, the main rationale for the course design and curricular decisions was based upon personal experience of teaching STEM Robotics Summer Camps for VEX Robotics Competition. Through understanding the competition requirements for a team, I was able to create the guiding concepts, essential questions, enduring outcomes, and important to know outcomes. As a result, the focus of the guiding concepts focused on engineering design, teamwork skills, project management, and the engineering design process. In choosing these topics, students are able to first use this summer program to understand the foundational knowledge needed to begin their season, while continuing to advance their knowledge through experiential learning and social interaction with team members. Through three years of experience, this curriculum design focuses on the feedback provided through past surveys completed by students who have finished the program. Furthermore, the curriculum rationale is focused also on prior experience in being a member of the college robotics and drone team as well as the president of the drone team at Vaughn College. This experience with my bachelor's degree in Mechatronic Engineering allowed me to see the impact of different disciplines such as Mechanical, Electrical, and Computer Engineering on robot systems.

3. ASSESSMENT

3.1. Salient Characteristics of the Intended Learners

3.1.1. Instruction Learning Objectives

As there are many different important components in the VEX Robotics Competition, the course must be able to address each of these requirements. In doing so, the following

1. Students will be able to demonstrate a strong understanding of the five phases of the engineering design process.
2. Students will be able to demonstrate a strong understanding of the VEX Robotics Competition season game and rules.
3. Students will be able to design a robot that can complete the challenges of the VEX Robotics Competition season game in the most efficient and effective manner.
4. Students will be able to document their entire season's progress, design process, and results in the engineering notebook, following the notebook rubric provided by the REC Foundation.
5. Students will be able to demonstrate a strong understanding of basic engineering concepts in mechanical, electrical, computer, and mechatronic (robotics) engineering.
6. Students will be able to function on a professional design team environment with developed teamwork skills.

3.1.2. Learning Objectives That Measure Difficult Concepts/ Misconceptions Understanding

The learning objectives I believe will measure if students have learned concepts you have listed as difficult concepts or misconceptions previously discussed are listed below.

1. Students will be able to demonstrate a strong understanding of the five phases of the engineering design process.
2. Students will be able to demonstrate a strong understanding of basic engineering concepts in mechanical, electrical, computer, and mechatronic (robotics) engineering.

1.1.3. Aligning Learning Objectives with Outcomes

The tables below illustrate the connections between the enduring outcomes, important-to-know outcomes, and good-to-be-familiar-with outcomes to each of the learning objectives previously stated. Furthermore, an explanation as to how each outcome aligns with a particular learning objective has been provided.

Table 1. Learning Objective 1 Alignment with Curricular Outcomes

Learning Objective #01	Curricular Outcomes
Students will be able to demonstrate a strong understanding of the VEX Robotics Competition season game and rules.	**Enduring Outcomes**
	1. How to design and build a robot that can best meet the requirements of the competition challenge.
	Good-to-be-familiar-with Outcomes
	1. Become familiar with VEX Robotics products that are available and legal for use in the design process of the robot.

The first learning objective of the curriculum is the student's ability to demonstrate a strong understanding of the VEX Robotics Competition season game and goals. This is aligned with the first enduring outcome as the competition season games and rules sets the engineering and design constraints that the students will have to follow in their design process. The VEX Robotics Competition sets specific robot requirements about size, limitations on electronic components, and more. As a result, these requirements can influence the methods that the students will use to solve the problems set forth by the competition theme. In the good-to-be-familiar-with outcomes, we see that this learning objective also aligns with the outcome of becoming familiar with VEX Robotics products that are available and legal for use. This alignment is comparable to that of enduring outcomes as the VEX Robotics Competition sets strict regulations on the type of parts and materials students can utilize to construct their competition robot.

Table 2. Learning Objective 2 Alignment with Curricular Outcomes

Learning Objective #02	Curricular Outcomes
Students will be able to demonstrate a strong understanding of the five phases of the engineering design process.	**Enduring Outcomes**
	1. How to design and build a robot that can best meet the requirements of the competition challenge. 2. How to develop program codes and autonomous paths that can achieve high scores in the demanding and intensive season schedule.
	Important-to-know Outcomes
	1. How to use the engineering design process in designing, building, and programming a competition grade robot. 2. Develop an understanding of how different robot subsystems impact the overall performance of the robot.

The second learning objective addresses the student's ability to demonstrate a strong understanding of the five phases of the engineering design process. The five phases of the engineering design process are identifying the problem, research and brainstorming possible solutions, building the best solution, testing the solution, and improving the solution. As a result, several curricular outcomes have a direct connection to this learning objective. As a result, outcomes in relation to the design process, building, and programming align directly with this learning objective.

Table 3. Learning Objective 3 Alignment with Curricular Outcomes

Learning Objective #03	Curricular Outcomes
Students will be able to design a robot that can complete the challenges of the VEX Robotics Competition season game in the most efficient and effective manner.	**Enduring Outcomes**
	1. How to design and build a robot that can best meet the requirements of the competition challenge. 2. How to develop program codes and autonomous paths that can achieve high scores in the demanding and intensive season schedule.
	Important-to-know Outcomes
	1. How to use the engineering design process in designing, building, and programming a competition grade robot. 2. Develop an understanding of how different robot subsystems impact the overall performance of the robot.
	Good-to-be-familiar-with Outcomes
	1. Develop a basic understanding of the concepts, principles, and limitations of other robot systems.

In the objective of students being able to design a robot that can complete the challenges of the VEX Robotics Competition season game in the most efficient and effective manner, there are several outcomes that align. In enduring outcomes, how to design and build a robot as well as programming the robot are two core components of robot development that are necessary to complete the challenges of the season game. In important-to-know outcomes, understanding how to use the engineering design process and understanding how each subsystem of the robot affects the overall performance are very important to the student's overall ability in meeting the competition challenges. Finally, a student is unable to design a robot without a basic understanding of the concepts, principles, and limitations of other robot systems.

Table 4. Learning Objective 4 Alignment with Curricular Outcomes

Learning Objective #04	Curricular Outcomes
Students will be able to document their entire season's progress, design process, and results in the engineering notebook, following the notebook rubric provided by the REC Foundation.	**Enduring Outcomes**
	1. How to design and build a robot that can best meet the requirements of the competition challenge. 2. How to develop program codes and autonomous paths that can achieve high scores in the demanding and intensive season schedule. 3. Effective methods in creating a technical engineering notebook that is presented in a manner that can be understood by anyone new to VEX Robotics Competition.
	Important-to-know Outcomes
	1. How to use the engineering design process in designing, building, and programming a competition grade robot. 2. Develop an understanding of how different robot subsystems impact the overall performance of the robot. 3. How to develop an engineering notebook that documents the design process and team's path to success.
	Good-to-be-familiar-with Outcomes
	1. Become familiar with VEX Robotics products that are available and legal for use in the design process of the robot. 2. Develop a basic understanding of the concepts, principles, and limitations of other robot systems. 3. What are core teamwork skills that are necessary in a team environment and what is their importance. 4. Understand project management and implement it within the team environment.

Most of the curricular outcomes align with the learning objective as the engineering notebook documents every aspect of the team's season. This includes the design process, project management, concepts and theories of engineering utilized, and more.

The fifth learning objective is for students to be able to document their season's progress, design process, and results in an engineering notebook. To achieve this learning objective, students must know how to design and build a robot that meets the requirements of the competition challenge to properly document the entire process from brainstorming to competing. Furthermore, as engineering notebooks consist of more than half a year of work and documentation, the notebook requires the students of the team to understand methods of project and time management. Furthermore, as the engineering notebook rubric provided by the competition organization requires the notebook to be organized following the design process, students must understand the engineering design process to create an engineering notebook meeting competition requirement. Lastly, as the engineering notebook must document every step of the team's progress, students must also be able to explain concepts, principles, and limitations of robot systems.

Table 5. Learning Objective 5 Alignment with Curricular Outcomes

Learning Objective #05	Curricular Outcomes
Students will be able to demonstrate a strong understanding of basic engineering concepts in mechanical, electrical, computer, and mechatronic (robotics) engineering.	**Enduring Outcomes**
	1. How to design and build a robot that can best meet the requirements of the competition challenge. 2. Effective methods in creating a technical engineering notebook that is presented in a manner that can be understood by anyone new to VEX Robotics Competition.
	Important-to-know Outcomes
	4. How to use the engineering design process in designing, building, and programming a competition grade robot. 5. How to develop an engineering notebook that documents the design process and team's path to success.
	Good-to-be-familiar-with Outcomes
	1. Develop a basic understanding of the concepts, principles, and limitations of other robot systems. 2. Understand project management and implement it within the team environment.

In functioning in a professional team environment, students should be able to explain the design process sin a method that can be understood by anyone. This allows for communication within the members of the team in a method that everyone can understand any feedback provided members of varying experience. Furthermore, given that judge interviews are done in a professional manner, a student's ability to function on a professional design team environment can heavily impact their success in preparing and conducting a successful judges' interview. Finally, core teamwork skills and project management are key components of a professional design team.

3.3. Authentic Assessment Criteria by Hansen

Edmund Hansen argues that an effective method of assessing a students' depth of understanding is to assign them a task that is representative of what a practitioner would perform in the real world. He continues to state that to develop a strong understanding of complex ideas would require the student to implement ideas in realistic context. As a result, instructors should create "authentic performance tasks" following a specific design criterion. The task assigned should evaluate a student's ability to transfer theoretical knowledge to a real-world context. A second criteria for authentic performance tasks are to ensure that the student is required to discover the actual problem statement of the task and the knowledge and skills necessary to develop an effective solution. The third criteria require that the student must apply their knowledge and complete the task. The fourth criteria states that these tasks should replicate key challenging situations in which professionals are realistically tested in the workplace. Furthermore, the task should evaluate the student's ability to use their repertoire of knowledge and skill to advance their current skill level and knowledge. The last criteria require that the task allows for opportunities to practice and receive feedback. (Hansen, 2011).

The learning objective worksheet assessment of students demonstrating a strong understanding of basic engineering concepts in mechanical, electrical, computer, and mechatronic (robotics) engineering meets the criteria described by Hansen.

1. **Be realistically contextualized.** The students are tasked with using their knowledge learned in lectures on programming concepts and theories to develop a specific autonomous task to complete a specific goal. The goal for this task is to be able to program both driver control and autonomous capability on the VEX Clawbot to complete the tasks provided.
2. **Require judgement and innovation.** Students are challenged to make decisions about the method of implementation and several other key factors. One such decision that students will make is the decision of how they will approach the autonomous program portion of the task. This includes the type of path taken, if functions are used or not, and what sensors should be used to complete the task. In the driver control portion of the task, students must decide on the best button mapping for the controller to provide easy control of the robot by the operator, possible limitations on robot motor turning, and speed. These are critical factors that can impact how effectively and efficiently the robot will complete the tasks required.
3. **Ask the student to "do" the subject.** As the task requires hands on activity, the students will be required to assemble a robot and program it to perform a task through autonomous capability and operator control. Students will be simulating actual competition programming following the competition template. The competition template is a required format that utilizes competition specific functions to allow for referees to control and limit the autonomous and driver control periods that the robot can operate. This is an accurate simulation of the tasks that competing team programmers will do in preparation for a tournament.
4. **Replicate key challenging situations in which professionals are truly "tested" in the workplace or in their personal life.** The key challenging

situations replicated in this task are the time limits set. The time limits for the autonomous and driver control period are the same as that of a competition match. Furthermore, challenges of truly tested in attempting to ensure that the robot can consistently and accurately follow the program path with minimal deviation each time that the autonomous program is run. In the competition, many teams are unable to create an autonomous path with a high success rate. As a result, a challenge of creating a program code that can consistently remain accurate challenges students to use sensors and mathematics to achieve the task. This is similar the challenge of professional team members who utilize advanced sensors and algorithms to create a consistent, high scoring autonomous.

5. **Assess the student's ability to use a repertoire of knowledge and skill.** The task requires students to use a wide range of knowledge gained in previous classes. Students must use their knowledge of math, programming, and robot mechanics to create functions that would be able to execute specific commands. An example of this is implementing a mathematical equation to convert optical shaft encoder sensor readings to distance units. Furthermore, the task challenges students to implement their knowledge of programming in the use of functions, conditional loops, and variables to achieve the required tasks.
6. **Allow appropriate opportunities to rehearse, practice, and get feedback**. Students will be required to first develop the path that the robot will follow to obtain the highest score they can in the given time frame. Students must also first create a detailed plan for the controller mapping to understand what functions and actions will be assigned to specific buttons. The students will then build the robot, create the program code, and use multiple tests to achieve the required tasks. This will require the students to make constant iterations to their program code, functions, and planned path. Students will receive feedback from mentors, instructors, and teacher's assistants on methods of improving their design process to achieve the tasks in a more effective and efficient manner.

3.4 Worksheet Assessment Grading Rubric

The figure below is the developed rubric used for evaluating the authentic assessment explained in the previous section. The rubric assesses the student's work on the assignment in five specific categories. The first two categories of the assessment evaluate the student's autonomous program code in terms of accuracy and point requirement. The robot's autonomous program will be run 5 consecutive times to test the accuracy of the program code. This allows the instructors to evaluate the student's use of mathematical formulation and incorporation of sensors to eliminate possible factors that may contribute to inconsistency in the program code. The autonomous requirement section of the rubric evaluates the student's implementation of their knowledge in maximizing the performance of the robot and their use of the design process to improve their originally designed robot path.

	Autonomous Accuracy	**Meets Expectations**	**Autonomous Requirement**	**Below Expectations**
Autonomous Accuracy Autonomous Program 4 points	The autonomous program code was consistent and accurate. more than 80% of the time.	The autonomous program code was consistent and accurate. more than 60% of the time.	The autonomous program code was consistent and accurate. more than 40% of the time.	The autonomous program code was consistent and accurate. less than 40% of the time.
Autonomous Requirement Autonomous Path 4 points	The autonomous program was able to score more than 5 points in the 15 second time period	The autonomous program was able to score 3-5 points in the 15 second time period	The autonomous program was able to score 1-2 points in the 15 second time period	The autonomous program was unable to score any points in the 15 second time period.
Driver Control Program 4 points	The driver control code provides the driver with control of all three subsystems of the VEX Clawbot Driver control code has macro-functions mapped to specified buttons.	The driver control code provides the driver with control of two subsystems of the VEX Clawbot	The driver control code provides the driver with control of one subsystem of the VEX Clawbot.	The driver control code provides the driver with control of zero subsystems of the VEX Clawbot.
Program Code Overview 4 points	The program is creatively organized. Excellent use of variables and constants. Excellent use of functions	The program is well organized. Good use of variables and constants. Good use of functions	The program is fairly organized Minimal use of variables and constants. Minimal use of functions	The program is not organized. Poor use of variables and constants. Poor use of functions
Entry Log Submission 4 points	Entry log explains thought process and knowledge used very well. Very easy to read and understand. No grammatical errors.	Entry log explains thought process and knowledge used well Easy to read and understand. 2 or 3 grammatical errors.	Entry log explains thought process and knowledge used decently Fairly easy to read and understand. 4 or 5 grammatical errors.	Entry log explains thought process and knowledge used poorly Difficult to read and understand. More than 5 grammatical errors.

Figure 2. Grading Rubric for Worksheet Assessment

The driver control program section evaluates if the student has properly programmed all subsystems of the robot. This includes the drivetrain, lift, and end manipulator of the robot. The purpose of this section is to evaluate the student's ability to create functions that are reliant on user input. Furthermore, the purpose of the section is to evaluate the student's ability to use knowledge gained in lectures to create functions that can operate simultaneously. The program code overview section of the grading rubric evaluates the student's ability to meet basic programming grading standards. In most programming class rubrics, organization, use of variables, and functions are key principles in developing efficient and effective program codes. Furthermore, organization is an important factor in competition robotics as multiple team members may be collaborating on the same program code.

The last section of the rubric assesses the student's ability to demonstrate an understanding of the programming principles and knowledge gained in class. As a result of the interview and engineering notebook requirements of the VEX Robotics Competition, students must be able to explain their design process in creating an effective and efficient program code that meets the challenges of the competition game. As a result, students must be able to explain how they were able to utilize their skills and knowledge to create the program code.

4. PEDAGOGY

4.1. Lesson Plan Sample

The lesson plan sample that will be provided will be taken from class 13, "Introduction to VEX Code Text and Motor Control." The lesson addresses the learning objective of Students will be able to demonstrate a strong understanding of basic engineering concepts in mechanical, electrical, computer, and mechatronic (robotics) engineering. Furthermore, the lesson plan will address the difficult concept of learning how to write program code.

4.2.1 Timeline and Activities List

First Activity (15 minutes) – General review of VEX V5 electronic systems and the properties of these components. The purpose of this activity is to generate a review of the V5 equipment that the students will now be programming in class. This is important as students will need to understand the VEX Brain, Controller, and motors to complete the programming activities later in this lesson.
Second Activity (10 minutes)- Introduction to VEXCode text software and installation process. During this activity, students will be guided through the installation process for the programming software used in the VEX Robotics Competition and the subsequent lessons. Students are also introduced to the user interface of the software and guided in the process of creating a new project, new project setup procedures, and how to export completed program codes.
Third Activity (45 minutes)- Students are introduced to the basic programming concepts that are needed in hardware programming. Students are taught the four steps to developing an embedded program and executing the downloaded program code. Furthermore, students are introduced to the use of variables in programming, rules of creating variables, variable types, and size.
Fourth Activity (30 minutes) – In this activity, the topic of discussion is transitioned to simple motor control. In this section, the instructor will introduce the methods of declaring electronic components of the robot subsystems in the program code. The instructor will explain and demonstrate the condensed and full format. In teaching the two different formats, the instructor will also explain the different reserved words that are necessary to complete the task. This includes a brief overview of header and main program files in programming. Finally, the instructor will introduce the basic commands that will allow the robot to spin for a certain time duration. This will include live demonstrations with alterations to motor speed and spin direction.
Fifth Activity (30 minutes) – In the fifth activity, students will be given three class exercises in programming two motors to spin at different speeds and direction. The instructor will utilize this time to observe students and answer questions and provide feedback to the students completing the activity.
Sixth Activity (20 minutes) – This activity will revolve around group discussion of experiences and discoveries students have made during the classwork exercises. This may include any problems they had encountered in completing the activity. Students will then discuss possible causes of the errors and potential solutions to the problem. The instructor will act as a facilitator, guiding the conversation.
Seventh Activity (20 minutes)- In this final activity, students will be assigned a task of creating an entry log on the class topic and create a short summary of the theories and concepts of programming. The students will also document problems they had encountered in the classwork exercises and solutions that worked. Students may also document any problems classmates had and the solutions that were found. The purpose of the idea is to reinforce the theories and concepts discussed in class, reinforce technical writing skills, and allow students to document their learning progress.

4.2. The Seven Principles in Making Learning Whole

4.2.1 Play the Whole Game

David Perkins explains that problem solving is the method of solving problems that are clearly stated. However, problem finding differs from this in that it focuses on first discovering what the problem is. (Perkins, D. , 2009). The instruction implements this with the use of the VEX Robotics Competition season challenge that students must build a robot that solves in an effective and efficient manner. This provides the foundation of the overall whole game, while each class topic targets a specific part of the competition process. The CAD and robot subsystems course targets the robot construction, while the programming courses are focused on the programming section of the robot. Furthermore, the technical writing, public speaking, and presentation courses are focused on the judges' interview portion of the competition. Finally, the teamwork section of the course focuses on team development and coordination of work to effectively meet the requirements and challenges of the competition.

A concrete example of the implementation of the principle of playing the whole game is seen in the programming sample lesson plan provided. Students are provided with predefined classwork exercises that are aligned with the goals of the programmers in the team. Furthermore, students in later lectures are given assignments that allow for them to develop their own functions and program codes to actuate the robot. Another concrete example of the use of this principle is in the design portion of the course topic in which students are given the opportunity to practice designing their own robots to meet the challenges provided by the game.

The instruction overall uses several strategies that are recommended by David Perkins to achieve this goal. David Perkins describes pace as where the learner is actively involved most of the time and time is adequately paced to avoid drift and moments of slack. (Perkins, 2009). This is evident in the lesson plan as students are given multiple discussion opportunities as well as hands on activity time in which they are actively working to complete the exercises. Each class is structured to have several segments giving students an opportunity to receive support and keep them engaged in the process. Another strategy implemented in the course is the use of focus. The activities and structure of each lesson are designed to assist students in learning the necessary knowledge and skills to compete in the VEX Robotics Competition. Students are given opportunities to learn through social interaction and experiences of class and homework exercises. Students also receive the opportunity to connect their class lectures with actual hands on experience through the Overclock mentorship program.

The last strategy that the instruction ties back to is that of Stick, which is described by Perkins as a pattern of activities that allows for retention of knowledge in the children. The students in the instruction are given opportunities to practice their newly learned skills and knowledge first through classwork and homework activities. Retention is also achieved through class discussions and actual implementation in the Overclock mentorship program. A key example of this is the VEX Clawbot laboratory assignments giving students the opportunity to program robots to meet specific goals like that of the VEX Robotics Competition.

4.2.2. Make the Game Worth Playing

The second principle discussed by Perkins was focused towards the motivation the instruction provides to learn what is being taught. Perkins argues that teachers should create a curriculum that is connected and full of knowledge that links to the future insights and applications (Perkins, 2009). The design of the instruction utilizes Perkins "Making the Most of Beginnings." The students are first introduced to the VEX Robotics Competition with several videos of the competition from past seasons that have been recorded by teams. The lessons are then designed to motivate student interest as each topic ties directly to how the skill or knowledge is used in the competition team. Several methods of achieving this may be through class exercises following competition formats, videos, and open group discussions. Furthermore, in many topics such as about the different subsystems of the robot, students are provided with an explanation of how the subsystem works. Students can then in discussion describe similar designs they have seen in the real world or how they can apply a robot subsystem design to a real-world problem or scenario.

The curriculum design also follows the Achievement Goal Orientation Theory that is described by Marilla Svinicki. The theory argues that individuals can achieve goals with different outcomes in mind and is often divided into two specific approaches to reach a goal. Students who interest in mastery goal orientation wish to master a skill and focus mainly on learning. On the other hands, students who are performance goal orientation have shown significantly better performance outcomes than others. (Svinicki, M, 2004) The curriculum design has several characteristic examples that follow this motivation theory. One example is the use of using a mastery orientation in which the students are all given the common challenge of preparing to compete in the VEX Robotics competition as a team. As a result, student activities such as the Overclock mentorship is based on the principle of students working together to achieve one common goal instead of focusing on the individual performance. As seen in the lesson plan example, students are given opportunities during discussion to share their solutions, discuss possible solutions to problems others have encountered, and how they can better improve their program code solutions to the class exercises. Furthermore, students are given the opportunity to use the classwork exercise time to work at their own pace in completing the exercises.

4.2.3. Work on the Hard Parts

A difficult concept that I have identified in the target domain is the difficulty of learning to program in general. It has been observed that programming has been a difficult concept for students to learn due to several reasons. However, the most common factors of difficulty in programming may be learning style and motivation. A common solution to this problem that is implemented in the course is the use of implicit assessment through peer feedback. According to Perkins, there are three different feedback types and all of them are relevant and useful not only in the classroom, but also in the workplace. The three feedback types are corrective conciliatory, and communicative (Perkins, D., 2009).

Through using communicative feedback, we can target the three key elements needed: clarification, appreciation, and concerns and suggestions. In the lesson plan, clarification during the classwork exercise activity is achieved with the presence of the teacher who checks on each student individually. This gives individual students an opportunity to ask for clarification and understand what the exercises require the student to do. Once this is done, appreciation is achieved by the instructor providing positive feedback to students when they have completed one or several of the exercises. This also addresses the concerns and suggestions element. The feedback provided the instructor is aimed towards providing positive reinforcement of well-done exercises and provide suggestions of improvement on student answers that can be improved.

4.2.4 Play Out of Town

In the curricular design, the use of transfer is one of the most critical roles in achieving the learning objectives of the course. One example of transfer is the constant relation of individual class topics to the overall picture of the engineering design process phases as well as the competition. An example of this is in the class topic on Solidworks Computer Aided Design (CAD). In this course, students are taught how to use the software to create 3D models. In using the 3D modeling software to complete exercises that are assigned, students must use their knowledge of shapes and their properties to determine the best approach to the problem. The reason for this is because the students are given the mindset that complex three dimensional shapes are.

As a result, students are using their knowledge of basic properties of shapes such as triangles, squares, rectangles, and circles to create complex models of objects they see in the real world. The far transfer of knowledge that exists is in its application of students using their knowledge of how to break down objects into their basic shapes to understand how complex robot systems work and be able to analyze the robot subsystems. This example of instruction ties with Perkin's shepherding transfer strategy. The shepherding transfer strategy requires teachers to foster transfer in the initial learning by creating the connection making that the students should rely on. In essence, the CAD design courses are designed so that students are able to learn how to break down complex structures into simple subcomponents that are easier to comprehend. This connection process is later reinforced and utilized in the lectures discussing the robot subsystems. In these classes, students are provided with videos of robots who use similar subsystems and discussions are conducted about the robot performance and limitations. Students are then able to use the skills of transfer and connection making to explain the robot performance and limitations based on the subsystems of the robot.

4.2.5 Uncover the Hidden Game

One of the hidden games that the students will engage in and discover in the curriculum is the strategies, statistics, and policies centered around VEX Robotics Competition. As the overall game the students are playing is the competition, a key aspect to success in the course is the student's ability to compete effectively and efficiently in the competition and place in high ranks. As such, students in the first lecture are introduced to the competition game for the season, the rules of the competition, and the robot limitation. In subsequent lectures such as robot subsystems, programming, control theory, and driver control, students are given opportunities to discuss strategies. These discussions give students the opportunity to discuss and discover what may be the most effective and efficient robot design solutions to meet the challenges of the competition. Furthermore, students are provided videos of teams who have used certain strategies and designs in previous seasons to complete competition objectives.

This example uses the strategy discussed by Perkins of simply teaching the hidden game. In further aligning with the strategy, many of the discussions may be broken down to specific aspects of the competition. For example, the autonomous match period or only the robot skills challenge autonomous period may be the focus of discussion in strategy with new knowledge taught in class. This provides students to apply previous knowledge with new knowledge to effectively develop connections and strategies for success.

4.2.6 Learn From the Team

Using the previous example of programming being a difficult concept for students to learn, I also utilize teamwork and co-construction of knowledge to help in learning. Given the importance of teamwork, students are required in lecture classes and in the program to constantly engage in team activities. An example of this implementation is in the mentorship program, where students are assigned to work with veteran members of the Overclock robotics team. Students are interdependent on each other working as a team to complete the tasks that are required in preparing for the competition. In the initial phases of the season, students will be assigned to work with a veteran member on brainstorming for robot subsystem designs. Each pairing on the team is required to collaboratively find efficient and effective subsystem designs that would be able to meet the objectives of the competition. In this section of design, students will be required to first individually find designs and possible solutions. After brainstorming, students will discuss with their partners about the designs that were found and select several top choices. The third phase would be the team discussions where all members of the team will discuss the different subsystems, they were responsible for, possible design choices, and the integration of each group's design.

This allows for the team to effectively maximize learning through individual research of their assigned topic as well as cooperative learning through the discussion by other groups of the subsystems that the student was not responsible for. This effectively meets the key elements of cooperative learning that were outlined by Karl Smith. Furthermore, this activity works in assisting students in understanding the difficult concept of understanding the engineering design process. As this process is repeated in the mentorship program for stage of progression on the team, the students are constantly engaged in cooperative learning to understand and master the concepts of the design process.

4.2.7 Learn the Game of Learning

Metacognition is described by Svinicki as the process in which the learner's cognitive resources are organized. As a result, the best learners are those who understand their own metacognitive processes and focuses on reaching a goal. As a result, for learners to be able to control their learning, they must understand alternative solutions and strategies to solve a problem. Learners must also understand that depending on the topic, the type of cognition required can differ dramatically. In addition, learners must understand the strengths and preferences of themselves to foster learning. Lastly, students must be able to manage their own learning, set goals, and how to solve problems they encounter. (Svinicki, M.D., 2004) In promoting metacognition learning in the students of the program, Svinicki's strategy of GAMES will be used.

Students will be given homework, quizzes, exams, and mentorship tasks to complete on a weekly basis. The goal of this is to promote the importance of time and project management in a team environment. As such, students will be given the opportunity during class time to set realistic deadlines for the assignments each week. This promotes students to realistically plan how they will complete assignments and study for exams and quizzes with the balance of their weekly schedule. As such students will understand goal-oriented studying by focusing on the points that are most important for the coming days and prioritize what they will study and complete each night. In active studying, students are actively engaged in processing material through classwork exercises, discussion, and application to real-world problems through the mentorship program. Furthermore, students are actively studying in the engineering entry logs that are assigned daily. On days in which students have class, entry logs will be assigned in which students must discuss the theory or concepts that were learned in class and their application to the whole game of the competition. On days of mentorship, entry logs will align with new methods and skills that were learned in the team assigned tasks.

In lectures, teachers will make notes in material and emphasis certain concepts, principles, and information. This will work to develop meaningful and memorable studying. As the lecture notes per day can range from 10 pages to 20 pages, students must learn to annotated and outline chapter notes to be more efficient in their studying and self-learning methods. Similarly, the entry logs work to address the "E" for explaining the material. The entry logs require students to explain theories, concepts, skills, and team assigned tasks in a way that a new member with no prior training would be able to replicate and understand the work. Finally, students will be self-monitoring their understanding and making corrections in group discussions where they can discuss problems they encountered and find possible solutions through discussions with peers. These class discussions also assist in allowing the students to understand what efficient methods are of approaching problems so that future learning is advanced.

5. Overall Synthesis

The most important enduring outcome of the course design is the development of a strong understanding in concepts and theories in the mechanical, programming, and electrical systems of the robot. The content is consistently addressed throughout the content of the summer program course. In the second and third week of the summer program, students focus mainly in Mechanical Engineering topics. The fourth week of the program focuses on electronic systems, AC/DC circuits, and the electronics that are provided by the VEX Robotics V5 product line. Furthermore, students are introduced to Computer engineering in the fifth through seventh week in learning the programming necessary for successful competition format programming.

The enduring outcome mentioned above is assessed in a wide range of methods throughout the summer program. One method of assessment is in the final examination that serves to assess the overall retention and skill level of students for final team assignments within Overclock organization. A second method of assessment that is used is through the mentorship program and evaluation forms provided by veteran members testing students ability to apply concepts and theories learned in class on real-world problem solving situations. A third form of assessment is using quizzes that are administered weekly. The quizzes are designed to be open ended questions that require students to apply concepts and theories of the different disciplines of engineering to find a solution to the given problem. The final method of assessment is through the engineering notebook that each student will be required to actively work to complete daily. The engineering notebook can be assessed to see if students are able to explain their thought process of completing different tasks and assignments using their knowledge and skills.

In each class students are provided with classwork and homework exercises. These exercises work to provide students with opportunities to apply what they have learned in class to actual problems. Furthermore, another opportunity provided to students is the use of class discussions that will encompass the topics of class as well as applications in the competition challenge. The discussion topics can range from solving problems experienced in class activities, analysis of past season robot designs, effectiveness of robot subsystem designs, and personal experiences that are relevant. A critical component of the summer program that allows students opportunities to engage in deliberate distributed practice of the enduring outcome is in the mentorship program. Students are given the ability to actively apply knowledge and skills learned in class in the development of an actual competition robot. Finally, the engineering notebook serves as another method of promoting learning as it requires students to explain their thought process, theories and concepts, and the design process in a specific way. The engineering notebook entries are required to be written in a manner such that anyone with no prior experience in the summer program can read the notebook and completely understand the engineering design process.

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