Framework Articulation for Common Core Math & Next Generation Science

STEM Integrated Robotics: Foundations Curriculum

STEM Integrated Robotics: Foundations		
Course: STEM Integrated Robotics: Foundations		**Total Framework Hours up to: 90**
CIP Code:	☒**Exploratory** ☐**Preparatory**	**Date Last Modified:**
Career Cluster: Science, Technology, Engineering and Mathematics		**Cluster Pathway: Engineering and Technology**

Curriculum Overview

The following is a STEM Integrated Robotics: Foundations curriculum outline for an exploratory elective, focusing on the use of MINDS-i Robotics within an elective curriculum. Integrated in the outline are the essential components of four core foundational areas: State Standards, National Standards, STEM Education, and CTE inclusion. The described outline is a brief, linear sequence of units in how they would flow during the contact period.

The overall focus of the curriculum is to seamlessly integrate the interdependent disciplines of Science, Technology, Engineering and Math (STEM) into a focussed and invigorating real-world relevant Robotics curriculum. Also embedded are engineering (mechanical, electrical, & software), design, innovation, communications, small group collaboration, and 21st century critical thinking skills and knowledge relevant for student success in college, career and the community.

Course Units

Unit 1: “Introduction to MINDS-i Robotics”
Unit 2: “Continuous Learning & Improvement“
Unit 3: “Variables of Force & Motion”
Unit 4: “Software Programming, Sensors & Servos”
Unit 5: “Autonomous Robotics”
Unit 6: “Mechanical & Structural Engineering”
Unit 7: “Culminating Project”

Resources

MINDS-i STEM Integrated Robotics-Foundations Lab
PC Work Stations; spreadsheet program capable of graphing (must be provided by school)

Unit 1: “Introduction to MINDS-i Robotics” **COMPONENTS AND ASSESSMENTS**	
Performance Assessments: • Student will be able to describe the many applications of Robotics technologies in today’s society including predictions of future applications and trends • Student will be able to describe STEM education as a system and learn about 21st century skills	
Standards and Competencies	
Standard/Unit: ISA (International Society for Automation) Certified Automation Professional (CAP) – (http://www.isa.org/)	
Competencies	**Total Learning Hours for Unit:**

- Understand a definition of STEM Education as an integrated and interdependent system of foundational disciplines
- Demonstrate understanding of the interdependent disciplines of S-T-E-M Education (Science, Technology, Engineering and Math)
- Describe various types of Robots including autonomous, semi-autonomous, and remote controlled
- Understand the Student Performance Development System based on 21st Century Skills
- Curriculum Overview

Unit 2: "Continuous Learning and Improvement"

COMPONENTS AND ASSESSMENTS

Performance Assessments:

- By applying a variety of technologies, students will be able to create and populate a PDSA cycle (Plan, Do, Study, Act) applied to a simple machine design and build challenge experiment

Standards and Competencies

Standard/Unit 2: ASQ (American Society for Quality) - Six Sigma Black Belt Certification – CSSBB (http://prdweb.asq.org/certification/control/six-sigma/index **)**

Competencies	**Total Learning Hours for Unit:**

- Design and construct a simple machine out of mechanical construction elements to perform a specified task objective; including measurement of both accuracy and variance from the target
- Demonstrate understanding of the PDSA cycle (Plan, Do, Study, Act) for continuous learning and improvement including various sub-steps, such as; objectives, questions, hypothesis, predictions, data baseline, experimentation, pilot-test, and data-analysis
- Plan – Brainstorm engineering design changes to improve upon the task performance of the simple machine
- Do – Select and implement engineering design changes, comparing the effectiveness of the original to the new design, and collect baseline data for both
- Study – Analyze the data and determine if the design change did in fact result in a performance improvement
- Act – Document results on a histogram for original and new design, and report out to the group on their findings
- Reflect and understand team dynamics

Alignment with Common Core Standards

Math	**6.SP Statistics and Probability** 6.SP1 Recognize a statistical question as one that anticipates variability in the data related to the question and accounts for it in the answers. 6.SP2 Understand that a set of data collected to answer a statistical question has a distribution, which can be described by its center, spread, and overall shape. 6.SP3 Recognize that a measure of center for a numerical data set summarizes all of its values with a single number, while a measure of variation describes how its values vary with a single number. 6.SP4 Display numerical data in plots on a number line, including dot plots, scatter plots, histograms, and box plots. 6.SP5 Summarize numerical data sets in relation to their context, such as by: a Reporting the number of observations. b Describing the nature of the attribute under investigation, including how it was measured and its units of measurement. 6.SP5d Relating the choice of measures of center and variability to the shape of the data distribution and the context in which the data were gathered. **7.SP Statistics and Probability** 7.SP3 Informally assess the degree of visual overlap of two numerical data distributions with similar variabilities, measuring the difference between the centers by expressing it as a multiple of a measure of variability. **HS Quantities**

	N-Q1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. N-Q2. Define appropriate quantities for the purpose of descriptive modeling. **HS Interpreting Functions** F-IF5. Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes. **HS Interpreting Categorical and Quantitative Data** S-ID1. Represent data with plots on the real number line (dot plots, histograms, and box plots). S-ID3. Interpret differences in shape, center, and spread in the context of the data sets, accounting for possible effects of extreme data points (outliers).
Science	**MS-ETS1 Engineering Design** MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. Analyze and interpret data to determine similarities and differences in findings. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs. A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. Models of all kinds are important for testing solutions. The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. **HS-PS3 Energy** HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

Unit 3: "Variables of Force & Motion"

COMPONENTS AND ASSESSMENTS

Performance Assessments:

- By applying a variety of technologies, students will be able to construct a robot that is capable of driving at variable speeds and steering at variable degrees
- Students will be able to apply Newton's Laws of Motion to understand lessons of force, motion and inertia in the context of the robot

Standards and Competencies

Standard/Unit 4: ASME (American Society of Mechanical Engineers) - Certifications (http://www.asme.org/kb/courses)

Competencies	**Total Learning Hours for Unit:**

- Select and build (as a shared team responsibility) one of three robot chassis designs (leaf spring, 4-link, or independent) and will wire and effectively control the robot through the transmitter and receiver
- Troubleshoot the robot chassis and suspension system using the PDSA cycle
- Demonstrate understanding of the different laws of force and motion and their impact on objects, including key factors such as; acceleration, inertia, mass, momentum, friction, speed, balanced and unbalanced forces
- Identify and describe the function robot components associated with force and motion, such as; motor, pinion gear, spur/ring gear, and tires, etc
- Perform gear ratio experiment to gain an understanding of how gear ratio changes effect force (torque) and motion (speed)
- Calculate the ratio of one of gear set, and mathematically determine it's effects on force (torque) and motion (speed), and will validate calculations with tachometer and torque meter, and mathematically compare to a second gear ratio set
- Calculate the robot speed using revolutions-per-minute (RPM), tire diameter and circumference
- Demonstrate understanding of friction and gravity and their impact on objects, including the relationship to the laws of force and motion
- Determine and compare the amount of amps (electrons) needed to propel the robot under "no-load" and with drive train "simulated-load"

Alignment with Common Core Standards	
Math	**6.RP Ratios and Proportional Relationships** 6.RP1 Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. 6.RP2 Understand the concept of a unit rate *a*/*b* associated with a ratio *a*:*b* with $b \neq 0$, and use rate language in the context of a ratio relationship. 6.RP3 Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalent ratios, tape diagrams, double number line diagrams, or equations. b. Solve unit rate problems including those involving unit pricing and constant speed. d. Use ratio reasoning to convert measurement units; manipulate and transform units appropriately when multiplying or dividing quantities. **7.G Geometry** 7.G4 Know the formulas for the area and circumference of a circle and use them to solve problems; give an informal derivation of the relationship between the circumference and area of a circle. **HS Quantities** N-Q1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. N-Q2. Define appropriate quantities for the purpose of descriptive modeling. **HS Reasoning with Equations and Inequalities** A-REI1. Explain each step in solving a simple equation as following from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution. Construct available argument to justify a solution method.
Science	**MS-PS2 Motion and Stability: Forces and Interactions** MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object. Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. Science knowledge is based upon logical and conceptual connections between evidence and explanations. The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. **MS-PS3 Energy** MS-PS3-1. Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object. Construct and interpret graphical displays of data to identify linear and nonlinear relationships. Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.

	Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. MS-PS3-5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. Science knowledge is based upon logical and conceptual connections between evidence and explanations. When the motion energy of an object changes, there is inevitably some other change in energy at the same time. **HS-PS2 Motion and Stability: Forces and Interactions** HS-PS2-1 Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-PS2-1) Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1) **HS-PS3 Energy** HS-PS3-3 Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PS3-2), (HS-PS3-3) Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-PS3-3) Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS3-3)

Unit 4: "Software Programming, Sensors & Servos"
COMPONENTS AND ASSESSMENTS

Performance Assessments:
- Students will be able to identify and describe the function of robot programming syntax and language components, and the various robot inputs and outputs in which they control
- By applying a variety of technologies, students will be able to apply a basic program capable of supporting manual robot navigation through the micro-controller, utilizing transmitter inputs
- The student will create a test environment bread-board for applying and understanding various robotic inputs, control structures, and output operations

Standards and Competencies

Standard/Unit 6: NCSA (National Computer Science Academy) C-Programming Certification (http://www.ncsacademy.com/)

Competencies	Total Learning Hours for Unit:

- Identify and describe the function of the core components associated with robotic control systems, such as sensors, transmitters, micro-controller, software, operating code, syntax, servos, motors, and their relationship to inputs, control structures, and outputs
- Create a test environment bread-board for applying and understanding various robotic inputs, control structures, and output operations
- Test, experiment with basic micro-controller and servo actuation outputs using prewritten programs on the bread-board
- Test, experiment with basic micro-controller and ESC and motor actuation outputs using prewritten programs on the bread-board
- Test and experiment with basic micro-controller and transmitter inputs using prewritten programs on bread-board
- Test, experiment with and understand a basic program capable of supporting manual operation through the micro-controller utilizing transmitter inputs, servo and EXC/motor outputs
- Test, experiment with, and understand basic micro-controller and ultrasound sensor input code using prewritten programs
- Test, experiment with, and understand basic micro-controller and QTI (line follower) sensor input code using prewritten programs
- Trouble-shoot basic bread-board electrical connections using the PDSA cycle
- Identify and describe core software code syntax language components, such as; setup, loops, comments, start and end brackets, data types, arithmetic operators,

comparisons, digital and analog input/output selection, and time

Alignment with Common Core Standards	
Science	**HS-PS4 Waves and Their Applications in Technologies for Information Transfer** HS-PS4-5. Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. Communicate technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. Systems can be designed to cause a desired effect.

Unit 5: "Autonomous Robotics"
COMPONENTS AND ASSESSMENTS

Performance Assessments:

- Students will be able to identify and describe, and apply the function of core robot programming control structures and the various robot inputs and outputs in which they control
- By applying a variety of technologies, students will be able to create an advanced robot program capable of autonomous navigation using sound and light sensors

Standards and Competencies

Standard/Unit 7: ISA (International Society for Automation) Certified Automation Professional (CAP) – (http://www.isa.org/)

Competencies	**Total Learning Hours for Unit:**

- Demonstrate understanding of basic control structures using prewritten programs, such as; IF; IF-ELSE, and WHILE
- Transfer test environment bread-board components onto robot frame
- Test, experiment with, apply, and optimize advanced micro-controller and multi-ultrasound sensor input code using prewritten programs for utilization with cumulative project
- Test, experiment with, apply, and optimize advanced micro-controller and multi-QTI (line follower) sensor input code using prewritten programs for utilization with cumulative project
- Demonstrate and understand the proportional relationships between the values of various inputs (e.g. transmitter and sensors) and the corresponding response of outputs (servos and motors)
- Practice/Assessment: Trouble-shoot and optimize basic software programs and electrical systems using the PDSA cycle, utilizing various team member points of view

Alignment with Common Core Standards	
Science	**MS-PS4 Waves and Their Applications in Technologies for Information Transfer** MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. Develop and use a model to describe phenomena. A sound wave needs a medium through which it is transmitted. When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency

	(color) of the light. Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

Unit 6: "Mechanical & Structural Engineering"
COMPONENTS AND ASSESSMENTS

Performance Assessments:

- Students will be able to demonstrate understanding of various forces, relate forces to structural stability, and explain the relationship among them
- By applying a variety of technologies students will be able to build a robotic arm and end of arm tool, and will apply various mathematics to analyze, understand, and explain the arm design

Standards and Competencies

Standard/Unit 3: ASME (American Society of Mechanical Engineers) - Certifications (http://www.asme.org/kb/courses)

Competencies	**Total Learning Hours for Unit:**

- Understand how gravity affects levers, cams, span and force.
- Calculate force required to lift an object on the end of a lever utilizing variable factors such length, position of fulcrum, and weight of object
- Calculate the distance traveled of a cam using the factor of rise
- Apply structural design principles using vertical and diagonal mechanical construction elements (i.e. triangles, rectangles, parallelograms) and actuators for bracing, spanning and mechanical actuation.
- Design and build a robot arm and end-of-arm tooling utilizing the structural design principles from above.
- Analyze the design and predict how it will behave in response to the application of the force from above.
- Practice/Assessment: Problem solve and optimize the robot arm and end-of-arm tooling using the PDSA cycle

Alignment with Common Core Standards

Math	**6.RP Ratios and Proportional Relationships** 6.RP1 Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. 6.RP2 Understand the concept of a unit rate *a*/*b* associated with a ratio *a*:*b* with $b \neq 0$, and use rate language in the context of a ratio relationship. 6.RP3 Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalent ratios, tape diagrams, double number line diagrams, or equations. b. Solve unit rate problems including those involving unit pricing and constant speed. d. Use ratio reasoning to convert measurement units; manipulate and transform units appropriately when multiplying or dividing quantities. **7.RP Ratios and Proportional Relationships** 7.RP1 Compute unit rates associated with ratios of fractions, including ratios of lengths, areas and other quantities measured in like or different units. 7.RP2 Recognize and represent proportional relationships between quantities b Identify the constant of proportionality (unit rate) in tables, graphs, equations, diagrams, and verbal descriptions of proportional relationships. c Represent proportional relationships by equations. d Explain what a point (x, y) on the graph of a proportional relationship means in terms of the situation, with special attention to the points (0, 0) and (1, r) where r is the unit rate.

Unit 7: "Culminating Project" COMPONENTS AND ASSESSMENTS	
Performance Assessments: • By applying a variety of technologies, students will be able to demonstrate an understanding of the basics of robot design, function and programming.	
Standards and Competencies	
Standard/Unit: ASME (American Society of Mechanical Engineers) - Certifications (http://www.asme.org/kb/courses) **Standard/Unit: IEEE (Institute of Electrical and Electronics Engineering) (http://www.ieee.org/index.html)** **Standard/Unit: NCSA (National Computer Science Academy) C-Programming Certification (http://www.ncsacademy.com/)** **Standard/Unit: ISA (International Society for Automation) Certified Automation Professional (CAP) – (http://www.isa.org/)**	
Competencies	**Total Learning Hours for Unit:**
• Demonstrate understanding and utilization of units 1 through 6 by demonstrating their application within the "Culminating Project". • Develop a project plan with specific goals and responsibilities and apply what has been learned to design, build and program a Robot capable of performing a specific autonomous and/or manual task in a classroom challenge(s) outlined in curriculum • Or, develop a project plan with specific goals and responsibilities and apply what has been learned to design, build and program a Robot; and compete in one of many Robotics competitions listed (or not listed) in the curriculum.	
Alignment with Common Core Standards	
Science	**MS-ETS1 Engineering Design** MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. Analyze and interpret data to determine similarities and differences in findings. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs. A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. Models of all kinds are important for testing solutions. The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. **HS-ETS1 Engineering Design**

	HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1) HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-2) Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2) HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3) When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3) HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.