Standards-Based Robotics Competition Curriculum Development Framework

Robotics
Education
Symposium

Science Technology Engineering Mathematics

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The Necessity:

The need to cultivate innovators who are scientifically and technologically literate in today's world is critical. People who are scientifically and technologically literate can ask, find, or determine answers to questions about everyday experiences. They are able to describe, explain, and predict natural phenomena. In turn, these skilled individuals then have the tools necessary to make meaningful contributions to society. In order for high school students to develop these skills, they must be motivated and engaged in the learning process. Using an integrated 'STEM' (Science, Technology, Engineering, Mathematics) approach, high school educators can readily exploit the natural enthusiasm and passion generated from student involvement in robotics competitions and related educational experiences to engage their students meaningfully.

The Process:

Supported by an NSF (National Science Foundation) grant, a primary goal generated from the TSA (Technology Student Association) 2006 Robotics Education Symposium was to develop a standards-based robotics assessment rubric and related instructional documentation in order to enable high school educators to effectively implement robotics competitions in their daily curriculum, instruction, and assessment. At the Symposium, the 'Framers' embraced current robotics education research and literature to compile a draft outline of the process used in developing the STEM approach while connecting the robotics content, skills, and assessment appropriate for all high school students.

The key components in achieving these goals were identified as: addressing the challenges that face teachers who utilize the STEM approach through robotics instruction; reviewing existing high school robotics competitions that use standards-based materials; developing criteria for standards-based assessment rubrics for robotics competitions with instructional explanations; and addressing how the use of standards-based robotics competition instruction can enhance professional development.

Building upon the STEM area standards (National Science Standards, Technological Literacy Standards, Career Cluster Standards, and the National Mathematics Standards), the four steps included in the development process were to:

1. Review robotics **content**, **skills**, and **assessments** that were identified during the symposium and correlate them to the core standards for each STEM area.
2. Align and correlate the identified standards matching the content, skill, and assessment strands in each standard category.
3. Review the identified standards to assure that all appropriate standards were addressed and insert additional standards that were also aligned to content, skill, and assessment strands.
4. Identify appropriate professional development and related high school teacher experiences recommended to cultivate viable robotics content through exposure to competitive activities as they connect and enhance the core STEM standards.

Utilizing This Document to Enhance the Classroom Experience:

This documentation provides an overview and set of tools to aid high school STEM educators from all disciplines in their efforts to integrate robotics competitions and related educational experiences in their classrooms and is intended to provide a starting point for high school educators. The curriculum overview puts forth sample robotics content, skills, and assessment directly linked to national standards. By no means is this a "complete" set of possibilities for the classroom, but rather a carefully selected set of examples that can be utilized directly, adapted to existing curricula, or as a guide for the development of specific "local" curriculum. The rubric and evaluation criteria can also be used directly in the classroom, adapted to existing curricula, or utilized as a starting point for further/more specific rubric development. Lastly, the curriculum resources have been selected to connect high school educators to pertinent curriculum materials and resources related to robotics competitions.

Standards-Based Robotics Competition Curriculum Overview

Content, Skills, Assessment, & Professional Development linked directly to applicable
NSTA Standards, Standards for Technological Literacy (ITEA), Career Cluster STEM Standards (States' Career Clusters), and NCTM Standards

NSTA Standards	Robotics Curriculum Content	Robotics Skills	Student Assessment	Professional Development
• **Unifying Concepts and Processes** - Systems, order, and organization. - Evidence, models, and explanation. - Change, constancy, and Measurement. - Evolution and equilibrium. - Form and function.	• Relationships among force, torque, mass, acceleration. • Budgeting(Energy, and Time). • Measure torque with various gear ratios. • Wheel size varies distance (wheel size, composition, smooth/knobby, width, number of wheels, power vs. passive). • Measure angle the robot stops going up the ramp. • Size/weight of the robot can vary performance.	• Accelerating your robot produces torque and speed. • Constraints are speed and power. (Flat course, then elevated ramp or push an obstacle). • Using a gearbox hoist to lift objects (What is the maximum weight of the object that the robot can lift?) • Measurement is a way of assessing effects and ravages of change (e.g. number of matches/test runs before screws are retightened, need for a lubricant fastener to mitigate loosening). • It is only through measurement that we can notice change. • Mechanical and electrical control systems.	• Build a robot or some portion of a robot and balance the energy budget. • Torque from the motor is amplified or reduced by the gearbox, which changes speed, and power delivered to the wheels. Build robots with different gear ratios to show this. • Determine the center of gravity with different chassis designs. • Describe the energy flow and forces within/between modules. • Inspect, disassemble, and reassemble simple mechanical devices and describe what the parts are for. Estimate the effect that making a change in one part of the system is likely to have on the system as a whole.	• Build a robot or some portion of a robot and balance the energy budget. • Explore a variety of opportunities to gain understanding of and investigate new technologies. • Using multidisciplinary opportunities to understand how things work and design solutions to problems through system analysis. • Novices can be overwhelmed when thinking about how to build an entire robot. Focusing on subsystems and interactions between subsystems makes the task manageable. • Evaluating and understanding how devices interact requires opportunities to investigate how they operate and influence each other.
• **Science as Inquiry** - Abilities necessary to do scientific inquiry. - Understandings about scientific inquiry.	• Using defined constraints, students will be able to communicate how they followed the engineering process to solve a problem.	• Assembling electronic components to control sequence of operations. • Perform an investigation, gather evidence, and formulate an answer to the original question.	• Be able to describe modules and how they fit together and interact to accomplish the task.	

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• **Physical Science** - Structure and properties of matter. - Motions and forces. - Conservation of energy. - Interactions of energy and matter.	• Photoelectric effect. • Energy in batteries, springs, gravity, and pneumatic (pressure, volume) devices. • Potential energy vs. Kinetic energy • Energy out of motion, heat, and friction. • Energy is a resource constrained in competition. • Remote controlled robots. • Signal strength and altering frequencies.	• Conservation of energy • Sliding friction, ex: rubbing hands together to create heat. • Over constrained axle. • Positive effects of friction. • 6 wheel robot: using physics principles of F(traction) = F(weight), to position models so Cg is over the drive wheels. • Understanding issues in rechargeable vs. expendable batteries. • Develop solutions to changing power supply. • Understand photoelectric effect in light sensors.	• Students should be able to map energy flow through a system. • The force on the robot from the wheels interact with the ground = torque on wheels delivered by wheel radius. Fr=Fm*N gearbox/ r wheel. • Understand photoelectric effect to predict and protect against problems with lighting in competitions.	See Page 4
• **Science and Technology** - Abilities of technological design. - Understandings about science and technology.	• Design process. Accomplish tasks subject to constraint rules. Explore strategies. Develop concepts to execute strategy. Detail modules to build the concept.	• Incorporate design, cost, risk, and benefits. • Teamwork – incorporating ideas from different science or technology concepts into solving a unified problem. • Brainstorming approaches. • Debating alternative design strategies.	• Always keep an eye open for the possibility of change, since it can happen when you least expect it. Explain how these changes have been incorporated in the robot. • Able to communicate how teamwork and the engineering process were used in their design model.	

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• **Science in Personal and Social Perspectives** - Personal and community health. - Population growth. - Natural resources. - Environmental quality. - Natural and human-induced hazards. - Science and technology in local, national, and global challenges.	• Scientific ingenuity is driven by the desire to understand the natural world and technological design is driven by the need to meet human's needs and to solve human's problems.	• Materials may change. Metal bent repeatedly may go from elastic to plastic mode. Metal can fatigue and not be reliable, plastics can snap, glass can shatter, screws can strip, nuts can loosen, and batteries can discharge.	• Science does not nail the truth of existence; it is always a working model.	See Page 4
• **History and Nature of Science** - Science as a human endeavor. - Nature of scientific knowledge. - Historical perspectives.	• Basic robots and how they advanced to encompass more systems and subsystems due to science and technological advances.	• Comparing and contrasting energy sources and the advancements in energy as technology advances. • How has programming languages advanced to give robots more options in our society?	• Describe how energy can be in many forms and why a push for renewable energy resources is essential for improving our environment.	

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Standards for Technological Literacy	Robotics Curriculum Content	Robotics Skills	Student Assessment	Professional Development
5.8 The Attributes of Design **-**The design process -Design problems are usually not clear -Designs need to be refined -Requirements of a design sometimes compete	• Students are challenged to develop solutions through a systematic process that identifies the problem and refines ideas for solutions within the stated requirements • Deterministic thinking: everything happens for a reason.	• Using the design process students are challenged to create possible solutions to a robotic transportation device/vehicle.	• Create a flow chart of the design process. • Identify components of their/others' designs that need refinement.	• Teachers should have engaged in multi-faceted robotic design projects. • Teachers should be exposed to a range of design projects. (both student and professionally designed) • Teachers should analyze the requirements of different robotic design projects. • Teachers should see and describe examples of successful and unsuccessful student use of the design process. (video documentary, expert/novice) • Teachers should understand that the design process. (A general framework ,not a linear or rigid process) • Teachers must practice using the design process with robotics projects. • Teachers must be trained in design practices. • Shadow/Mentor new teachers and mentors. • Attend in-service workshops, pre-service teacher training.
5.9 Engineering Design -Design principles -Influence of personal characteristics -Prototypes for testing design concepts -Factors in engineering design	• The principles of design include flexibility, balance, function and proportion • Personal experiences and knowledge influence the design process and the perceived robotic solution.	• Students will individually, or in teams, incorporate design principles in the development of robotic prototypes given specific constraints.	• Identify the factors that impacted their design. (FIRST Vex Challenge Engineering Notebook, as an example) • Identify the design principles that were utilized in the development of the robotic prototype.	
5.10 The Role of Troubleshooting, Research and Development, Invention and Innovation, and Experimentation in Problem Solving. -Research and development -Researching technological problems -Not all problems are technological or can be solved using technology -Multidisciplinary approach	• Invent a robotic challenge within defined design constraints.	• Students design a robotics competition to be used by their peers, which includes a robotic invention, design brief, scoring rubric, and related materials.	• Create a narrative of a robotics challenge that satisfies an identified human want or need. • Generate a list of design constraints for a problem. • Identify how to optimize and improve a solution.	

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Standards for Technological Literacy (cont.)	Robotics Curriculum Content	Robotics Skills	Student Assessment	Professional Development
6.11 Apply the Design Process -Identify a design problem -Identify criteria and constraints -Refine the design -Evaluate the design using models -Develop a product or system using a design process -Evaluate final solutions(s)	• Build, test and evaluate a prototype robotic device.	• Apply the design process in the design of a prototype robotic system working with a small team of students to meet the requirements of a class robot competition.	• Modify a robotic design based on peer/teacher feedback. • Test, document, and verify results as part of a robotics design competition.	See Page 7
6.12 Use and Maintain Technological Products and Systems -Document and communicate processes and procedures -Diagnose and repair a malfunctioning system -Troubleshoot and maintain systems -Operate systems to function as designed -Use computers to employ data and information in order to communicate	• The design of robotic processes and procedures must be clearly documented and communicated. • Test, verify, and maintain robotic inventions. • Robotics involves computers and media to communicate ideas and concepts of the engineering and design process. • Students will be able to identify, use and troubleshoot systems. • Communicate effectively using a variety of methods.	• Students design, build, and test a gear train. • Students are required to give a multimedia presentation that describes their team's design process and procedures used for a robotic system. • Identify, use, and maintain various systems within a robotic vehicle.	• Write a narrative of a design process. • Plan & function in robotic team design meetings • Identify parts of the universal system model (input-process-output-feedback). • Troubleshoot a system. • Communicate in multiple roles (leader, participant, consultant, outsider). • Understand one or more symbol systems.	
7.18 Transportation Technologies -Relationship between transportation and other technologies -Intermodalism -Transportation services and methods -Positive and negative impacts of transportation systems -Transportation processes and efficiency	• Laws of conservation of energy with respect to motors, pneumatics systems, gear trains, and transmission (power budgets).	• Design an autonomous multi-terrain vehicle that is intended to safely transport cargo or people. • Discuss transportation issues such as pollution, congestion and accidents and devise solutions to these problems.	• Manipulate robotic systems to achieve a transportation goal. • Identify the positive and negative impacts of various transportation systems.	

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Standards for Technological Literacy (cont.)	Robotics Curriculum Content	Robotics Skills	Student Assessment	Professional Development
7.19 Manufacturing Technologies -Servicing and obsolescence -Materials -Manufacturing systems -Interchangeability of parts -Marketing products	• Identify, utilize, and maintain appropriate materials in the design of a robotic system. • Identify use and application of robotics with manufacturing systems. • Market robotic invention for intended purposes.	• Students will create a manufacturing process and flowchart that includes the transformation of raw materials into a finished product.	• Identify the need for manufacturing and its various applications. • Choose appropriate materials to satisfy the design challenge through comparison and contrast. • Develop marketing and advertising strategies for the end-product of the design challenge.	See Page 7

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Career Cluster Standards	Robotics Curriculum Content	Robotics Skills	Student Assessment	Professional Development
• **Safety, Health, & Environment** - Develop good safety and health practices. - Use appropriate safety techniques, equipment and procedures.	• Apply safety practices in your environment.	• Students exhibit appropriate safety practices while working with equipment and tools during robot construction. • Students promote safety and look after others.	• Construct events to promote safety with safety supervisors, and safety awards. • Building robots involves using machinery, hand tools & equipment – students will do so with the proper attention to safety. This is paramount for the project to be sustainable. • Operating robots must shown to be done in a safe manner. • Identify the safety factors that impacted their design. • Identify the design principles that were utilized in the development of the robotic prototype.	• Develop the necessary skills to enable your students to describe and exhibit appropriate safety techniques, equipment, and procedures.

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Career Cluster Standards (cont.)	Robotics Curriculum Content	Robotics Skills	Student Assessment	Professional Development
• **Leadership & Team Work** - Work effectively with others from diverse backgrounds. - Exercise the ability to lead or follow in a team environment - Exercise leadership and teamwork skills.	• Participate effectively on a team. • Understand how and when to form teams. • Gracious professionalism	• Lead brainstorming session. • Make group decisions on a design. • Work/collaborate with other. • Recruit teams from a variety of populations at school. • Produce presentations that integrate art, programming, engineering, etc. • Establish team hierarchy. • Work effectively on robotics tournament. • Has strong team identity to facilitate success via operations (drivers, programmers, support staff, spirit, etc.). • Excellent communication between operators and pit crew. • Project management skills. • Mentoring younger teams (e.g. HS mentoring MS teams). • Teams ability to regroup as necessary through phases of the project.	• Creates a team that is inclusive where all opinions are solicited and valued, regardless of where they are from. • Shows project management skills to meet time and budget constraints. • Shows leadership in team development. • Sets meeting agendas, keeps a meeting on focus, allows everyone to speak, and keeps the meeting fun.	• Diversity training. • Leadership training. • Teamwork training. • Communications training to lead and coordinate multi-disciplinary teams.

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Career Cluster Standards (cont.)	Robotics Curriculum Content	Robotics Skills	Student Assessment	Professional Development
• **Ethics & Legal Responsibilities** - Adhere to ethical and legal standards.	• Know current ethical and legal standards in the scientific and mathematics areas, as well as in engineering, technology, and in the community.	• Follows "letter" and "intent" of design/operating rules. • Displays graciousness whether winning or losing. • Develops strategies that focus on team success, not opponent failure.	• Adheres to fair play, demonstrating good sportsmanship. • Shows respect for other teams.	• Develop a strong knowledge base as it relates to personal ethics, copyrights and organizational codes of ethics. • Career awareness training. • Ability to inform students on available career paths, appropriate workplace behaviors and resources available to find employment. • Stimulate student interest in STEM-related fields. • Use of multimedia. • Knowing/understanding your audiences. • Effective communication skills: writing, reading and speaking. • Keeping current with trends in the industry and technological advancements.
• **Employability & Career Development** - Develop skills and knowledge for career growth. - Identify performance expectations of a job. - Engage in a large variety of science, technology, engineering or mathematics experiences to determine personal interest in respective pathways.	• Exhibit continuous improvement for personal and professional growth. • Research career pathways in STEM.	• Be responsible to complete assigned tasks on schedule. • Respectful behavior to all team members especially in high stress situations. • Presenting robotics program to potential donors and community leaders. • Develop career opportunities via mentorship, internship and interviews. • Documentation notebook of design and building process. • Develop website as a means of presenting timelines, documentation and journals. • Develop presentation skills using various media.	• Be able to identify potential careers related to robotics competition tasks (engineering, programming, computer science, graphics, marketing, etc.). • Able to explain and demonstrate work habits needed to succeed in team or workplace (on time, complete tasks, act responsibly, etc.). • Identify and explain career opportunities related to robotics and relate to own interests, skill and abilities. • Presentations to professional organizations sharing competition experience. • Presentation on careers. • Conduct interviews of professionals in career. • Presentations to team by professionals in career. • Identify potential partners in the business community.	

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Career Cluster Standards (cont.)	Robotics Curriculum Content	Robotics Skills	Student Assessment	Professional Development
• **Communications** - Discuss effective methods to communicate essential concepts to diverse audiences. - Effectively communicate scientific, technological, engineering or mathematical information to the intended audience. - Read, interpret and analyze technical materials, discerning information and concepts.	• Demonstrate effective oral, written and visual communications. • Documentation, diary, website, CAD drawings.	• Develop public web page to describe design. • Make presentations to judges who may include non-tech members. • Sub-team members (ex: programmers) explain process to other team members. • Present to other classes at school. • Prepare research report. • Ordering supplies for construction. • Effective communication to organize construction. • Explaining algorithmic design and connecting code. • Research information on technology process. • Research elements of robot design. • Reading, explaining, and applying robot rules/design constraints for competition. • Using design to build competition field/arena.	• Be able to explain technical materials to a non-technical audience. • Provide technical communications to a targeted technical audience. • Gather, synthesize and apply technical information pertinent to robot design.	• Conveying information to technical audiences. • Effectively writing technical materials.

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Career Cluster Standards (cont.)	Robotics Curriculum Content	Robotics Skills	Student Assessment	Professional Development
• **Information Technology** - Use information as it supports the gathering, storage and transfer of data and information. - Select and use different forms of information technology. - Apply technology to visualize a problem. - Use information technology tools to manipulate and create information from data. - Use modeling, simulation and visualization to efficiently analyze, synthesize and communicate information. - Write and execute a simple program, i.e. : basic, java, C++.	• Use information technology to gather, store, apply and communicate data. • Evaluate the different technological tools used to manipulate and model data.	• Gather sensor data to determine the location of obstacles or field geometry. • Collect data mapping temperature in a room looking for heat sources. • Determine characteristics of components through the use of datasheets, websites, etc. • Use spreadsheets or programs to calculate expected sensor values, motor performance, or overall robot speed and characteristics. • Develop or choose appropriate software to help visualize the operation of robot wheel speeds and sensor readings. • Develop or use simulation tools to understand and communicate the operation of the robots. • Use appropriate software to allow the robot to perform autonomously. • Use software to augment the operation of mechanical systems. • Use appropriate software to remotely collect data from a robot for display.	• Students will be able to effectively select and utilize appropriate software technologies/languages. • Select storage media for the input, storage and dissemination of information. • Research competition robot specifications and rules using computer/internet. • Use 3D modeling software to prototype robot(autodesk invention). • Use databases to contact team members via email. • Download sensor data to spreadsheet or graphing software to plot or analyze statistically. • Use analysis to apply to robot redesign. • Design of algorithm to run autonomous robot (flow chart, finite state machine). • Write, implement, test and debug the program that runs the autonomous robot.	• Develop the ability to effectively select and utilize appropriate software technologies, languages and storage media for the input, storage and dissemination of information.

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NCTM Standards	Robotics Curriculum Content	Robotics Skills	Student Assessment	Professional Development
• **Number and Operations** - Understand numbers, ways of representing numbers, relationships among numbers and number systems. - Understand numbers, meanings of operations and how they relate to one another. - Compute fluently and make reasonable estimates.	• Power budget. • Energy budget. • Power consumption. • Force, mass, and acceleration. • Use of Binary, Octal and Decimal numbering systems. • Conversion of numbers among various systems.	• Complex program using different microprocessor chips and require binary/octal programming for input and outputs. • Use of linear equations to solve real world problems.	• Create a race where the team closest to the goal wins. • Speed can also be measured Assumption: robot goes straight, can turn specified degrees. • Students explain how the robot ended up or where it stopped (explain errors). • Prepare a power consumption budget to determine the minimum energy required to complete a task.	• Teachers will have engaged in multi-faceted robotic design projects. • Teachers should be exposed to a range of student design projects. • Teachers must be able to analyze the requirements of different robotic design projects. • Teachers must understand the design process as a general framework. • Teachers will practice using the design process with robotics/math projects. • Teachers should be trained in design practices and mathematical content. • Shadow/Mentor new teachers and mentors. • The ability to lead and coordinate multi-disciplinary teams via effective communications, strong leadership and team building skills.

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NCTM Standards (cont.)	Robotics Curriculum Content	Robotics Skills	Student Assessment	Professional Development
• **Algebra** - Understand patterns, relationships and functions. - Represent and analyze mathematical situations and structures using algebraic symbols. - Use mathematical models to represent and understand qualitative and quantitative relationships. - Analyze change of variables in changing environments.	• Algebraic functions used in robotic programming. • Simple and compound gear ratios.	• Using model equations to set parameters and predict outcome. • Gear trains. • Calculate unknown variables based on known parts of an equation. • Determine amount of work needed to move a part or force needed to lift an object. • Torque equations • Motion models.	• Calculate the gear ratio of a drive train. • Calculate amount of energy expended vs. amount of work completed. • Show the mathematical equations used to calculate energy used.	• Develop a strong knowledge base as it relates to measurement, proofs and statistical analysis. • Stimulate student interest in STEM-related fields. • Effectively writing technical proofs and materials. • The ability to effectively select and utilize appropriate software technologies, languages and storage media for the input, storage and dissemination of information. • The ability to show how robotics projects help students understand mathematics? • Ability to go from the concrete robot to the abstract math representation, and vice-versa.

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NCTM Standards (cont.)	Robotics Curriculum Content	Robotics Skills	Student Assessment	Professional Development
• **Geometry** - Analyze characteristics and properties of two-and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships. - Specify locations and describe spatial relationships using coordinate geometry and other representational systems. - Apply transformations and use symmetry to analyze mathematical situations. - Use visualization, spatial reasoning and geometric modeling to solve problems.	• Navigation. • Modeling free-body force diagrams. • Intercepting a moving object. • Calculating properties of shapes based on desired design. • Use CAD to design robotics components.	• Program a robot to move from one point to another given coordinates in polar or Cartesian coordinates. • Model basic shapes using drafting and CAD tools. • Model a motor with gears and gear trains. • Calculate travel of moving object and plan a course of action to intercept the object at a future time (intersection of two lines). • Model a robot using difference shapes and determine which shape holds the most weight. Shapes will affect design and durability of robot. • Using three-dimensional CADD software, perform a vector analysis to predict the behavior of a robotic device.	• Identify and draw, using two- and three-dimensional software, various geometric shapes commonly found in robotic design. • Draw and construct representations of two- and three-dimensional geometric objects using common drafting and design techniques. • Utilize CAD software to apply trigonometric relationships to determine lengths and angle measures found in robotic design. • Use geometric models to gain insights into, and solve robotic/mechanical design problems. • Accurately construct a CAD model of a gear train. • Calculate rotational speed of a wheel within a drive train. • Calculate the surface area of a robotic competition playing surface. • Calculate the volume of various three-dimensional geometric shapes commonly found in robotic design.	See Pages 15-16

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NCTM Standards (cont.)	**Robotics Curriculum Content**	**Robotics Skills**	**Student Assessment**	**Professional Development**
• **Statistics and Measurement** - Understand measurable attributes of objects and the units, systems and processes of measurement. - Apply appropriate techniques, tools and formulas to determine measurements. - Understand converting of measurements in relation to size of project.	• Scale models. • Dead reckoning repeatability. • Measurement and calculations of shapes and how they fit together to build a robot. • Tolerances and how they affect the ability of parts to fit together.	• Create a scale model. • Move from point A to point B many times and record individual and average distance to point B after many trials. • Program different robots to move in different scales and units for accuracy comparison. • Create a robot that can fit into a 2'x2'x2' box that meets requirements of the instructor. • Determine and work within tolerances. • Using various shapes, determine the physical properties of shapes (ex: strength, durability).	• Create a ½ scale model of a robotic arm. • Meet design requirements, similar to what engineers do in the workforce.	See Pages 15-16

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NCTM Standards (cont.)	Robotics Curriculum Content	Robotics Skills	Student Assessment	Professional Development
• **Data Analysis and Statistical Probability** - Formulate questions that can be addressed with data and collect, organize and display relevant data to answer them. - Select and use appropriate statistical methods to analyze data. - Develop and evaluate inferences and predictions that are based on data. - Understand and apply basic concepts of probability and statistics.	• Robot hardware design. • Sensor data analysis. • Thresholds for sensors. • Robot visual blob tracking. • Uncertainty analysis (where did the energy really go). • Weight balance. • Material density. • System Error Analysis (RSS)	• Look at sensor data (light, touch, etc) to either preplan motion paths or determine current location (occupancy grids). • Inequality relationships of determining significant measurement. • Track a robot as it moves using color blob tracking cameras. Using equations, predict changes in the tracked color object. • Estimate weight of components given a design, considering material properties such as density. Also estimate center of gravity and then measure. • Analyze and construct the distribution mean and standard deviation of a set of data points. • Using Root-Sum-Square Analysis of system components determine overall system error.	• Use other document for idea Graph the success rate of an autonomous operation using a histogram or scatter-plot. • Use programming software to analyze data collected from an ultrasonic sensor. • Use elasticity testers to measure properties of materials and calculate their breaking point. • Calculate system error using RSS analysis of all components.	See Pages 15-16

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NSTA Standards, Standards for Technological Literacy (ITEA), Career Cluster STEM Standards (States' Career Clusters), and NCTM Standards

NCTM Standards (cont.)	Robotics Curriculum Content	Robotics Skills	Student Assessment	Professional Development
• **Mathematics Process Standards** - Mathematical problem solving skills and applying formulas to achieve a desired outcome. - Reasoning and Calculus based Proofs. - Communicate mathematical thinking coherently and clearly to peers, teachers and others - Recognize and use Connections and relationships among mathematical ideas. - Create and use representation to organize, record and communicate mathematical ideas.	• Mathematics Problem solving models are used to understand the dynamics of systems and subsystems in robots. • Mathematical reasoning is used to determine the functionality and purpose of a robotic design. • Communication is used to share and mold everyone's ideas into a robotic related product that meets or exceeds the goals of the design challenge. • Recognize and apply mathematics in a variety of robotics contexts to interconnect and build upon one another. • Incorporate graphic representation into a design engineering notebook.	• Mathematics problem solving skills are used to analyze gear trains and systems to determine mechanical advantage and how to adjust for increased torque or speed. • Students will identify and make estimations through conjecture in relationship to the outcome of a robotic design. • Students will use the language of mathematics to express mathematical ideas precisely when designing and communicating robotic solutions to an individual and/or team. • Use mathematical reasoning to connect parts and subsystems within the development of a completed/whole system. • Analyze and graph the motor output of a robotic solution	• Students will identify the appropriate problem solving skills and mathematical formulas to understand and communicate key items involved in utilizing technology in a system (e.g. mechanical advantage). • Students will identify patterns or irregularities and determine if these patterns are accidental or if they occur for a reason. (e.g. Using proofs to answer how variable x affects y). • Students will accurately and professionally express their mathematical ideas to the appropriate audience. • Students will convey their recognition of mathematical connections in a design engineering notebook. • Students will create and use representation to organize, record, and communicate mathematical ideas when designing engineered solutions to robotic challenges.	See Pages 15-16

Standards-Based Robotics Competition Curriculum Overview

Content, Skills, Assessment, & Professional Development linked directly to applicable
NSTA Standards, Standards for Technological Literacy (ITEA), Career Cluster STEM Standards (States' Career Clusters), and NCTM Standards

<u>Standards References</u>

NSTA: National Science Education Standards - http://www.nsta.org/standards
ITEA: Standards for Technological Literacy - http://www.iteaconnect.org/TAA/Publications/TAA_Publications.html
States' Career Clusters: Career Cluster STEM Standards – http://www.careerclusters.org/clusters/sre.cfm
NCTM: Principles & Standards for School Mathematics - http://standards.nctm.org

Standards-Based Robotics Competition Rubric Description:

Scoring rubrics are one of many alternatives available for evaluating student work and are well suited for performance based robotics assessments. Scoring rubrics are based on descriptive scales regarding the extent to which **<u>criteria</u>** has been met. Starting with the highest level and moving toward the lowest, these levels of performance are used to assess the defined set of tasks as they relate to a final product or described behavior. Each rubric level describes degrees of proficiency and each level is assigned a value that rates student performance.

The following rubric sample provides a basis for high school STEM area teachers to use, build upon, and customize to meet their specific robotic curricular needs. These performance-based assessments evaluate student performance on any given task or set of tasks that ultimately leads to a final **<u>robotics</u>** product, or learning outcome. The robotics rubric included in this project is designed to provide general criteria as a basis for evaluating or assessing student performances as indicated in the standards alignment and correlating descriptions. The robotics content, skills, and assessment narratives from each of the standards areas are used in this sample to identify the rubric criteria.

Rubric and Evaluation Criteria for Standards-Based Robotics Competitions & Related Learning Experiences

Evaluation Criteria	Expert = 4	Proficient = 3	Emergent = 2	Novice = 1	Assessment			Comments
					Self	Peer	Instructor	
Design & Process Criteria								
Creating Viable Solutions to a Variety of Human Wants, Needs, and Challenges.	Multiple, well developed solutions exist meeting all critical criteria	Multiple solutions are evident & one is developed meeting majority of criteria	Multiple, undeveloped solutions are evident	A solution that may or may not be developed is evident				
Simple and Complex Systems	All simple & complex systems are identified & function efficiently	Functioning simple and complex systems exist	Multiple simple systems exist that may function	One functioning simple system exists				
Design Process (scientific method, technological problem solving process, etc.)	Formal design process utilized, documented & enhances efficiency	Formal design process utilized and fully documented	Formal design process utilized consistently	Some evidence that formal design process was utilized				
Utilization of Resources: (Tools/Machines, Materials, Information, People, Capital, Energy, & Time)	Resources used within constraints, efficiency maximized, environmental harm minimized	Resources utilized to maximize efficiency	Evidence that some resources utilized meeting intended purpose	A few resources (e.g., tools & materials) utilized randomly				
Technical Criteria								
Programming (Autonomous and/or tele-op)	Efficiency and sophistication evident in multiple programs	Consistency evident in one or more programs	Functional, but inconsistent programming	Programming incomplete or rarely functional				
Control Systems	Completely functional and consistent control systems	Consistently functional control systems	Functional, but inconsistent control systems	Non-functional or incomplete control systems				
Electrical Systems	Completely functional and consistent electrical systems	Consistently functional electrical systems	Functional, but inconsistent electrical systems	Non-functional or incomplete/unsafe electrical systems				
Mechanical Systems	Completely functional and consistent mechanical systems	Consistently functional mechanical systems	Functional, but inconsistent mechanical systems	Non-functional or incomplete/unsafe mechanical systems				
Fluid Systems (pneumatics, hydraulics, etc)	Completely functional and consistent fluid systems	Consistently functional fluid systems	Functional, but incon-sistent fluid systems	Non-functional/incom-plete/unsafe systems				
Unifying Themes (This area emphasizes the Interaction of Science, Technology, & Human Endeavor)								
Communication (written and oral)	Sophisticated and highly efficient communication for all audiences	Purposeful, consistent, effective communication	Purposeful, fairly consistent communication	Communication very inconsistent and lacks purpose				
Teamwork	Integrated teamwork that maximizes outcomes is evident	Participants fully define roles, goals, & work together	Participants partially define roles, goals, & work together	Participants function separately within a group				
Ethics in Decision-Making	Ethical behavior is fully exhibited and advocated for throughout the process	Decisions guided by design constraints, Asimov's laws, and interpersonal ethics	Ethical decisions concerning design constraints evident	Ethics considered, but not applied to decisions				

Standards-Based High School Robotics Competitions & Related Experiences
Curriculum Resources

Battlebots IQ: www.battlebotsiq.com
Site includes an overview of the competition and a curriculum sample at
http://www.battlebotsiq.com/preview.preview.php

BEST: www.bestinc.org
Along with the competition, you can find teacher/team resources, including curriculum materials at
http://www.bestinc.org/MVC/Resources/resources_page

Botball: www.botball.org
Competition and helpful information, especially the educational resources page at
http://www.botball.org/educational-resources/

Carnegie Mellon Robotics Academy: http://www-education.rec.ri.cmu.edu/
Curriculum materials and resources

Exploravision: www.exploravision.org
Competition, information, and teacher resources available at http://www.exploravision.org/teacher-resources/

***FIRST* Robotics Competition & *FIRST* Vex® Challenge:** www.usfirst.org
Resources, documents & updates, archived workshop presentations, and engineering notebooks available at
http://www.usfirst.org/robotics/ and http://www.usfirst.org/vex/

Future Scientists and Engineers of America Club: www.fsea.org
Competitions using the design process, including a robotic mouse challenge

The Intel International Science and Engineering Fair: http://www.sciserv.org/isef/
Competition categories include Engineering and Robotics

NASA's Educational Robotics Matrix: and corresponding resources
http://robotics.nasa.gov/edu/matrix.php

National Robotics Challenge: www.nationalroboticschallenge.org
Nine different robotics contests and robotics "curwikilum" for educators and teams

Odyssey of the Mind: www.odysseyofthemind.com
Annual competition to promote creative team-based problem solving

Project Lead The Way: www.pltw.org
Offers comprehensive, project-based curricula with specific intended learning outcomes congruently aligned with national learning standards. Sample curriculum available at http://www.pltw.org/sampcurr.shtml

RoboCup Junior: www.robocupjunior.org
Challenge and resources

Robofest: http://www.robofest.net/
Challenge and resources for educators

SMART: http://mechatronics.poly.edu/smart/
Resources page for educators

Technology Student Association: http://www.tsaweb.org/
Competitions, including engineering and robotics categories, using the design process and technological problem-solving model

Glossary of Key Terms

Actuator: A mechanism that supplies and transmits a measured amount of energy for the operation of another mechanism or system. Also called a Final Control Element

Autonomous: Describes a self-contained robotic system that carries out programs or performs tasks without outside control by acquiring, processing and acting on environmental information.

Blob-tracking: One of the simplest forms of tracking; the tracking is based on finding the center of mass of a ``blob."

Cartesian Coordinates: a system of coordinates for locating a point on a plane (Cartesian plane) by its distance from each of two intersecting lines, or in space by its distance from each of three planes intersecting at a point.

Chassis: the frame and machinery of a robot, on which the body is supported.

Constraints: Applicable restrictions that will affect the scope of a project.

CAD or CADD: Computer-aided design or Computer-aided Drafting and Design

Dead Reckoning: The processing of streams of data—directions, speeds, and times—involved in keeping track of position.

Design Brief: A written plan that identifies a problem to be solved, its criteria, and its constraints. The design brief is used to encourage thinking of all aspects of a problem before attempting a solution.

Design Principles: Balance, rhythm, proportion, dominance, and unity

Design Process: A systematic problem solving strategy with criteria and constraints, used to develop many possible solutions to solve a problem or satisfy human needs and wants, and to narrow down the possible solutions to one final choice.

Engineering Design Notebook: A written and/or electronic document that includes all of the elements of a design brief as well as sketches/drawings, calculations, testing of solution iterations, and reflective thinking,

Ethics: Moral principles that govern a person's or group's behavior.

Framers: Attendees of the 2006 Robotics Education Symposium who, under the direction and supervision of symposium faculty, worked toward the creation of the Standards-Based Robotics Competition Curriculum Development Framework

Intermodalism: The use of multiple types of transportation to reach one destination; includes combining the use of trains and buses, automobiles, bicycles, and pedestrian transport on a given trip.

ITEA: International Technology Education Association

Mechanical Advantage: Torque-amplifying effectiveness of a simple machine, such as a lever, an inclined plane, a wedge, a wheel and axle, a pulley system, or a jackscrew. The theoretical mechanical advantage of a system is the ratio of the force that performs the useful work to the force applied, assuming there is no friction in the system.

NCTM: National Council of Teachers of Mathematics

NSTA: National Science Teachers Association

Obsolescence: One of the causes of depreciation brought about by changes in design, new concepts and/or new inventions.

Glossary of Terms (continued)

Optimize: To allocate such things as resources or capital as efficiently as possible.

Photoelectric Effect: The emission of free electrons from a metal surface when light strikes it.

Pneumatic: Of, relating to, or using gas (as air or wind); moved or worked by air pressure.

Polar Coordinates: Coordinates that provide a method of rendering graphs and indicating the positions of points on a two-dimensional (2D) surface

Prototype: A model suitable for use in complete evaluation of form, design, performance, safety, and material processing.

Robot: An electro-mechanical device that can perform tasks. A robot may act under the direct control of a human and/or autonomously under the control of a programmed computer.

Robotics: The branch of technology that deals with the design, construction, operation, and application of robots.

Sensor: An electronic device used to measure a physical quantity such as temperature, pressure or loudness and convert it into an electronic signal of some kind (e.g a voltage). Sensors are normally components of some larger electronic system such as a computer control and/or measurement system.

STEM: Science, Technology, Engineering, Mathematics

System: A collection of components and/or processes organized to accomplish a specific function or set of functions.

Torque: A force that produces or tends to produce rotation or torsion.

Universal Design: An approach to the design of all products and environments to be as usable as possible by as many people as possible regardless of age, ability, or situation.

Universal Systems Model: A model that is used to evaluate systems. All technological systems can be described with the Universal Systems Model, and the five elements that define this model are: Goals, Inputs, Processes, Outputs, and Feedback.

Vector Analysis: A branch of mathematics that deals with quantities having both magnitude and direction.