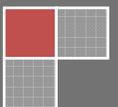


2012

# *Analysis of Relevant Educational Standards*

A report prepared for *FIRST*



## **Introduction**

Conceived as a high-school single program to inspire and engage children in science and technology through robotics, *FIRST* has grown into a family of programs covering the entire K-12 spectrum. During this time of growth, educational standards have been taking on a larger, more prominent role in formal educational settings. As *FIRST* undergoes a comprehensive strategic planning process it seems natural that the alignment between *FIRST* programming: 1) Junior *FIRST* LEGO League; 2) *FIRST* LEGO League; 3) *FIRST* Tech Challenge; and, 4) *FIRST* Robotics Competition be considered.

## **Standards Analysis Preparation and Data Collection**

As part of the *FIRST* strategic planning process, the Progression of Programs Working Group commissioned an analysis of the educational standards addressed by the various levels of *FIRST* programming. A series of interviews were conducted with key *FIRST* stakeholders to identify the key goals of each program and collect their perspective on the key elements of each program. Based on these conversations it was determined that *FIRST* programs address three major areas: mathematics, science, and life skills. A review of the literature was conducted to identify the most up-to-date and relevant educational standards that addressed these topics. Another criteria added to this search was that the standards used in the analysis were comprehensive enough to address the national scope of the *FIRST* programs. A final criterion was that the standards selected had been previously aligned to, or identified as a resource, by other programs or initiatives which would indicate their acceptance in the larger educational community. It was decided that the following standards best met the criteria:

- Common Core State Standards Mathematics<sup>1</sup>
- National Science Education Standards<sup>2</sup>
- Partnership for 21<sup>st</sup> Century Skills Framework<sup>3</sup>

An initial analysis of the alignment between the various *FIRST* programs and these standards was conducted by Loehr Educational Consultants. In this *FIRST* analysis, interview summaries from *FIRST* stakeholders, program documentation, and *FIRST* web resources were reviewed by an educational expert with knowledge of and experience with *FIRST* programming as well as Kindergarten through 12<sup>th</sup> Grade science and mathematics instruction.

The initial analysis of the alignment between *FIRST* programming and educational standards was shared with and reviewed by the Progression of Programs Working Group. At this time, the Working Group reviewed the document and offered feedback on the accuracy of the information presented based on their knowledge and experience with *FIRST*. Their suggested changes were incorporated into the analysis. The analysis was then shared with the Education Working Group. This group was composed of *FIRST* stakeholders particularly aware of and interested in the educational issues associated with program delivery. Some of the members of this group had previously seen the analysis through their membership on the Progression of Programs Working Group. Others were seeing the analysis for the

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<sup>1</sup> National Governors Association Center for Best Practices, Council of Chief State School Officers. (2010) *Common Core State Standards Mathematics*. Washington D.C.: National Governors Association Center for Best Practices, Council of Chief State School Officers.

<sup>2</sup> National Research Council (NRC). (1996). *National science education standards*. Washington D.C.: National Academy Press.

<sup>3</sup> Partnership for 21<sup>st</sup> Century Skills. (2009). P21 Framework Definitions. Washington D.C.: Partnership for 21<sup>st</sup> Century Skills

first time. Again, members of this working group were asked to provide feedback about the analysis. Their feedback was incorporated into the analysis to improve its accuracy.

In addition, two online surveys were conducted to offer more individuals the opportunity to comment on and offer feedback about the alignment between the selected educational standards and the various *FIRST* programs. Invitations to participate in each survey were sent out via email to stakeholders identified by *FIRST* staff. Each email contained a link to the online survey along with a draft of the standards alignment report. The first survey was conducted to solicit feedback from *FIRST* headquarters and field staff who worked with specific programs. This survey was operational from mid-June 2012 through mid-July 2012 and a copy can be found in Appendix A. Sixteen individuals responded to the questions asked in this survey. Roles that these individuals play within *FIRST* are reported in Table 1. Since some individuals within the organization operate in multiple roles the total number of responses is greater than 16.

Table 1: Role within *FIRST* of Headquarters Survey Participants

<b>Role within <i>FIRST</i></b>	<b>Number of Responses</b>	<b>Percent of Sample</b>
Headquarters Staff	2	12.5
Regional Director	4	25.0
FLL Partner	4	25.0
FTC Affiliate Partner	1	6.3
Education Task Force Member	5	31.3
<i>FIRST</i> Team Coach/Mentor	2	12.5
Other (i.e. Principal Investigator, Referee)	3	18.8

As with their roles within the organization, *FIRST* headquarters and field staff who responded to this survey most often worked with multiple programs. A detailed distribution of their program affiliation can be found in Table 2.

Table 2: Program Affiliation of *FIRST* of Headquarters Survey Participants

<b><i>FIRST</i> Program</b>	<b>Number of Responses</b>	<b>Percent of Sample</b>
Junior <i>FIRST</i> LEGO® League	0	0.0
<i>FIRST</i> LEGO® League	4	25.0
<i>FIRST</i> Tech Challenge	3	18.8
<i>FIRST</i> Robotics Competition	4	25.0
Multiple Programs**	5	31.3

\*\* : Two of the multiple programs respondents indicated that they also worked with Junior *FIRST* LEGO® League.

While the respondents differed on many criteria, a typical respondent would be best described as a *FIRST* field-based staffer who worked with multiple levels of programming, most often *FIRST* Robotics Competition in combination with another program. The feedback from all the respondents was reviewed, analyzed and used to improve the quality of the alignment analysis. In particular, these respondents were able to identify areas of alignment that were not apparent through document analysis.

After the alignment documents were updated, a second survey targeting *FIRST* coaches and mentors was distributed via email to coaches and mentors identified by *FIRST* staff. Each email contained a link to the online survey along with a revised draft of the standards alignment report. This second survey followed the Headquarters survey by approximately two weeks. This survey was active for six weeks to allow sufficient time for teachers to return to school from summer vacation. A copy of this survey can be found in Appendix B. At the conclusion of the survey 62 individuals responded. The *FIRST* programs that these individuals were associated with are reported in Table 3.

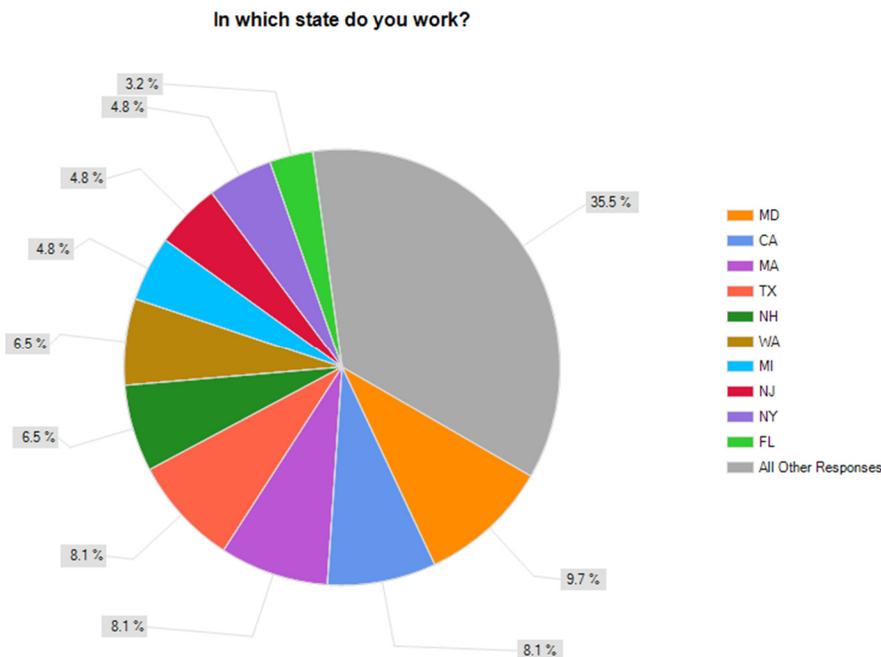
Table 3: Program Affiliation of *FIRST* of Headquarters Survey Participants

<i>FIRST</i> Program	Number of Responses	Percent of Sample
Junior <i>FIRST</i> LEGO® League	15	24.2
<i>FIRST</i> LEGO® League	12	19.4
<i>FIRST</i> Tech Challenge	4	6.5
<i>FIRST</i> Robotics Competition	8	12.9
Multiple Programs**	23	37.1

\*\* : Fourteen of the multiple programs respondents indicated that they worked with Junior *FIRST* LEGO® League and *FIRST* LEGO® League. The remaining respondents were involved in some combination of *FIRST* Robotics Competition and another program.

The 62 *FIRST* coaches and mentors who responded to the survey were from 27 different states. Maryland produced the most respondents (5) followed by California, Massachusetts, and Texas (4 each). Twelve states are represented by a single respondent. A detailed breakdown of respondents by state can be found in Graph 1.

Graph 1: Distribution of *FIRST* coaches and mentors across states



In terms of experience, the majority of respondents had been working with their *FIRST* program for 3 to 5 years. However, some of the respondents were brand new to the program; while others had been involved with *FIRST* since the early stages of the organization. A detailed breakdown of the respondents based on their experience can be found in Table 4.

Table 4: Years of Experience for Coach/Mentor Survey Participants

Years of Experience	Number of Responses	Percent of Sample
New this Year	4	6.5
1 to 2	16	25.8
3 to 5	25	40.3
6 to 10	14	22.6
11 to 15	2	3.2
15 or more	1	1.6

As before, the respondents differed on many criteria; however, a typical respondent would be best described as a coach with 3 to 5 years of *FIRST* experience who worked with multiple programs, most often Junior *FIRST* LEGO League and *FIRST* LEGO League. Again, the feedback from all the respondents was reviewed, analyzed and used to improve the quality of the alignment analysis. The information provided by the respondents informed about areas of alignment that were not apparent through document analysis as well as ways in which this information could be distributed to and used by coaches and mentors.

### **Results of Standards Analysis**

An examination of the educational standards shows, not unexpectedly, that the degree to which the standards are addressed by *FIRST* programs varies depending on the program, the standards in question, and the age level of the students. For example, in the Common Core Mathematics Standards for Kindergarten through Third Grade it is expected that students will count the number of objects present. It can be expected that as part of the construction process during Junior *FIRST* LEGO® League students will need to count in order to determine the number of LEGO® bricks available to construct their motorized simple machines. Performing this task will provide the opportunity for students to develop the ability with this standard. In the *FIRST* Robotics Competition, a similar pattern is observed with regard to the National Science Education Standards for Force and Motion. These concepts are potentially addressed as part of the competition because students will have to account for such ideas as vectors and friction as they work on their robot’s motion. Potentially 41% to 90% of any given standard set, such as the National Science Education Standards, can be addressed by participation in a *FIRST* program (see Table 5).

Table 5: *FIRST* Program Overall Standard Coverage

<b>Educational Standards Addressed</b>	<b>Junior <i>FIRST</i> LEGO® League</b>	<b><i>FIRST</i> LEGO® League</b>	<b><i>FIRST</i> Tech Challenge</b>	<b><i>FIRST</i> Robotics Competition</b>
Common Core Mathematics	23/34 - 68%	39/51 - 76%	55/61 - 90% (HS) 20/29 - 70% (MS)	55/61 - 90%
21 <sup>st</sup> Century Skills	73/88 - 83%	74/88 - 84%	67/88 - 76%	67/88 - 76%
National Science Standards	25/60 - 41%	42/60 - 70%	29/60 - 48%	29/60 - 48%

## Common Core Mathematics Standards

Analysis shows that the coverage of standards is the best in mathematics (Table 5) where the programs are potentially addressing between 68% and 90% of the Common Core Mathematics Standards depending upon the program in question. Also, *FIRST* programs support children's mastery of the Common Core Mathematical Practices. These varying forms of mathematical expertise are the ultimate goal of mathematical education. An analysis of the activities associated with the *FIRST* programs shows that any Mathematical Practice can be addressed by any level of *FIRST* programming (See Table 6). The two best programs at covering their respective mathematics standards are the *FIRST* Tech Challenge and the *FIRST* Robotics Competition. Both of these programs have the potential to address 90% of the Common Core Mathematics Standards. The only topics that are not routinely addressed through *FIRST* high school level programs are: Understanding of rational, irrational, and imaginary numbers. A full breakdown of the Common Core Mathematics Standards analysis can be found in Table 7.

Table 6: *FIRST* Common Core Mathematics Practice Analysis

Rating Code	Rating Rationale
	Standard is not developmental appropriate for the vast majority of students in that program.
	No evidence that the standard is addressed as part of the program.
	Standard may be addressed through program preparation conducted at local sites. For example, a coach or mentor may have Junior <i>FIRST</i> LEGO® League students group building pieces to determine the number of structures that can be constructed. At an advanced level, a <i>FIRST</i> Robotics Competition coach or mentor may require design decisions to be justified with probability models.
	Standard may be addressed through the design of a particular program's game. For example, in a <i>FIRST</i> LEGO® League game students may be required to fill a cylinder with pieces, not exceeding a given level. This would require that students master the concepts of volume and its geometric principles.
	The standard is clearly addressed by program activities. For example, <i>FIRST</i> Tech Challenge students are going to solve single variable equations in order to program their robots.

Common Core Mathematical Practice	Junior <i>FIRST</i> LEGO® League	<i>FIRST</i> LEGO® League	<i>FIRST</i> Tech Challenge	<i>FIRST</i> Robotics Competition
Make sense of problems and persevere in solving them.				
Reason abstractly and quantitatively.				
Construct viable arguments and critique the reasoning of others.				
Model with mathematics.				
Use appropriate tools strategically.				
Attend to precision.				
Look for and make use of structure.				
Look for and express regularity in repeated reasoning.				

Table 7: *FIRST* Common Core Mathematics Standards Analysis

Rating Code	Rating Rationale
	Standard is not developmental appropriate for the vast majority of students in that program.
	No evidence that the standard is addressed as part of the program.
	Standard may be addressed through program preparation conducted at local sites. For example, a coach or mentor may have Junior <i>FIRST</i> LEGO® League students group building pieces to determine the number of structures that can be constructed. At an advanced level, a <i>FIRST</i> Robotics Competition coach or mentor may require design decisions to be justified with probability models.
	Standard may be addressed through the design of a particular program’s game. For example, in a <i>FIRST</i> LEGO® League game students may be required to fill a cylinder with pieces, not exceeding a given level. This would require that students master the concepts of volume and its geometric principles.
	The standard is clearly addressed by program activities. For example, <i>FIRST</i> Tech Challenge students are going to solve single variable equations in order to program their robots.

Common Core Mathematics Standards	Junior <i>FIRST</i> LEGO® League	<i>FIRST</i> LEGO® League	<i>FIRST</i> Tech Challenge	<i>FIRST</i> Robotics Competition
<i>Kindergarten through Third Grade Standards</i>				
<b>Counting and Cardinality</b>				
Know number names and the count sequence.				
Count to tell the number of objects.				
Compare numbers.				
<b>Operations and Algebraic Thinking</b>				
Understand addition as putting together and adding to, and understand subtraction as taking apart and taking from.				
Represent and solve problems involving addition and subtraction.				
Understand and apply properties of operations and the relationship between addition and subtraction.				
Add and subtract within 20.				
Work with addition and subtraction equations.				
Represent and solve problems involving addition and subtraction.				
Work with equal groups of objects to gain foundations for multiplication.				
Represent and solve problems involving multiplication and division.				
Understand properties of multiplication and the relationship between multiplication and division.				
Multiply and divide within 100.				
Solve problems involving the four operations, and identify and explain patterns in arithmetic.				

Table 7: *FIRST* Common Core Mathematics Standards Analysis (continued)

Common Core Mathematics Standards	Junior <i>FIRST</i> LEGO® League	<i>FIRST</i> LEGO® League	<i>FIRST</i> Tech Challenge	<i>FIRST</i> Robotics Competition
<i>Kindergarten through Third Grade Standards (continued)</i>				
<b>Number and Operations in Base Ten</b>				
Work with numbers 11–19 to gain foundations for place value.				
Extend the counting sequence.				
Understand place value.				
Use place value understanding and properties of operations to add and subtract.				
Use place value understanding and properties of operations to perform multi-digit arithmetic.				
<b>Number and Operations—Fractions</b>				
Develop understanding of fractions as numbers.				
<b>Measurement and Data</b>				
Describe and compare measurable attributes.				
Classify objects and count the number of objects in categories.				
Measure lengths indirectly and by iterating length units.				
Tell and write time.				
Represent and interpret data.				
Measure and estimate lengths in standard units.				
Relate addition and subtraction to length.				
Work with time and money.				
Geometric measurement: recognize perimeter as an attribute of plane figures and distinguish between linear and area measures.				
Solve problems involving measurement and estimation of intervals of time, liquid volumes, and masses of objects.				
Geometric measurement: understand concepts of area and relate area to multiplication and to addition.				
<b>Geometry</b>				
Identify and describe shapes.				
Analyze, compare, create, and compose shapes.				
Reason with shapes and their attributes.				
<i>Fourth through Fifth Grade Standards</i>				
<b>Operations and Algebraic Thinking</b>				
Use the four operations with whole numbers to solve problems.				
Gain familiarity with factors and multiples.				

Table 7: *FIRST* Common Core Mathematics Standards Analysis (continued)

Common Core Mathematics Standards	Junior <i>FIRST</i> LEGO® League	<i>FIRST</i> LEGO® League	<i>FIRST</i> Tech Challenge	<i>FIRST</i> Robotics Competition
<i>Fourth through Fifth Grade Standards (continued)</i>				
<b>Operations and Algebraic Thinking (continued)</b>				
Generate and analyze patterns.				
Write and interpret numerical expressions.				
Analyze patterns and relationships.				
<b>Number and Operations in Base Ten</b>				
Generalize place value understanding for multi-digit whole numbers.				
Use place value understanding and properties of operations to perform multi-digit arithmetic.				
Understand the place value system.				
Perform operations with multi-digit whole numbers and with decimals to hundredths.				
<b>Number and Operations—Fractions</b>				
Extend understanding of fraction equivalence and ordering.				
Build fractions from unit fractions by applying and extending previous understandings of operations on whole numbers.				
Understand decimal notation for fractions, and compare decimal fractions.				
Use equivalent fractions as a strategy to add and subtract fractions.				
Apply and extend previous understandings of multiplication and division to multiply and divide fractions.				
<b>Measurement and Data</b>				
Solve problems involving measurement and conversion of measurements from a larger unit to a smaller unit.				
Represent and interpret data.				
Geometric measurement: understand concepts of angle and measure angles.				
Convert like measurement units within a given measurement system.				
Geometric measurement: understand concepts of volume and relate volume to multiplication and to addition.				
<b>Geometry</b>				
Draw and identify lines and angles, and classify shapes by properties of their lines and angles.				
Graph points on the coordinate plane to solve real-world and mathematical problems.				

Table 7: *FIRST* Common Core Mathematics Standards Analysis (continued)

Common Core Mathematics Standards	Junior <i>FIRST</i> LEGO® League	<i>FIRST</i> LEGO® League	<i>FIRST</i> Tech Challenge	<i>FIRST</i> Robotics Competition
<i>Fourth through Fifth Grade Standards (continued)</i>				
<b>Geometry (continued)</b>				
Classify two-dimensional figures into categories based on their properties.				
<i>Sixth through Eighth Grade Standards</i>				
<b>Ratios and Proportional Relationships</b>				
Understand ratio concepts and use ratio reasoning to solve problems.				
Analyze proportional relationships and use them to solve real-world and mathematical problems.				
<b>The Number System</b>				
Apply and extend previous understandings of multiplication and division to divide fractions by fractions.				
Compute fluently with multi-digit numbers and find common factors and multiples.				
Apply and extend previous understandings of numbers to the system of rational numbers.				
Apply and extend previous understandings of operations with fractions to add, subtract, multiply, and divide rational numbers.				
Know that there are numbers that are not rational, and approximate them by rational numbers.				
<b>Expressions and Equations</b>				
Apply and extend previous understandings of arithmetic to algebraic expressions.				
Reason about and solve one-variable equations and inequalities.				
Represent and analyze quantitative relationships between dependent and independent variables.				
Use properties of operations to generate equivalent expressions.				
Solve real-life and mathematical problems using numerical and algebraic expressions and equations.				
Work with radicals and integer exponents.				
Understand the connections between proportional relationships, lines, and linear equations.				
Analyze and solve linear equations and pairs of simultaneous linear equations.				

Table 7: *FIRST* Common Core Mathematics Standards Analysis (continued)

Common Core Mathematics Standards	Junior <i>FIRST</i> LEGO® League	<i>FIRST</i> LEGO® League	<i>FIRST</i> Tech Challenge	<i>FIRST</i> Robotics Competition
<i>Sixth through Eighth Grade Standards (continued)</i>				
<b>Functions</b>				
Define, evaluate, and compare functions.				
Use functions to model relationships between quantities.				
<b>Geometry</b>				
Solve real-world and mathematical problems involving area, surface area, and volume.				
Draw, construct and describe geometrical figures and describe the relationships between them.				
Solve real-life and mathematical problems involving angle measure, area, surface area, and volume.				
Understand congruence and similarity using physical models, transparencies, or geometry software.				
Understand and apply the Pythagorean Theorem.				
Solve real-world and mathematical problems involving volume of cylinders, cones and spheres.				
<b>Statistics and Probability</b>				
Develop understanding of statistical variability.				
Summarize and describe distributions.				
Use random sampling to draw inferences about a population.				
Draw informal comparative inferences about two populations.				
Investigate chance processes and develop, use, and evaluate probability models.				
Investigate patterns of association in bivariate data.				
<i>High School Mathematics Standards</i>				
<b>NUMBER &amp; QUANTITY</b>				
<b>The Real Number System</b>				
Extend the properties of exponents to rational exponents.				
Use properties of rational and irrational numbers.				
<b>Quantities</b>				
Reason quantitatively and use units to solve problems.				

Table 7: *FIRST* Common Core Mathematics Standards Analysis (continued)

Common Core Mathematics Standards	Junior <i>FIRST</i> LEGO® League	<i>FIRST</i> LEGO® League	<i>FIRST</i> Tech Challenge	<i>FIRST</i> Robotics Competition
<i>High School Mathematics Standards (continued)</i>				
NUMBER & QUANTITY (continued)				
<b>The Complex Number System</b>				
Perform arithmetic operations with complex numbers.				
Represent complex numbers and their operations on the complex plane.				
Use complex numbers in polynomial identities and equations.				
<b>Vector and Matrix Quantities</b>				
Represent and model with vector quantities.				
Perform operations on vectors.				
Perform operations on matrices and use matrices in applications.				
ALGEBRA				
<b>Seeing Structure in Expressions</b>				
Interpret the structure of expressions.				
Write expressions in equivalent forms to solve problems.				
<b>Arithmetic with Polynomials and Rational Expressions</b>				
Perform arithmetic operations on polynomials.				
Understand the relationship between zeros and factors of polynomials.				
Use polynomial identities to solve problems.				
Rewrite rational expressions.				
<b>Creating Equations</b>				
Create equations that describe numbers or relationships.				
<b>Reasoning with Equations and Inequalities</b>				
Understand solving equations as a process of reasoning and explain the reasoning.				
Solve equations and inequalities in one variable.				
Solve systems of equations.				
Represent and solve equations and inequalities graphically.				
FUNCTIONS				
<b>Interpreting Functions</b>				
Understand the concept of a function and use function notation.				
Interpret functions that arise in applications in terms of the context.				
Analyze functions using different representations.				

Table 7: *FIRST* Common Core Mathematics Standards Analysis (continued)

Common Core Mathematics Standards	Junior <i>FIRST</i> LEGO® League	<i>FIRST</i> LEGO® League	<i>FIRST</i> Tech Challenge	<i>FIRST</i> Robotics Competition
<i>High School Mathematics Standards (continued)</i>				
<b>FUNCTIONS (continued)</b>				
<b>Building Functions</b>				
Build a function that models a relationship between two quantities.				
Build new functions from existing functions.				
<b>Linear, Quadratic, and Exponential Models</b>				
Construct and compare linear, quadratic, and exponential models and solve problems.				
Interpret expressions for functions in terms of the situation they model.				
<b>Trigonometric Functions</b>				
Extend the domain of trigonometric functions using the unit circle.				
Model periodic phenomena with trigonometric functions.				
Prove and apply trigonometric identities.				
<b>MODELING</b>				
Identify variables in the situation and select those that represent essential features.				
Formulate a model by creating and selecting geometric, graphical, tabular, algebraic, or statistical representations that describe relationships between the variables.				
Analyze and perform operation on these relationships to draw conclusions.				
Interpret the results of the mathematics in terms of the original situation.				
Validate the conclusions by comparing them with the situation.				
Improve the model, if warranted.				
Report on the conclusions and the reasoning behind them (e.g. choices, assumptions, and approximations present throughout this cycle).				
<b>GEOMETRY</b>				
<b>Congruence</b>				
Experiment with transformations in the plane.				
Understand congruence in terms of rigid motions.				
Prove geometric theorems.				
Make geometric constructions.				

Table 7: *FIRST* Common Core Mathematics Standards Analysis (continued)

Common Core Mathematics Standards	Junior <i>FIRST</i> LEGO® League	<i>FIRST</i> LEGO® League	<i>FIRST</i> Tech Challenge	<i>FIRST</i> Robotics Competition
<i>High School Mathematics Standards (continued)</i>				
<b>GEOMETRY (continued)</b>				
<b>Similarity, Right Triangles, and Trigonometry</b>				
Understand similarity in terms of similarity transformations.				
Prove theorems involving similarity.				
Define trigonometric ratios and solve problems involving right triangles.				
Apply trigonometry to general triangles.				
<b>Circles</b>				
Understand and apply theorems about circles.				
Find arc lengths and areas of sectors of circles.				
<b>Expressing Geometric Properties with Equations</b>				
Translate between the geometric description and the equation for a conic section.				
Use coordinates to prove simple geometric theorems algebraically.				
<b>Geometric Measurement and Dimension</b>				
Explain volume formulas and use them to solve problems.				
Visualize relationships between two-dimensional and three-dimensional objects.				
<b>Modeling with Geometry</b>				
Apply geometric concepts in modeling situations.				
<b>STATISTICS &amp; PROBABILITY</b>				
<b>Interpreting Categorical and Quantitative Data</b>				
Summarize, represent, and interpret data on a single count or measurement variable.				
Summarize, represent, and interpret data on two categorical and quantitative variables.				
Interpret linear models.				
<b>Making Inferences and Justifying Conclusions</b>				
Understand and evaluate random processes underlying statistical experiments.				
Make inferences and justify conclusions from sample surveys, experiments and observational studies.				
<b>Conditional Probability and the Rules of Probability</b>				
Understand independence and conditional probability and use them to interpret data.				

Table 7: *FIRST* Common Core Mathematics Standards Analysis (continued)

Common Core Mathematics Standards	Junior <i>FIRST</i> LEGO® League	<i>FIRST</i> LEGO® League	<i>FIRST</i> Tech Challenge	<i>FIRST</i> Robotics Competition
<i>High School Mathematics Standards (continued)</i>				
STATISTICS & PROBABILITY				
<b>Conditional Probability and the Rules of Probability (continued)</b>				
Use the rules of probability to compute probabilities of compound events in a uniform probability model.				
<b>Using Probability to Make Decisions</b>				
Calculate expected values and use them to solve problems.				
Use probability to evaluate outcomes of decisions.				

### 21<sup>st</sup> Century Skills Framework

With regard to the 21<sup>st</sup> Century Skills Framework developed by the Partnership for 21<sup>st</sup> Century Skills (Table 8), analysis shows that these skills are also well addressed by all levels of *FIRST* programming. Between 76% and 83% of the skills identified by this organization to be successful in the 21<sup>st</sup> Century economy are potentially addressed by a *FIRST* program. In a unique difference from the Common Core Mathematics Standards, Junior *FIRST* LEGO® League and *FIRST* LEGO® League have the potential to address more standards, 83% and 84% respectively, than either the *FIRST* Tech Challenge or the *FIRST* Robotics Competition, both at 76%. This likely occurs because both Junior *FIRST* LEGO® League and *FIRST* LEGO® League use of an overarching theme to organize their programs and include a formal research requirement. This means that standards addressing 21<sup>st</sup> Century Global Issues and Information Literacy are potentially met by those programs. With the focus on engineering and ultimately a head to head competition *FIRST* Tech Challenge or the *FIRST* Robotics Competition do not offer this opportunity. A full breakdown of 21<sup>st</sup> Century Skills Framework analysis can be found in Table 8.

Table 8: *FIRST* 21<sup>st</sup> Century Skills Analysis

Rating Code	Rating Rationale
	No evidence that the standard is addressed as part of the program.
	Standard may be addressed through program preparation conducted at local sites.
	Standard may be addressed through the design of a particular program’s game.
	The standard is clearly addressed by program activities.

Table 8: *FIRST* 21<sup>st</sup> Century Skills Analysis

21 <sup>st</sup> Century Learning Skills	Junior <i>FIRST</i> LEGO® League	<i>FIRST</i> LEGO® League	<i>FIRST</i> Tech Challenge	<i>FIRST</i> Robotics Competition
<i>21st century interdisciplinary themes</i>				
<b>Global Awareness</b>				
Using 21st century skills to understand and address global issues.				
Learning from and working collaboratively with individuals representing diverse cultures, religions and lifestyles in a spirit of mutual respect and open dialogue in personal, work and community contexts.				
Understanding other nations and cultures, including the use of non-English languages.				
<b>Financial, Economic, Business and Entrepreneurial Literacy</b>				
Knowing how to make appropriate personal economic choices.				
Understanding the role of the economy in society.				
Using entrepreneurial skills to enhance workplace productivity and career options.				
<b>Civic Literacy</b>				
Participating effectively in civic life through knowing how to stay informed and understanding governmental processes.				
Exercising the rights and obligations of citizenship at local, state, national and global levels.				
Understanding the local and global implications of civic decisions.				
<b>Health Literacy</b>				
Obtaining, interpreting and understanding basic health information and services and using such information and services in ways that enhance health.				
Understanding preventive physical and mental health measures, including proper diet, nutrition, exercise, risk avoidance and stress reduction.				
Using available information to make appropriate health-related decisions.				
Establishing and monitoring personal and family health goals.				
Understanding national and international public health and safety issues.				
<b>Environmental Literacy</b>				
Demonstrate knowledge and understanding of the environment and the circumstances and conditions affecting it, particularly as relates to air, climate, land, food, energy, water and ecosystems.				

Table 8: *FIRST* 21<sup>st</sup> Century Skills Analysis (continued)

21 <sup>st</sup> Century Learning Skills	Junior <i>FIRST</i> LEGO® League	<i>FIRST</i> LEGO® League	<i>FIRST</i> Tech Challenge	<i>FIRST</i> Robotics Competition
<i>21st century interdisciplinary themes (continued)</i>				
<b>Environmental Literacy (continued)</b>				
Demonstrate knowledge and understanding of society's impact on the natural world (e.g., population growth, population development, resource consumption rate, etc.).				
Investigate and analyze environmental issues, and make accurate conclusions about effective solutions.				
Take individual and collective action towards addressing environmental challenges (e.g., participating in global actions, designing solutions that inspire action on environmental issues).				
<i>CREATIVITY AND INNOVATION</i>				
<b>LEARNING AND INNOVATION SKILLS</b>				
<b>Think Creatively</b>				
Use a wide range of idea creation techniques (such as brainstorming).				
Create new and worthwhile ideas (both incremental and radical concepts).				
Elaborate, refine, analyze and evaluate their own ideas in order to improve and maximize creative efforts.				
<b>Work Creatively with Others</b>				
Develop, implement and communicate new ideas to others effectively.				
Be open and responsive to new and diverse perspectives; incorporate group input and feedback into the work.				
Demonstrate originality and inventiveness in work and understand the real world limits to adopting new ideas.				
View failure as an opportunity to learn; understand that creativity and innovation is a long-term, cyclical process of small successes and frequent mistakes.				
<b>Implement Innovations</b>				
Act on creative ideas to make a tangible and useful contribution to the field in which the innovation will occur.				
<b>CRITICAL THINKING AND PROBLEM SOLVING</b>				
<b>Reason Effectively</b>				
Use various types of reasoning (inductive, deductive, etc.) as appropriate to the situation.				

Table 8: *FIRST* 21<sup>st</sup> Century Skills Analysis (continued)

21 <sup>st</sup> Century Learning Skills	Junior <i>FIRST</i> LEGO® League	<i>FIRST</i> LEGO® League	<i>FIRST</i> Tech Challenge	<i>FIRST</i> Robotics Competition
<i>CREATIVITY AND INNOVATION (continued)</i>				
<b>CRITICAL THINKING AND PROBLEM SOLVING (continued)</b>				
<b>Use Systems Thinking</b>				
Analyze how parts of a whole interact with each other to produce overall outcomes in complex systems.				
<b>Make Judgments and Decisions</b>				
Effectively analyze and evaluate evidence, arguments, claims and beliefs.				
Analyze and evaluate major alternative points of view.				
Synthesize and make connections between information and arguments.				
Interpret information and draw conclusions based on the best analysis.				
Reflect critically on learning experiences and processes.				
<b>Solve Problems</b>				
Solve different kinds of non-familiar problems in both conventional and innovative ways.				
Identify and ask significant questions that clarify various points of view and lead to better solutions.				
<b>COMMUNICATION AND COLLABORATION</b>				
<b>Communicate Clearly</b>				
Articulate thoughts and ideas effectively using oral, written and nonverbal communication skills in a variety of forms and contexts.				
Listen effectively to decipher meaning, including knowledge, values, attitudes and intentions.				
Use communication for a range of purposes (e.g. to inform, instruct, motivate and persuade).				
Utilize multiple media and technologies, and know how to judge their effectiveness a priori as well as assess their impact.				
Communicate effectively in diverse environments (including multi-lingual).				
<b>Collaborate with Others</b>				
Demonstrate ability to work effectively and respectfully with diverse teams.				
Exercise flexibility and willingness to be helpful in making necessary compromises to accomplish a common goal.				

Table 8: *FIRST* 21<sup>st</sup> Century Skills Analysis (continued)

21 <sup>st</sup> Century Learning Skills	Junior <i>FIRST</i> LEGO® League	<i>FIRST</i> LEGO® League	<i>FIRST</i> Tech Challenge	<i>FIRST</i> Robotics Competition
<i>CREATIVITY AND INNOVATION (continued)</i>				
<b>COMMUNICATION AND COLLABORATION (continued)</b>				
<b>Collaborate with Others</b>				
Assume shared responsibility for collaborative work, and value the individual contributions made by each team member.				
<i>INFORMATION, MEDIA AND TECHNOLOGY SKILLS</i>				
<b>INFORMATION LITERACY</b>				
<b>Access and Evaluate Information</b>				
Access information efficiently (time) and effectively (sources).				
Evaluate information critically and competently.				
<b>Use and Manage Information</b>				
Use information accurately and creatively for the issue or problem at hand.				
Manage the flow of information from a wide variety of sources.				
Apply a fundamental understanding of the ethical/legal issues surrounding the access and use of information.				
<b>MEDIA LITERACY</b>				
<b>Analyze Media</b>				
Understand both how and why media messages are constructed, and for what purposes.				
Examine how individuals interpret messages differently, how values and points of view are included or excluded, and how media can influence beliefs and behaviors.				
Apply a fundamental understanding of the ethical/legal issues surrounding the access and use of media.				
<b>Create Media Products</b>				
Understand and utilize the most appropriate media creation tools, characteristics and conventions.				
Understand and effectively utilize the most appropriate expressions and interpretations in diverse, multi-cultural environments.				
<b>ICT (Information, Communications and Technology) LITERACY</b>				
<b>Apply Technology Effectively</b>				
Use technology as a tool to research, organize, evaluate and communicate information.				

Table 8: *FIRST* 21<sup>st</sup> Century Skills Analysis (continued)

21 <sup>st</sup> Century Learning Skills	Junior <i>FIRST</i> LEGO® League	<i>FIRST</i> LEGO® League	<i>FIRST</i> Tech Challenge	<i>FIRST</i> Robotics Competition
<i>INFORMATION, MEDIA AND TECHNOLOGY SKILLS</i>				
<b>ICT (Information, Communications and Technology) LITERACY (continued)</b>				
<b>Apply Technology Effectively (continued)</b>				
Use digital technologies (computers, PDAs, media players, GPS, etc.), communication/networking tools and social networks appropriately to access, manage, integrate, evaluate and create information to successfully function in a knowledge economy.				
Apply a fundamental understanding of the ethical/legal issues surrounding the access and use of information technologies.				
<i>LIFE AND CAREER SKILLS</i>				
<b>FLEXIBILITY AND ADAPTABILITY</b>				
<b>Adapt to Change</b>				
Adapt to varied roles, jobs responsibilities, schedules and contexts.				
Work effectively in a climate of ambiguity and changing priorities.				
<b>Be Flexible</b>				
Incorporate feedback effectively.				
Deal positively with praise, setbacks and criticism.				
Understand, negotiate and balance diverse views and beliefs to reach workable solutions, particularly in multi-cultural environments.				
<b>INITIATIVE AND SELF-DIRECTION</b>				
<b>Manage Goals and Time</b>				
Set goals with tangible and intangible success criteria.				
Balance tactical (short-term) and strategic (long-term) goals.				
Utilize time and manage workload efficiently.				
<b>Work Independently</b>				
Monitor, define, prioritize and complete tasks without direct oversight.				
<b>Be Self-directed Learners</b>				
Go beyond basic mastery of skills and/or curriculum to explore and expand one's own learning and opportunities to gain expertise.				
Demonstrate initiative to advance skill levels towards a professional level.				
Demonstrate commitment to learning as a lifelong process.				

Table 8: *FIRST* 21<sup>st</sup> Century Skills Analysis (continued)

21 <sup>st</sup> Century Learning Skills	Junior <i>FIRST</i> LEGO® League	<i>FIRST</i> LEGO® League	<i>FIRST</i> Tech Challenge	<i>FIRST</i> Robotics Competition
<i>LIFE AND CAREER SKILLS (continued)</i>				
<b>INITIATIVE AND SELF-DIRECTION (continued)</b>				
<b>Be Self-directed Learners (continued)</b>				
Reflect critically on past experiences in order to inform future progress.				
<b>SOCIAL AND CROSS-CULTURAL SKILLS</b>				
<b>Interact Effectively with Others</b>				
Know when it is appropriate to listen and when to speak.				
Conduct themselves in a respectable, professional manner.				
<b>Work Effectively in Diverse Teams</b>				
Respect cultural differences and work effectively with people from a range of social and cultural backgrounds.				
Respond open-mindedly to different ideas and values.				
Leverage social and cultural differences to create new ideas and increase both innovation and quality of work.				
<b>PRODUCTIVITY AND ACCOUNTABILITY</b>				
<b>Manage Projects</b>				
Set and meet goals, even in the face of obstacles and competing pressures.				
Prioritize, plan and manage work to achieve the intended result.				
<b>Produce Results</b>				
Work positively and ethically.				
Multi-task.				
Participate actively, as well as be reliable and punctual.				
Present oneself professionally and with proper etiquette.				
Collaborate and cooperate effectively with teams.				
Respect and appreciate team diversity.				
Be accountable for results.				
<b>LEADERSHIP AND RESPONSIBILITY</b>				
<b>Guide and Lead Others</b>				
Use interpersonal and problem-solving skills to influence and guide others toward a goal.				
Leverage strengths of others to accomplish a common goal.				
Inspire others to reach their very best via example and selflessness.				

Table 8: *FIRST* 21<sup>st</sup> Century Skills Analysis (continued)

21 <sup>st</sup> Century Learning Skills	Junior <i>FIRST</i> LEGO® League	<i>FIRST</i> LEGO® League	<i>FIRST</i> Tech Challenge	<i>FIRST</i> Robotics Competition
<i>LIFE AND CAREER SKILLS (continued)</i>				
<b>LEADERSHIP AND RESPONSIBILITY (continued)</b>				
<b>Guide and Lead Others (continued)</b>				
Demonstrate integrity and ethical behavior in using influence and power.				
<b>Be Responsible to Others</b>				
Act responsibly with the interests of the larger community in mind.				

### National Science Education Standards

*FIRST* programs were least likely to offer opportunities to address the National Science Education Standards (Table 9). *FIRST* programs have the potential to address between 41% and 70% of these standards (Table 5). The best potential standard coverage was observed with the *FIRST* LEGO® League program. This result is not all that surprising in that the National Science Education Standards, developed in 1996, have a strong emphasis on specific science content (e.g. Characteristics of organisms, Geochemical cycles). With the presence of the overarching theme, *FIRST* LEGO® League, and to some extent Junior *FIRST* LEGO® League, is positioned to address these concepts depending upon the theme selected and the challenges used for a given year. This finding may change upon the release of the Next Generation Science Standards called for by the National Research Council and the National Science Teachers Association. These standards are currently under review with a projected release later this calendar year. Examination of early drafts suggest that Engineering and Technology concepts will be featured more prominently in the new standards and will be better distributed across all levels of the K-12 educational system. A full breakdown of National Science Education Standards analysis can be found in Table 9.

Table 9: *FIRST* National Science Education Standards Analysis

Rating Code	Rating Rationale
	No evidence that the standard is addressed as part of the program.
	Standard may be addressed through program preparation conducted at local sites. For example, a coach or mentor may have Junior <i>FIRST</i> LEGO® League students characterize the properties and make-up of all the building materials before starting to build their structures. At an advanced level, a <i>FIRST</i> Robotics Competition coach or mentor teach the students about how energy is converted within the motors of the robot.
	Standard may be addressed through the design of a particular program’s game. For example, in a <i>FIRST</i> LEGO® League game students may be required to complete challenges that simulated the structure of an atom providing an opportunity to learn about atomic structure.
	Standard is addressed through an analogous concept. For example, students can learn about the behavior of organisms by interacting with their robot and programming it to complete tasks.
	The standard is clearly addressed by program activities. For example, <i>FIRST</i> Tech Challenge students are going to solve problems in the competition with their robot. As they engage in this problem solving and design activity they will have the opportunity to learn and develop technological abilities.

Table 9: *FIRST* National Science Education Standards Analysis

National Science Education Standards	Junior <i>FIRST</i> LEGO® League	<i>FIRST</i> LEGO® League	<i>FIRST</i> Tech Challenge	<i>FIRST</i> Robotics Competition
<i>Science as Inquiry Standards</i>				
Abilities necessary to do scientific inquiry.	[Grid Pattern]			
Understanding about scientific inquiry.	[Grid Pattern]			
<i>Physical Science Standards</i>				
Properties of objects and materials.				
Position and motion of objects.				
Light, heat, electricity, and magnetism.				
Properties and changes of properties in matter.				
Motions and forces.				
Transfer of energy.				
Structure of atoms.				
Structure and properties of matter.				
Chemical reactions.				
Conservation of energy and increase in disorder.				
Interactions of energy and matter.				
<i>Life Science Standards</i>				
Characteristics of organisms.	[Grid Pattern]			
Life cycles of organisms.	[Grid Pattern]	[Grid Pattern]		
Organisms and environments.		[Grid Pattern]	[Grid Pattern]	[Grid Pattern]
Structure and function in living systems.	[Grid Pattern]	[Grid Pattern]	[Grid Pattern]	[Grid Pattern]
Reproduction and heredity.				
Regulation and behavior.		[Grid Pattern]	[Grid Pattern]	[Grid Pattern]
Populations and ecosystems.				
Diversity and adaptations of organisms.				
The cell.				
Molecular basis of heredity.				
Biological evolution.				
Interdependence of organisms.		[Grid Pattern]	[Grid Pattern]	[Grid Pattern]
Matter, energy, and organization in living systems.				
Behavior of organisms.		[Grid Pattern]	[Grid Pattern]	[Grid Pattern]
<i>Earth and Space Science Standards</i>				
Properties of earth materials.				
Objects in the sky.				
Changes in earth and sky.				
Structure of the earth system.				
Earth's history.				
Earth in the solar system.				
Energy in the earth system.				
Geochemical cycles.				

Table 9: *FIRST* National Science Education Standards Analysis (continued)

National Science Education Standards	Junior <i>FIRST</i> LEGO® League	<i>FIRST</i> LEGO® League	<i>FIRST</i> Tech Challenge	<i>FIRST</i> Robotics Competition
<i>Earth and Space Science Standards (continued)</i>				
Origin and evolution of the earth system.				
Origin and evolution of the universe.				
<i>Science and Technology Standards</i>				
Abilities to distinguish between natural objects and objects made by humans.				
Abilities of technological design.				
Understanding about science and technology.				
<i>Science in Personal and Social Perspectives</i>				
Personal health.				
Characteristics and changes in populations.				
Types of resources.				
Changes in environments.				
Science and technology in local challenges.				
Populations, resources, and environments.				
Natural hazards.				
Risks and benefits.				
Science and technology in society.				
Personal and community health.				
Population growth.				
Natural resources.				
Environmental quality.				
Natural and human-induced hazards.				
Science and technology in local, national, and global challenges.				
<i>History and Nature of Science Standards</i>				
Science as a human endeavor.				
Nature of science.				
History of science.				
Nature of scientific knowledge.				
Historical perspectives.				

**Additional Findings**

Besides collecting data about the accuracy and presentation of the Standards Alignment Analysis the surveys also asked questions about:

- How might this analysis be used by coaches and mentors?

- How should this information be distributed?
- Would this information lead to changes in how they approached *FIRST*?

The findings associated with these questions are elaborated on in the following sections.

### **How might this analysis be used by coaches and mentors?**

Respondents reported that the information about standards alignment would be useful to their work with *FIRST* programs. Overall, 73% of all respondents indicated that they agreed or strongly agreed with the usefulness of this information. As one respondent reported:

*Connecting it to the standards adds value to the program when trying to convince administrators and museum directors why they should implement a Lego League at their facility.*

Besides being a useful tool for communicating about *FIRST* programs to a less engaged audience, 60% of the mentor and coach respondents felt that this information would make it easier to use *FIRST* activities during the school day. As one respondent reported:

*The document was superb. Very easy to follow and prompted ideas on how to integrate with lesson planning.*

### **How should this information be distributed?**

When it came to distributing the information, the respondents were offered two venues, on the web and with the *FIRST* print materials as possible distribution options. A greater percentage of respondents (82%) agreed or strongly agreed with this information being featured on the *FIRST* website than agreed or strongly agreed (71%) with this information being included with the *FIRST* printed coaching materials. Two possible explanations for this result may be found in other responses that were provided. First, it is possible that this information along with all the other information provided by *FIRST* may be too much to respond to at the start of a program season. As one respondent wrote:

*I think it takes a few years of coaching to feel comfortable enough with the program to really start thinking about these things, it could even overwhelm a new coach.*

Additionally, several respondents suggested changes to the graphics and layout of the document. While finding the information useful they felt it was difficult to navigate. Placement on the internet would allow for more search features to accompany the information and resolve some of the issues mentioned.

### **Would this information lead to changes in how they approached *FIRST*?**

While 65% of respondents agreed or strongly agreed that using the information provided would make their *FIRST* program better, only 42% agreed or strongly agreed that the information would change how they structured their *FIRST* program. One respondent reported that:

*...this document is so good that it makes a little more work because now I'm not as naive and I know how important it will be to get this information shared with others and apply these standards effectively in the program.*

Another explanation for the difference between these two linked questions may be found in this quote from a respondent:

*A big THANK YOU to everyone involved to pull this off! This is information that I think many people involved with FIRST really believe, and now it is almost complete, in a concise document, in a user-friendly format, and gives substantial confirmation of everything we thought to be true, but couldn't fully support.*

Given that the most popular response regarding how are coaches and mentors are currently using educational standards with their *FIRST* programs was “Educational standards help me show the value of *FIRST* to my school administrators” it is not surprising that the information would be helpful but not immediately change practice in all cases.

### **Other Comments for Future Consideration**

As part of the survey process, respondents had an opportunity to answer four open ended items. Three of the items asked the respondents to give feedback about the analysis for a particular set of educational standards. The fourth item was an opportunity to provide feedback about the project on any topic that was not specifically asked for by prior items. While a number of the comments addressed issues with the analysis or provided more detailed answers several comments brought up issues for future consideration with this project. The three most relevant ideas for possible extension of this work are highlighted here for the Education Working Group’s consideration.

### **Examples and Teaching Ideas**

By far the most common comment, mentioned on 23 occasions, asked that specific examples of how to address the standards are provided along with the alignment analysis of *FIRST* programs and educational standards. Some examples of the comments are:

*After each section, there should be examples of how some or all standards can be applied in the classroom or in a team setting, for example: Work with equal groups of objects to gain foundations for multiplication (JrFLL) The team members will arrange LEGO® bricks and discuss the color and or stacking arrays. I have found in the past with many educators if it is not "in their face" they will not necessarily have the time or means to implement.*

*I would include typical math problems that can be used to test whether the standard is met or not.*

*...specific examples will need to be included in order for a non-mathematics instructor (or someone not familiar with the standards) to effectively use this document.*

This finding was to be expected as the standards and their accompanying alignment documents that gain the most traction in the educational community are the ones that provide some instructional ideas or resources. The challenge for *FIRST* will be in deciding how much additional information will be provided because this can quickly become a very time consuming and involved task. One respondent broached the idea of addressing this issue with a resource exchange or forum. Essentially an online space where teachers can post and share information. Another respondent suggested that:

*Since my experience is primarily with Jr. FIRST LEGO® League, the only thing that I would find helpful is perhaps a reference to which standards are being met by the particular challenge. Two years ago when we worked on biomedical engineering, we hit a lot of the Science objectives.*

### **Audience Specific**

With not all *FIRST* coaches and mentors being classroom teachers some comments suggested a need for more audience specific documents. Some representative comments were:

*When sharing the document or the information on the website, it should also be parent friendly. That is, focusing on how having your child involved in FIRST will help him/her succeed in school and the work place, based on the universal standards that are within the Common Core and throughout the country.*

*The document is not user friendly for coaches that may not be teachers and are not familiar with educational standards and how to use them. Suggest creating a different guide for parents that presents the information in a lay format. Maybe bullets or something like that.*

### **Other Standards**

This analysis only explored the alignment between *FIRST* programs and three different sets of educational standards. Given the nature of the *FIRST* programs and how they can be implemented differently at the participating sites it is conceivable that other standards may be addressed by the programs. Two such standard sets, Common Core Language Arts and Fine Arts Standards, were mentioned during data collection. In addition, a “Next Generation” of national science standards is expected to be released and adopted in late 2012 or early 2013. The expectation is these standards will become the basis for curricula and assessments in the next few years. Their adoption will make the information provided by the current alignment obsolete.

## **Appendix A: Online Survey for Headquarters Staff**

## **Appendix B: Online Survey for Coaches and Mentors**