Exploring Physics Curriculum App
NGSS and Mathematics Common Core
Alignment Study

Alignment by eUnit to Mathematics Practices

NGSS Alignment was conducted by the Biological Sciences Curricular Study (BSCS), Colorado Springs, Co, 2014.

Exploring Physics, The Curriculum App is an interactive inquiry- and modeling-based conceptual physics curriculum. It combines hands-on activities with a discussion-based pedagogy where students construct mental models of scientific concepts. The content covers a F year's conceptual physics curriculum for 9th grade through early college.

Exploring Physics is compatible with iPad, PC, Mac and Chromebook platforms.

www.exploringphysics.com

This alignment study focused on one subject area taught during one year of high school, and compared it to all of high school physical science ideas and practices as well as all the high school math standards and practices. No single curriculum is intended to engage students thoroughly in all aspects of the disciplinary core ideas, science practices, math standards and math practices at once. Rather, with this alignment study, BSCS highlighted standards that are M closely connected and supported by the curriculum. It is assumed that other ideas, practices, and standards that are not aligned to or emphasized by this curriculum are more appropriately covered in other subjects and grade levels during high school (i.e., trigonometry, geometry, chemistry).

For reference, Exploring Physics eUnits are listed below		
1. Introduction to Electricity	4. Accelerated Motion	7. Linear Momentum
2. Electrical Circuits	5. Forces and Newton's Laws	8. Energy
3. Uniform Motion	6. Applications of Newton's Laws: Free Fall and Projectile Motion	9. Waves (in preparation)

Common Core State Standards for Mathematics

The alignment study found close connections to the math standards in multiple places within the Number and Quantity, Algebra, Functions, and Statistics domains. With Number and Quantity, M connections were made around units and scales, using the correct measurements for modeling, and solving problems with vectors, such as those with vectors. Within the Algebra domain, the closest connections were made between creating equations with one or more variables and solving for one variable. Within the Functions domain, students were often working primarily with linear functions and using graphs of functions to determine relationships. However, students were not taught about "functions" as a mathematical topic and did not use function notation. As a result, the alignment in this domain was limited because writing functions, in the spirit of the standards, means not only using function notation, but also understanding the definition of a function. The final domain that was often addressed was that in Statistics where students were often plotting variables on a scatterplot (often to show a linear relationship) and then interpreting slope.

The connection to the math standards often repeated the same pattern in each unit, with S units touching on an additional standard, but all units seem to address the same core group of standards (see table below).

Common Core State Standards: Practices of Mathematics

Five of the eight math practices were well addressed in the physics curriculum. Practices addressed are: MP1: Make Sense of Problems and Persevere to Solve Them, MP2: Reason Abstractly and Quantitatively, MP4: Model with Mathematics, MP5: Use Appropriate Tools Strategically (although this was a weak connection), and MP6: Attend to Precision. Multiple units addressed each of these math practices.

There was not enough evidence to support three of the math practices: MP3: Construct viable arguments and critique the reasoning of others, MP7: Look for and make use of structure, and MP8: Look for and express regularity in repeated reasoning. There is a good opportunity for improvement in both MP3: Construct viable arguments and critique the reasoning of others and SP7: Engaging in argument from evidence as both of these math and science practices focus on students developing, evaluating and critique arguments and reasoning of themselves and their peers.

Alignment scheme

A four-level scheme was chosen: Not aligned, Some Alignment, Mostly Aligned, and Fully Aligned. These levels are defined as:

- Not aligned: No evidence was found OR evidence found, but at a lower grade level.
- Some Alignment: Evidence for part of the idea, practice, or standard was found OR students had Swhat superficial engagement with the idea, practice, or standard OR students only had a few opportunities with this idea, practice, or standard.
- Mostly Aligned: Evidence for part or all of the idea, practice, or standard was found AND/OR students had more meaningful engagement with the idea, practice, or standard AND/OR students had multiple opportunities with this idea, practice, or standard [at least 1 AND].

Alignment key:		No Alignment	S	S: Some alignment	M	Mostly aligned	F	Fully aligned

Fully Aligned: Evidence for all of the idea, practice, or standard was found AND students had meaningful engagement with the idea, practice, or standard AND students had multiple opportunities with this idea, practice, or standard.

Detailed Table of Alignment by eUnit to Common Core State Standards Mathematics Practices:

Description of CCSS Math Practices	Exploring Physics eUnits								
	1	2	3	4	5	6	7	8	9
MP1 Make sense of problems and persevere in solving them. Mathematically proficient students start by explaining to themselves the meaning of a problem and looking for entry points to its solution. They analyze givens, constraints, relationships, and goals. They make conjectures about the form and meaning of the solution and plan a solution pathway rather than simply jumping into a solution attempt. They consider analogous problems, and try special cases and simpler forms of the original problem in order to gain insight into its solution. They monitor and evaluate their progress and change course if necessary. Older students might, depending on the context of the problem, transform algebraic expressions or change the viewing window on their graphing calculator to get the information they need. Mathematically proficient students can explain correspondences between equations, verbal descriptions, tables, and graphs or draw diagrams of important features and relationships, graph data, and search for regularity or trends. Younger students might rely on using concrete objects or pictures to help conceptualize and solve a problem. Mathematically proficient students check their answers to problems using a different method, and they continually ask themselves, "Does this make sense?" They can understand the approaches of others to solving complex problems and identify correspondences between different approaches.	S	S	M	M	M	M	M	M	S
MP2 Reason abstractly and quantitatively. Mathematically proficient students make sense of quantities and their relationships in problem situations. They bring two complementary abilities to bear on problems involving quantitative relationships: the ability to decontextualize—to abstract a given situation and represent it symbolically and manipulate the representing symbols as if they have a life of their own, without necessarily attending to their referents—and the ability to contextualize, to pause as needed during the manipulation process in order to probe into the referents for the symbols involved. Quantitative reasoning entails habits of creating a coherent representation of the problem at hand; considering the units involved; attending to the meaning of quantities, not just how to compute them; and knowing and flexibly using different properties of operations and objects.	M	M	F	F	M	F	F	F	M

Alignment key:		No Alignment	S	**S**: Some alignment	M	Mostly aligned	F	Fully aligned

Description of CCSS Math Practices	Exploring Physics eUnits								
	1	2	3	4	5	6	7	8	9
MP3 Construct viable arguments and critique the reasoning of others. Mathematically proficient students understand and use stated assumptions, definitions, and previously established results in constructing arguments. They make conjectures and build a logical progression of statements to explore the truth of their conjectures. They are able to analyze situations by breaking them into cases, and can recognize and use counterexamples. They justify their conclusions, communicate them to others, and respond to the arguments of others. They reason inductively about data, making plausible arguments that take into account the context from which the data arose. Mathematically proficient students are also able to compare the effectiveness of two plausible arguments, distinguish correct logic or reasoning from that which is flawed, and—if there is a flaw in an argument—explain what it is. Elementary students can construct arguments using concrete referents such as objects, drawings, diagrams, and actions. Such arguments can make sense and be correct, even though they are not generalized or made formal until later grades. Later, students learn to determine domains to which an argument applies. Students at all grades can listen or read the arguments of others, decide whether they make sense, and ask useful questions to clarify or improve the arguments.									
MP4 Model with mathematics. Mathematically proficient students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace. In early grades, this might be as simple as writing an addition equation to describe a situation. In middle grades, a student might apply proportional reasoning to plan a school event or analyze a problem in the community. By high school, a student might use geometry to solve a design problem or use a function to describe how one quantity of interest depends on another. Mathematically proficient students who can apply what they know are comfortable making assumptions and approximations to simplify a complicated situation, realizing that these may need revision later. They are able to identify important quantities in a practical situation and map their relationships using such tools as diagrams, two-way tables, graphs, flowcharts and formulas. They can analyze those relationships mathematically to draw conclusions. They routinely interpret their mathematical results in the context of the situation and reflect on whether the results make sense, possibly improving the model if it has not served its purpose.	S	S	M	M	M	M	M	M	M
MP5 Use appropriate tools strategically. Mathematically proficient students consider the available tools when solving a mathematical problem. These tools might include pencil and paper, concrete models, a ruler, a protractor, a calculator, a spreadsheet, a computer algebra system, a statistical package, or dynamic geometry software. Proficient students are sufficiently familiar with tools appropriate for their grade or course to make sound decisions about when each of these tools might be helpful, recognizing both the insight to be gained and their limitations. For example, mathematically proficient high school students analyze graphs of functions and solutions generated using a graphing calculator. They detect possible errors by strategically using estimation and other mathematical knowledge. When making mathematical models, they know that technology can enable them to visualize the results of varying assumptions, explore consequences,									S

Alignment key:		No Alignment	S	**S**: Some alignment	M	Mostly aligned	F	Fully aligned

Description of CCSS Math Practices	Exploring Physics eUnits								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
and compare predictions with data. Mathematically proficient students at various grade levels are able to identify relevant external mathematical resources, such as digital content located on a website, and use them to pose or solve problems. They are able to use technological tools to explore and deepen their understanding of concepts.									
MP6 Attend to precision. Mathematically proficient students try to communicate precisely to others. They try to use clear definitions in discussion with others and in their own reasoning. They state the meaning of the symbols they choose, including using the equal sign consistently and appropriately. They are careful about specifying units of measure, and labeling axes to clarify the correspondence with quantities in a problem. They calculate accurately and efficiently, express numerical answers with a degree of precision appropriate for the problem context. In the elementary grades, students give careFy formulated explanations to each other. By the time they reach high school they have learned to examine claims and make explicit use of definitions.	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**S**
MP7 Look for and make use of structure. Mathematically proficient students look closely to discern a pattern or structure. Young students, for example, might notice that three and seven more is the same amount as seven and three more, or they may sort a collection of shapes according to how many sides the shapes have. Later, students will see 7 × 8 equals the well remembered 7 × 5 + 7 × 3, in preparation for learning about the distributive property. In the expression $x^2 + 9x + 14$, older students can see the 14 as 2 × 7 and the 9 as 2 + 7. They recognize the significance of an existing line in a geometric figure and can use the strategy of drawing an auxiliary line for solving problems. They also can step back for an overview and shift perspective. They can see complicated things, such as S algebraic expressions, as single objects or as being composed of several objects. For example, they can see $5 - 3(x - y)^2$ as 5 minus a positive number times a square and use that to realize that its value cannot be more than 5 for any real numbers x and y.									
Mathematically proficient students notice if calculations are repeated, and look both for general methods and for shortcuts. Upper elementary students might notice when dividing 25 by 11 that they are repeating the same calculations over and over again, and conclude they have a repeating decimal. By paying attention to the calculation of slope as they repeatedly check whether points are on the line through (1, 2) with slope 3, middle school students might abstract the equation $(y - 2)/(x - 1) = 3$. Noticing the regularity in the way terms cancel when expanding $(x - 1)(x + 1)$, $(x - 1)(x^2 + x + 1)$, and $(x - 1)(x^3 + x2 + x + 1)$ might lead them to the general formula for the sum of a geometric series. As they work to solve a problem, mathematically proficient students maintain oversight of the process, while attending to the details. They continually evaluate the reasonableness of their intermediate results.									