Working Together: Mathematics and Physics First

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Project Background

Cross-College Collaboration
University of Missouri
Department of Physics
Science Education
Mathematics Education
Missouri State University
Columbia Public Schools

Partnership with Public Schools:
95 Science Teachers
15 Mathematics Teachers
15 School Administrators

Funded 2006-2008 by MO-DESE
### Physics First: Changing the Sequence

<table>
<thead>
<tr>
<th>Traditional Sequence</th>
<th>Revised Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>9th Grade</td>
<td>9th Grade</td>
</tr>
<tr>
<td>– Biology</td>
<td>– Physics</td>
</tr>
<tr>
<td>10th Grade</td>
<td>10th Grade</td>
</tr>
<tr>
<td>– Chemistry</td>
<td>– Chemistry</td>
</tr>
<tr>
<td>11th Grade</td>
<td>11th Grade</td>
</tr>
<tr>
<td>– Physics</td>
<td>– Biology</td>
</tr>
<tr>
<td>12th Grade</td>
<td>12th Grade</td>
</tr>
<tr>
<td>– Elective</td>
<td>– Elective</td>
</tr>
</tbody>
</table>

### Grant Expectations

- Develop rigorous science curricular materials that are responsive to districts need, aligned with MO-GLEs in content, informed by research, and connected to real-world applications
- Train 9th grade science teachers in modeling and inquiry-based instruction, student assessment, and effective use of technology
- Improve student academic achievement in science and mathematics, increase number of students who succeed in university courses in science and engineering
- Promote interdisciplinary learning and collaboration between science and mathematics teachers
- Increase teachers’ content and pedagogical content knowledge, earn graduate credits, and achieve physics certification
- Provide ongoing support through the effective use of Professional Learning Teams, lesson studies, coaching, and mentoring
Framing Questions for Today’s Session

• What implications does the Physics First program have for the teaching of mathematics in middle and secondary schools in your school district?
• How can the mathematics and science (physics) curricula become better coordinated in your school or school district?
• In what other ways can mathematics teachers support the successful implementation of the Physics First program in your school or school district?

Physics First is Data-Driven and Laden with Mathematics!

Some Mathematics Concepts Embedded in Physics First

• Algebra
  – Literal equations
  – Linear functions
  – Quadratic functions
  – Graphing functions
  – Systems of equations

• Geometry
  – Area (including area under a line in a graph)
  – Tangent lines
  – Similarity
  – Transformational geometry
Physics First is Data-Driven and Laden with Mathematics!

Some Mathematics Concepts Embedded in Physics First

- **Number & Operation**
  - Exponents
  - Scientific notation
  - Ratio and proportion

- **Data Analysis & Probability**
  - Data displays
  - Measures of central tendency and variation
  - Linear and quadratic regression

- **Measurement**
  - Understanding, selecting, and using units of appropriate size to measure phenomena
  - Converting one unit to another unit (“dimensional analysis”)

“Dimensional Analysis”

The World’s Fastest Human can run at an approximate velocity of 10 meters/second. What fast can he run in miles per hour?

<table>
<thead>
<tr>
<th>10 m</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>sec</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The World’s Fastest Human can run at an approximate velocity of 10 meters/second. What fast can he run in miles per hour?

<table>
<thead>
<tr>
<th>10 m</th>
<th>60 sec</th>
<th>60 min</th>
<th>3.26 ft</th>
<th>1 mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>sec</td>
<td>min</td>
<td>hour</td>
<td>m</td>
<td>5280 ft</td>
</tr>
</tbody>
</table>

Answer: 22.22 miles per hour

Translating between Representations

E. Motion of a motorcycle:

From this description, draw a speed vs time graph (don’t forget the units for v and t):

Describe the motion represented in the graph:

Calculate the average speed of this motion.
Emphasis on Slope: Interpreting and Calculating

Constant Speed Problem

- Abby and Whitney are having breakfast at Whitney's house. Suddenly, Whitney remembers that they have track practice that morning, stands up and starts running at a constant speed of 2 meters/second toward the track field that is 800 meters ways from Whitney's house. After 2 minutes, Abby finishes her breakfast and starts running towards the track field at a constant speed of 4 meters/second.
  - At what time does Abby pass Whitney on their way to the track field?
  - Find Abby's position when she passes by Whitney.
  - How much time did Whitney need to reach the track field?
  - How much time did Abby need to reach the track field?
• How might you expect typical 9th graders to solve this problem?
• What different problem solving strategies are available to 9th graders?
• How can mathematics and/or science teachers manage the diversity of strategies for solving this problem?
• What role, if any, does technology play in helping to solve this problem?

**Constant Speed Problem: Range of Strategies**

<table>
<thead>
<tr>
<th>Level</th>
<th>Strategy Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most sophisticated</td>
<td>Setting up and solving a system of two linear equations using a variety of methods</td>
</tr>
<tr>
<td>▲</td>
<td>Setting up one equation and solving it algebraically</td>
</tr>
<tr>
<td>Sophisticated</td>
<td>Graphing Whitney and Abby’s positions, using graphing calculator features to determine precise solution</td>
</tr>
<tr>
<td></td>
<td>Sketching graph of Whitney and Abby’s positions, estimating point of intersection</td>
</tr>
<tr>
<td>Less sophisticated</td>
<td>Creating a table, looking for common position</td>
</tr>
<tr>
<td>▼</td>
<td>Drawing a series of motion diagrams, showing each runner’s position at different times, estimating solution</td>
</tr>
<tr>
<td>Least sophisticated</td>
<td>Guess and check</td>
</tr>
</tbody>
</table>
Some Contrasts between Science & Mathematics Classrooms

Science classrooms:
- Primary emphasis on metric units of measure
- Use of non-standard units (e.g., flashes, tiles)
- Importance of carrying through units when solving a problem
- Heterogeneous grouping of students by ability
- Flexible use of variables
- Data-driven curriculum
- Real-world contextual problems
- “Messy” numbers: decimals (e.g., 0.02631)
- “Positive” can be in any direction
- Extensive use of technology

Mathematics classrooms:
- Emphasis on standard units of measure
- Use of customary units (e.g., seconds, feet)
- Can get away with ignoring units when solving a problem
- Homogeneous grouping of students by ability
- Traditional use of variables
- “Top-down” curriculum
- Contrived problems
- “Clean” numbers: Integers, fractions (e.g., 4, 3/8)
- “Positive” is always “to the right”
- Inconsistent access to technology

Writing Prompts for Science Teachers

1. What challenges have you experienced related to the mathematics of Physics First? Explain.

2. In what ways can mathematics teachers in your building support you in the successful implementation of the Physics First curriculum? Explain.
Patterns in Responses: Issues Specific to Mathematics

- Students struggle to manipulate variables in expressions, equations, and formulas
- Students struggle to correctly interpret the meaning of slope
- Students experience challenges in graphing: Appropriate scales, interpretation of graphs
- Students have little prior knowledge of secant/tangent lines, and quadratic functions
- Student struggle with dimensional analysis/unit conversions
- Students rely on being told what to “plug in” to the calculator

Patterns in Responses: Broader Issues in Teaching Physics First

- Physics First implies many mathematics skills have already been mastered by all students
- Teaching more mathematics than science teachers “signed on” for
- Perceived deficiencies in the mathematics background of science teachers, and feeling they “need help” from mathematics department
- The wide range of mathematics abilities in any Physics First classroom poses challenges to science teachers
Patterns in Responses: Suggestions and Solutions

• More, earlier algebra!
• Expect full answers from students
• Be flexible, using different variables for axes
• Use same terminology:
  \[ x = \text{velocity} \times \text{time} \quad \text{vs.} \quad \text{distance} = \text{rate} \times \text{time} \]
• Give real-life problems to help with connections
• The ability to shuffle sequences of modules
• Use of graphing calculators
• More graphing in 8th grade
• Coordinate algebra problems that relate to Physics First
• Who should tutor? Math or science?

What Science Teachers Want from Mathematics Teachers

• Use more contextualized mathematics problems (instead of typical “naked number” exercises).
• Make numbers mean something!
  • Slope isn’t just a number that is computed -- it represents a rate of change (e.g., miles per hour, price per unit)
• Whenever problems involve units of measure, require students to include units in their final answer and even in each step as they show their work.
• Use of subscripts earlier in the year, transitioning to their use:
  • Time for Whitney \( \Rightarrow T_{\text{Whitney}} \Rightarrow T_W \)
• When using the graphing calculator, require students to understand what the coordinates represent
  • (5.406, 1.362) means “at 5.406 seconds, the cars collide at a position of 1.362 meters from the slower car’s initial position”
What Science Teachers Want from Mathematics Teachers

- Use metric units more often (not just in one lesson on the Metric System)
- Practice Order of Operations problems using Physics First equations
- Provide and emphasize general problem solving skills:
  - What is given?
  - What is unknown?
  - How can I represent what I know?
  - What formula can be applied here?
  - Do I end up with the appropriate units?
  - Is my answer reasonable?
- Begin to use common language or at least point out translations between languages:
  - “dimensional analysis” = “unit conversion”

What Mathematics Teachers Want from Science Teachers

- Obtain a list of all formulas used in Physics First for use in mathematics lessons (e.g., solving literal equations using formula from Physics First)
- Appropriate calculator use!
- Share data sets from Physics First labs for use in math
- List of mathematics concepts in the Physics First materials
- Physics First problems they can incorporate into mathematics lessons and/or homework assignments
  - Area under a velocity-time graph (science) ⇒ Area of a triangle (math)
  - Accelerated motion (science) ⇒ Quadratic functions (math)
- Point out that the formula used in science class is related to the formula used in mathematics class
  - position = velocity * time (science) ⇒ distance = rate * time (mathematics)
What Science & Mathematics Teachers Want from Administrators

• Time at the beginning of the year for mathematics & science teachers to discuss where their curricula overlap
  • Mathematics CLEs that apply to Physics First lessons?
• Time for science and mathematics teachers to better coordinate their respective curricula:
  • Discuss what is taught and when it is taught
  • Consider adjustments to the sequence of topics, units
  • Provide each other updates on our progress through the curriculum
• Opportunities for:
  • Science teachers to observe mathematics classes when needed, especially during units on linear functions
  • Mathematics teachers to observe Physics First lessons that are laden with mathematics.
  • Team teaching some Physics First lessons

Questions?

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Project Website
www.PhysicsFirstMO.org