The Importance of Teacher Content Knowledge for Student Learning

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ATLAST Overview
Implicit Theory of Action

- Professional Development
  - Increased Teacher Knowledge for Teaching Science
  - Improved Classroom Practice in Science
  - Increased K-12 Student Achievement in Science

ATLAST project overview
ATLAST Force and Motion assessment
Preliminary results
Conclusions and implications
Teacher Content Knowledge and Student Learning

- Very thin research base
- Reliance on proxy measures of teacher content knowledge:
  - College GPA
  - College courses taken in a discipline
  - Certification
- Purpose of ATLAST
Implicit Theory of Action

Professional Development → Increased Teacher Knowledge for Teaching Science → Improved Classroom Practice in Science → Increased K-12 Student Achievement in Science
Content Areas

• **Force and motion**
• Processes that shape Earth (Plate Tectonics)
• Flow of matter and energy in living systems
The ATLAST Assessments
Common Features of All Items

- All are multiple choice
- Keyed to a specific idea

For Teacher items specifically:
- Set in context of what teachers do
- Types of items
  - Knowledge of science content
  - Using content knowledge to analyze student thinking
  - Using knowledge to make instructional decisions
Development of Teacher Assessments

1. Clarify the benchmark.
2. Identify student and teacher thinking about the benchmark.
3. Write open-ended items for teachers.
4. Write multiple choice items for teachers.
5. Interview teachers.
6. Pilot and field test items.
7. Create assessment.
Clarifying the Force and Motion Benchmark

- Original Benchmark: An unbalanced force acting on an object changes its speed or direction of motion, or both. If the force acts toward a single center, the object's path may curve into an orbit around the center.

- “Unpack” benchmark into sub-ideas
Examples of Sub-ideas Assessed in Force and Motion

A: A force is a push or pull interaction between two objects, and has both magnitude and direction.

I: If an object has constant speed in a straight line (or zero speed), then there is no net force acting on the object. This can occur either when the forces on the object are balanced, or when there are no forces exerted on the object.

J: The force of friction acts to oppose the relative motion of two objects in contact. Friction acts on both objects along the surfaces in contact with each other.
Examples of Sub-ideas for Teachers Only

**C:** A force diagram uses arrows to represent the forces acting on an object at a particular moment. The length of the arrow represents the relative magnitude of the force. The direction of the arrow represents the direction of the force acting on the object.

**G:** If there is an unbalanced force acting on an object, the greater the strength of the unbalanced force, the greater the change in the object’s velocity.
Sub Idea J

The force of friction acts to oppose the relative motion of two objects in contact. Friction acts on both objects along the surfaces in contact with each other.
A girl kicks a box so that it slides across the level ground. The box moves slower and slower as it slides and eventually stops.

Which one of the following is the best explanation for why the box moves slower and slower?

A. The force due to the kick slowly dies out.
B. The force of friction is acting on the box.
C. The force due to the kick is gradually overcome by the force of friction.
D. The force of friction and the force due to the kick become equal to each other.
A Sample Teacher Item
Sub Idea J

A teacher slides a box across a desk top by giving it a quick push to the right. The teacher asks the students to draw a diagram showing the \textit{horizontal} forces on the box \textit{after} it has left her hand and while it is still moving. Most of the students draw the following diagram:

Which one of the following is a correct assessment of this response?

\begin{itemize}
  \item[A.] The students should \textit{not} have drawn the “force of friction” arrow because friction is not a horizontal force.
  \item[B.] The students should have drawn the arrow representing the teacher’s push longer than the arrow representing friction.
  \item[C.] \textbf{The students should have drawn only the “force of friction” arrow.}
  \item[D.] The students drew and labeled the diagram correctly.
\end{itemize}
The Relationship Between Teacher Content Knowledge and Student Learning

A Preliminary Study
Research Questions

1. Do students score higher on the assessment following instruction, and if so, what is the magnitude of the change?

2. Assuming a significant change in student scores exists, is there a relationship between this change and scores on the teacher assessment?
The Sample of Teachers and Students

- State-funded MSP administered the force and motion teacher assessment to the 60 high school teachers.
- Same teachers were invited to administer the student assessment.
- 25 teachers returned completed materials, representing 1,730 students.
Results

- Post-test student assessment scores were significantly different than the pre-test scores, with an effect size of 0.84 standard deviations.

![Bar chart showing average Force and Motion Student Assessment Scores](chart.png)
Student Gains Linked to Teacher Assessment Scores

- Statistically significant relationship between teacher knowledge of Force and Motion and the change from pre- to post-test on the student Force and Motion assessment
- An effect of 0.19 standard deviations

Student Scores by Teacher Content Knowledge

- Below Average Teacher: Pre-test 48.6, Post-test 63.5
- Average Teacher: Pre-test 48.6, Post-test 67.5
- Above Average Teacher: Pre-test 48.6, Post-test 71.6

*Below and above average refer to one standard deviation below or above the average.
In-depth Look at 1 Sub-idea

I: If an object has constant speed in a straight line (or zero speed), then there is no net force acting on the object. This can occur either when the forces on the object are balanced, or when there are no forces exerted on the object.

Related misconception: If an object is moving at constant speed, there must be a constant net force in the direction of motion.

Two groups of students to look at:
1. Students whose teacher correctly answered two selected items about sub-idea I
2. Students whose teacher did not correctly answer two selected items about sub-idea I
To see how well students understand the force ideas she has been teaching, a teacher asks her students to write statements describing the net force on a ball and its motion. The diagram shows the ball and all the forces acting on it.

Most students in the class write two statements:

“Forces in opposite directions always cancel each other out and result in a net force of zero.” and

“Since the net force acting on the ball is zero, it must not be moving.”

Which one of the following represents the best assessment of these students’ understanding?

A. Both statements are incorrect.
B. Statement 1 is correct and statement 2 is incorrect.
C. Statement 1 is incorrect and statement 2 is correct.
D. Both statements are correct.
A teacher puts a drawing on the board like the one below showing an object and all the forces acting on that object. The teacher asks the students to describe what motion the object could be exhibiting.

One student says,

"The object could be moving to the right at a constant speed."

Which one of the following would be the best assessment of this student's answer?

A. The student is incorrect. The student does not understand that the arrows in the diagram represent the direction of the forces.

B. The student is incorrect. The student does not understand that the length of the arrows in the diagram represents the strength of the forces.

C. The student is incorrect. The student does not understand that the equal and opposite forces cancel each other out.

D. The student's answer is a correct response for the described scenario.
Results for Student I items

Student Post-Test Scores on Sub Idea I Items

Percent Correct

Teacher w/misconception
Teacher w/out misconception

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Student Question

After being hit, a hockey puck moves across the ice until it hits a wall. Imagine there is no friction and no air resistance. Which one of the following best describes the puck's motion after it leaves the stick but before it hits the wall?

A. The puck moves with a constant speed.
B. The puck moves slower and slower.
C. The puck moves at a constant speed for a while, then moves slower and slower.
D. The puck moves faster and faster for a while, then moves slower and slower.
Results for Question 22

Comparison of Two Student Groups for Question 22

- Teachers w/out misconception
  - Pre-Test: 40
  - Post-Test: 70

- Teachers w/ misconception
  - Pre-Test: 40
  - Post-Test: 56

Student Group

Pre-Test
Post-Test
A roller coaster is moving forward along its track in a straight line.

In which one of the following situations is the total force in the direction of the roller coaster's motion equal to the total force in the opposite direction?

A. The roller coaster moves at a constant speed.
B. The roller coaster moves faster and faster.
C. The roller coaster moves slower and slower.
D. The roller coaster moves faster and faster and then moves slower and slower.
Results for Question 1

Comparison of Two Student Groups for Question 1

![Bar chart showing the comparison of two student groups.](chart.png)

- **Teacher w/out misconception**
  - Pre-test: 54%
  - Post-test: 78%

- **Teacher w/misconception**
  - Pre-test: 57%
  - Post-test: 69%

**Legend**
- Green bars: Pre-test
- Blue bars: Post-test

**Notes**
- ATLAST project overview
- ATLAST Force and Motion assessment
- Preliminary results
- Conclusions and implications
Conclusions and Implications
Other Factors Influencing the Data

- Many other factors besides teacher content knowledge affect student learning
- No data collected on instruction
- Project provided all teachers with instructional materials
- Materials are educative for teachers
- Probable that the materials compensated for some gaps in teacher content knowledge
Conclusions

• Student gains on the Force and Motion assessment after instruction were significant

• Higher teacher content knowledge (measured by the ATLAST assessment) relates to higher student gains in Force and Motion

• The study probably underestimated the relationship between teacher content knowledge and student learning
ATLAST

Assessing Teacher Learning About Science Teaching

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