A Sound Beginning: Mr. P and Physical Science

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Day one

It's the first day of school. Students arrive at Mr. P's Physical Science class with a mix of anxiety, interest and uncertainty. What will this year be like in science class? How difficult will the class be? Where are my friends sitting? Who are these new students I do not know? I can't believe I'm sitting in class right now when just yesterday at this time I was fishing at Bear Creek with my best friend Justin, enjoying the last day of summer vacation…

Thoughts are also racing through Mr. P's mind as the students amble into class and take a seat. I can't believe how much Charlie grew this summer. Who are these new students I don't recognize? I hope I give a good introduction to the course and am able to foster some genuine interest in the subject today.

Mr. P sits at his desk calling out roll. When his name is called, each student comes forward to get a copy of his textbook and a marble notebook for class notes. Mr. P stands and instructs the students to take out their notebooks and write today's date on the first page. He goes over basic class procedures and how grading will work. Some students start writing notes right away. Others start once he mentions his "rule" that if it is written on the board then it had better also be written in the notebook.

And then the critical time arrives. All the administrative details are complete. Mr. P has the full attention of the class and twenty-five minutes remain. He knows that what he says now will set the tone for the entire year. He knows that he needs to say something about science, what it is and why we should be interested in learning it. He knows that he needs to specifically explain what this eighth grade Physical Science class is all about. The textbook, though it has some great material on Newton's laws and chemical reactions, is not particularly good at introducing the subject. How should Mr. P begin?

Defining terms

The logical place to start is defining science in general and Physical Science in particular. Doing so addresses the key questions that naturally occur to an interested student: what is going to be covered? What will we learn? What method will we use to gain this knowledge? How does this course fit into the big picture of what we are learning in all our classes? Addressing these questions is one way to respect the students as rational agents, as persons meant to be sovereign knowers.

The problem, however, is that giving a simple definition of science or Physical Science is not easy. Even among scholars in philosophy of science and the history of the philosophy of science there is not a settled definition of modern science. And since experts are unsure about how to best define science it is understandable that it is challenging to say the right things to a class of eighth graders.

What follows is a possible way a particular teacher could begin a Physical Science class for a particular group of eighth graders. This somewhat fictionalized scenario attempts to provide reasonable working definitions of science and Physical Science. These explanations are not only a good start to the course but are something the teacher can refer back to throughout the year, particularly when confusions about what science is interfere with learning. The lesson begins by drawing upon a pre-modern understanding of the word science as knowledge, an approach that is modified to take into consideration that modern science is this type of knowledge only in an analogous and approximate way. This becomes clear when the class learns about the differences between the methods of pre-modern and modern science.

The Lesson

Mr. P starts by writing "Physical Science" on the board. He draws an arrow from science to a working definition given in two bullet points:

- A science is a unified body of knowledge
- A science has a particular subject matter and a particular way this subject matter is considered, a "point of view".

(The word "unified" is circled and another arrow is drawn from it to the 2nd bullet point, emphasizing that the 2nd bullet point describes how a science is a unified body of knowledge.)

Mr. P then explains that there are many examples of sciences. He puts a chart on the board and begins to fill in the chart. Students are encouraged to suggest examples of sciences, which they readily do. Mr. P asks students for input on filling out the columns of the chart. The chart ends up looking like this:

Examples of sciences

Science	Subject matter	Point of View
Medical science	Human body	Health and illness
Military science	Armies, weapons, fortifications	Strategies for defending or attacking a territory
Ballistic science	Projectiles, especially bullets, bombs and rockets	As objects that move through the air, water or space and the methods by which they are launched or propelled

Economics	Money / wealth / resources	How goods and services are produced and distributed
Biology	Living things	As alive and interacting with their environment
Earth science	World around us	Physical structures and features of the earth, the atmosphere and weather
Physical science	Material objects	Changes these objects undergo, both "accidental" (motion, work, temperature) and "substantial" (chemical reactions)
Philosophy	Reality, being, what exists	Truth = correspondence between the mind and reality
Theology	God	What God has revealed to us and, in "natural theology," what we can know about God from unaided reason

This paradigm makes sense to a class of eighth graders. Some of the students joke about studying a human body as a projectile under the science of ballistics, a joke that shows that they are engaged with the explanatory power of this paradigm. At first it is not intuitive to most of them that philosophy and theology are sciences. Mr. P spends a bit of time explaining this.

Mr. P goes deeper the next class. He again writes the words "Physical Science" on the board. He starts by drawing an arrow from science and asks the class for the working definition of the word science and writes it again. Then he draws an arrow from the word physical and asks the class how to define "physical." There is much class discussion, eventually leading to the following notes:

Physical

- Something that has matter
- All physical things are a particular type of thing and can change to become a different type of thing (as opposed to spiritual things)

Q: What distinguishes physical things from spiritual things?

- All physical things can become something else; they can substantially change.
  - To be something is to have a particular nature, to be a particular type of substance
  - Physical things can undergo substantial change, becoming something with a different nature

        - Hydrogen gas and oxygen gas can combine to form water (the resulting water is a new substance that is substantially different from the substances of hydrogen and oxygen – hydrogen continues to be hydrogen only virtually and not formally in water)
        - A living organism can undergo the substantial change of death, losing the principle that accounts for life and consequently start to decay, becoming a corpse, part of the soil, a skeleton, etc.
    - Physical things can also undergo accidental change, change that modifies the thing in some way without changing it from one thing to a different thing (such as moving the thing from one place to another or changing its temperature)
- All spiritual things (ex: angel, God, human soul) cannot become something else.
    - Spiritual things cannot change into a different type of thing (ex: an angel cannot become a tree and a human soul cannot change into a rock)
    - Spiritual things can undergo accidental change (Some "accidental" changes are quite profound: a demon is a fallen angel, an angel which was profoundly changed by its rebellion against God, even though this did not change its nature as a particular spiritual being)

The eighth graders remain intellectually engaged. It makes sense to them that there are both physical and spiritual things and that substantial change is the key differentiating factor between these types of things. They ask logical and interesting questions like if there is a "Spiritual Science"? They search for ways to challenge these definitions and this paradigm. Mr. P allows them to probe further up to a point, judging that this sidetrack is worth the time. This leads to additional notes in response to their questions:

All that exists – all being – can be summarized here:

Fullness of Being	*God*
Chain of being	*Angels*
	Humans
	Animals
	Plants
	Minerals

Being can be divided into spiritual and physical:

Fullness of Being	*God*	Pure spirit – not physical	
Chain of being	*Angels*		
	Humans	Both spiritual and physical	Living things are studied in physical science not as living things but merely as physical things
	Animals	Physical	
	Plants		
	Minerals		Inanimate things are properly studied in physical science

Matter is what enables physical things to undergo change. Spiritual things do not have matter. So, what is matter?

- The most common definition of matter is that which has mass and occupies space / the "stuff" of the universe
    - But this definition is incomplete. It may suffice for "secondary matter" but not "prime matter."
- A more technical definition of matter is that which accounts for the ability of something to change (It is the answer to the question: why is change possible?)
    - Prime matter – "undifferentiated matter" / "pure potentiality" / strictly speaking, not any "thing" or "stuff" at all but rather a principle of a thing that accounts for it being able to become a specific type of thing, and to change into something else (i.e. accounts for "substantial change")
    - Secondary matter – the potentiality in a thing to change in some aspect or property without becoming a different type of thing (i.e. accounts for "accidental change")

At this point Mr. P cuts off the natural philosohy digression. He tells the class to save these questions for their natural philosophy class that they will take sophomore year. He tells them that this year we are going to learn physical science and what we have covered thus far is more than enough to help us get oriented. Our attempts to grapple with defining science and physical science segue well with our next topic: the scientific method. (Some student groans…)

The traditional definition of science as a "body of knowledge" works for the most part for modern science, although not completely. What is overlooked in this way of approaching science is the question of method. Method describes how scientists go about doing scientific work. Modern scientists use a method that is similar in many respects to pre-modern thinkers but there are also some important differences. This year we are going to study Physical Science primarily as a modern science.

The Methods of Science

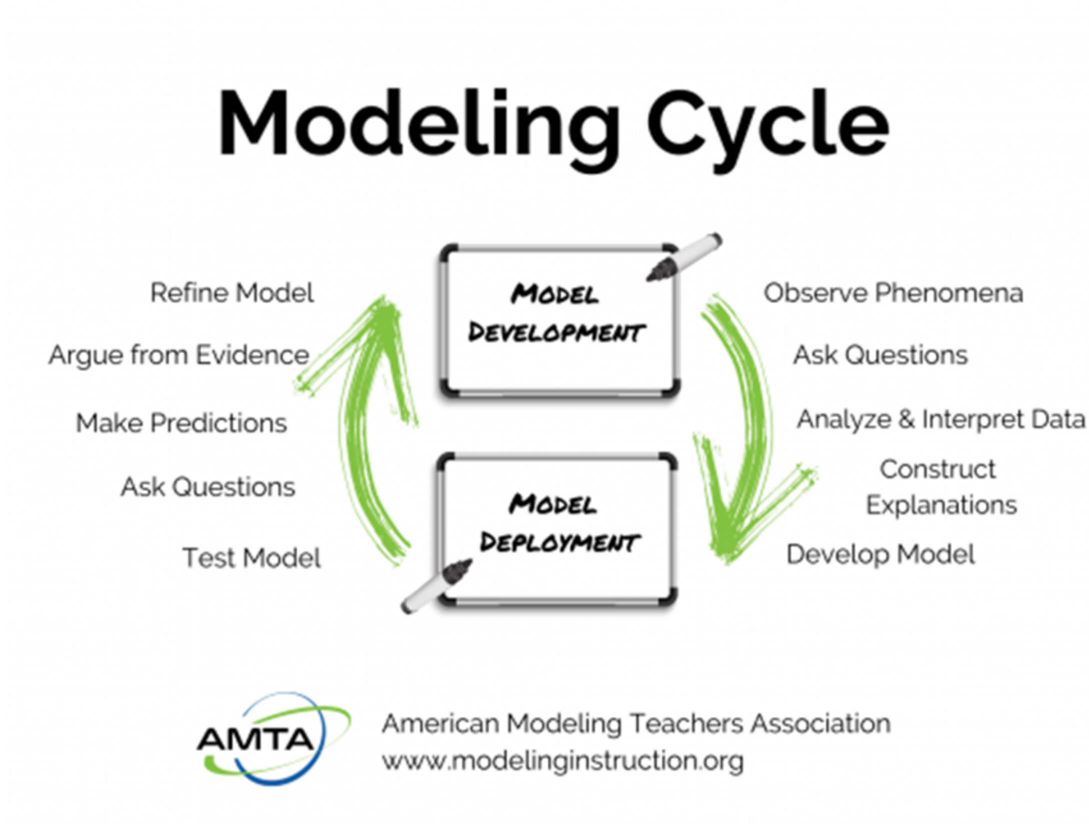
- All science reasons from previous knowledge or information to further knowledge
- All science seeks order and explanations

Traditional science (pre-modern)		• Starting from previous knowledge, a further body of knowledge is derived [Aristotle: "All teaching and all intellectual learning come about from already existing knowledge." (*Posterior Analytics*, 71a1)] • For example, from 5 reasonable assumptions Euclid derives a significant body of geometrical knowledge. • Ethics, politics, logic, natural philosophy, metaphysics and theology are all sciences that can proceed by this pre-modern "deductive" method

The modern scientific method		• The starting point of modern science is often observations, typically aided by technical instruments, carefully recorded as a data set
		• Laws summarize patterns / order in the data (an "inductive process")
		• Theories attempt to provide coherent explanations of the principles behind the observed order
		• Laws and theories are models
		  ○ It is fair to say that they are approximately true, meaning that they have explanatory power and limitations (ex: F = ma works for normal conditions but breaks down at extreme speeds)
		  ○ All scientific models have limitations, and can be improved

Key distinctions	*Traditional science (pre-modern)*	▪ Narrow scope / only a limited number of things can be known

	▪ Certainty is possible – there is such a thing as settled science ▪ Deductive reasoning
Modern science	▪ Broad scope / many things can be investigated ▪ Certainty is impossible – settled science is a myth ▪ Inductive and deductive reasoning



Types of Modern Science

Natural Sciences	Physics, Chemistry, Biology (in Physical Science we focus on physics and chemistry)
Social Sciences	Economics, Psychology, Sociology, Political Science

Onwards...

At this point Mr. P is ready to dive into course material. He will often begin a class with a description of a real-world phenomenon or historical perspective. He will be demonstrating reactions, such as a hydrogen filled balloon going up in flames as it reacts to the oxygen in the air when held over a candle. He will explain the history of the use of projectiles in warfare, from catapults to rockets. He will present key historical moments of scientific discovery in such a way that the students are encouraged to reason through the evidence "alongside" great scientific thinkers.

While he begins with these real-world situations, he is constantly encouraging the students to recognize patterns and seek explanations for what they observe or learn about. He steers lessons toward known scientific laws and theories. And in doing so he is keenly aware that his students are likely to forget the foundational lessons outlined above. Some students will fall into the trap of considering particular models as certain knowledge; they will absolutize the models. They may think of an equation from Newtonian physics such as $F = ma$ or a particular model of the atom as absolute in this way. Mr. P will explain how, in both these examples, the model has significant explanatory power but also limitations. The understanding of force as mass times acceleration breaks down in extreme conditions (such as on the quantum level or with relativity) and the valence electron model of the atom, while explaining why certain reactions occur, fails to account for actual structure of an atom. In clarifying these points, he reminds the class that complete certainty is only possible in deductive traditional science, such as in Euclidian Geometry, and that modern science is all about the explanatory power of models and how to improve them.

Deeper intellectual formation

In beginning a class this way and returning to these foundational ideas, Mr. P is not only helping his class better understand the physical science they are learning. He is also helping them avoid common errors that people today tend to fall into, such as:

- Scientism. Scientism can be defined as the ideology that holds that the only way to reach objectivity is through the methods of modern science. If scientism were true there could be no such thing as a pre-modern science, including metaphysics (from which modern science derives necessary foundational principles, such as the principle of non-contradiction). This prevalent ideology is directly countered by the initial exercise of listing different sciences and by teaching about methods, particularly presenting a correct understanding of modeling in modern science.
- Subjectivism. A related ideology goes something like this: since science is the only or the main way to reach objective understanding, everything else is subjective, meaning having to do with opinions. Science is about facts and everything that is not knowable by the methods of modern science are opinions. This means that all questions of ethics or any human values are not about what is objectively real. They are private matters that are part of the emotional world of the individual human subject. There may be particularly gifted people with a refined appreciation for finer things, with "good taste," but this does not change the fact that all human values are subjective, cut off from what is objectively real. The paradigm that we suggest directly counters subjectivism by showing that not all sciences follow the methods of modern science. Indeed, a subject such as ethics can be considered as a science according to sound rational principles.
- Materialism. It is surprising how many young people think that modern science teaches (or takes for granted) that only matter exists. This erroneous philosophical position is in no way supported by modern science. And it is false not only because it discounts spirit but also because it rests on a simplistic understanding of matter (as suggested above). A more complete understanding of matter is covered in natural philosophy and metaphysics, as well as in modern physics. Some modern physicists like Werner Heisenberg have noted that Aristotle's notion of prime matter seems closer to

our understanding of matter on the quantum level than Democritus' notion of small, massy particles. The above approach opens up the space for a more expansive perspective and shows how natural philosophy and metaphysics can harmoniously relate to modern science.

- Relativism. Science also can fall under the post-modern critique that identifies all attempts to express meaning as mere word games. There is no objectivity as is evidenced by the fact that concepts that at one point seemed certain, such as Newton's F = ma, have been shown to be false. This is not just an academic exercise carried out by post-modern college professors. Today young people (and older people as well) often use the word "science" in an ironic way, making fun of how much credibility science has lost throughout the pandemic. Students will not be easily taken by a simplistic relativism that dismisses science if they are taught what modern science actually is. F = ma should not be thought of as absolute truth. Instead, it is an approximately true model that can be, and has been, improved. A more accurate understanding of the possibility of certainty in different sciences is quite helpful in countering post-modern ideologies.

Conclusion

How a science teacher introduces his subject can make a tremendous difference. Given the complexity involved in understanding what modern science is and how it relates to other ways of knowing, it is understandable that many teachers tend to avoid saying much of substance on these foundational matters. This is a mistake and a missed opportunity. Teaching science in a way informed by sound thinking is important both for science and for the human flourishing of students. That it is difficult to do this is not a good reason to avoid making the attempt.

There is a legitimate diversity in the way different teachers cover material. There can also be significant differences between how a teacher covers material from one year to the next, as part of what is taught depends on interactions in the classroom. What is outlined above is one possible path, even if a fictional one, that a teacher could have taken for a particular class during a particular year. It is not intended to be a script to be simply copied. If this exercise is helpful for teachers as they think through their own approaches then it will have more than served its purpose.