Part II: Implementation in a Classroom

It is my personal feeling that Galileo's pendulum and free fall would be best suited to Physics 2204 (assuming my idea to offer a separate course devoted to scientific inquiry is a non-starter just yet). Students taking Physics 2204 should be in the process of developing the mathematical skills necessary to do some simple equation derivation. At this point, students should also have the foundation knowledge necessary to understand concepts like what the gravitational constant is and how distance and acceleration graphs work (introduced in Science 1206). I would also hope that students are in the process of developing a base knowledge of historical scientists, and they will at least recognize Galileo's name for one of his great contributions at this level.

Curriculum Outcomes:

The following curriculum outcomes could be addressed in my unit plan:

116-2 analyse and describe examples where scientific understanding was enhanced or revised as a result of the invention of technology

116-4 analyze and describe examples where technologies were developed based on scientific understanding

116-6 describe and evaluate the design of technological solutions and the way they function, using scientific principles

116-7 analyze natural and technological systems to interpret and explain their structure and dynamics

117-2 analyze society's influence on scientific and technological endeavours

212-3 design an experiment identifying and controlling major variables

213-2 carry out procedures controlling the major variables and adapting or extending procedures where required

213-3 use instruments effectively and accurately for collecting data

214-3 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots

214-5 interpret patterns and trends in data, and infer or calculate linear and non-linear relationships among variables

325-2 analyse graphically and mathematically the relationship among displacement, velocity, and time

Also touches on the following curriculum outcomes from other courses:

From Math 1201: Linear Functions:

RF3 Demonstrate an understanding of slope with respect to:

- rise and run
- line segments and lines
- rate of change
- parallel lines
- perpendicular lines.

RF6 Relate linear relations expressed in:

- slope-intercept form $y = mx + b$
- general form
  $Ax + By + C = 0$

RF7 Determine the equation of a linear relation, given:

- a graph
- a point and the slope
- two points
- a point and the equation of a parallel or perpendicular line to solve problems.

From the General Outcomes for World History 3201:

- Historical events that are the result of a combination of factors: political, social, intellectual, religious, and economic.
- The role of prejudice and propaganda in influencing historical events and processes.

From Senior High English General Curriculum Outcomes:

- Students will be expected to speak and listen to explore, extend, clarify, and reflect on their thoughts, ideas, feelings, and experiences.
- Students will be expected to communicate information and ideas effectively and clearly, and to respond personally and critically.
- Students will be expected to interact with sensitivity and respect, considering the situation, audience, and purpose.
- Students will be expected to interpret, select, and combine information using a variety of strategies, resources, and technologies.
- Students will be expected to use writing and other forms of representation to explore, clarify, and reflect on their thoughts, feelings, experiences, and learnings; and to use their imaginations.
- Students will be expected to create texts collaboratively and independently, using a variety of forms for a range of audiences and purposes.

Outside of the prescribed curriculum, I would hope to have students creatively apply their scientific knowledge to problem solving. I would love them to have the opportunity to see things in the way that Galileo did (in as much as possible) in the 1600s while working to understand acceleration and pendulum motion. This unit will require critical thinking, an understanding that technology/equipment can facilitate science (but are independent), and especially that scientific theories are not absolute. Through this unit I would like for students to realize that discoveries may not be finite, theoretical (not just experimental science) can be valid, and that social scenarios impact scientific progress.

Unit Plan:

The basis of my unit would be the incorporation of inquiry. In order to do this, I would very much like to peak my students' interest in the topics, but not give away too much information as this would reduce the exploration they could do on their own. My plan would be:

Total Unit Time: 1 class per week for 12 weeks (running concurrently with the Kinematics and Dynamics units)

Class 1: Have students do a brain dump on everything they know about Galileo Galeli on a large poster. As a class we could create a poster with words, drawings, pictures, quotes, etc. that reflected students' present knowledge. This can act as a pre-assessment and will help guide unit. Once this poster was done (about 20 – 25 mins), I would show them the video from the biography page of my website (https://youtu.be/NMM8vx9vDiE) OR dress in garb similar to what Galileo is depicted as wearing in many drawings and give a short in-character autobiography.

Now that they know a little something about Galileo, I would ask them to consider the following for next class (have notes prepared for discussion):

1. Should science be based only on observable facts?
2. How did Aristotle and Galileo disagree in their thoughts on acceleration?

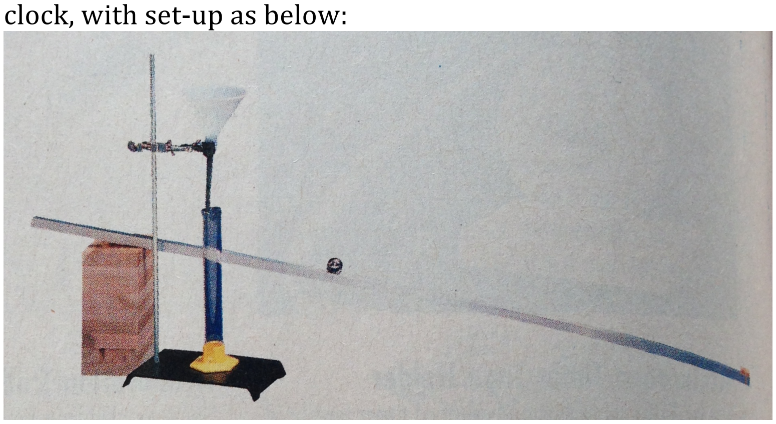
Class 2: Small group (4 groups) discussion. Each group should discuss their thoughts on posed questions. One or two group members from each group will share cumulative thoughts. This should drive the debate about observable facts vs philosophy and get students thinking about the realities of each. Within this class I will introduce the definitions of theory, hypothesis, and the scientific method as we know it/as scientists work with it.

Class 3: Have stations set-up around room. Students, in three groups, will circulate to each station for observations. Station 1 will have 2 balls of same size but different masses. Station 2 will have a ball and a feather. Station 3 will have 2 connected rocks. Each station will have a 2 timing devices, water tank and area designated for dropping objects inside (of specified height). Prior to starting at each station, students will be asked to predict what will happen when each of the 2 objects are dropped in air and in water. Doing a simple replication of Galileo's Pisa experiment, students will note what they observe when dropping each of the objects. Two students from each group will be responsible for timing the objects as they drop (one student assigned per object). Each drop will be repeated 5 times to attempt to increase accuracy of timing. Students will be asked to write in words what they observe, without using the timed values. From their descriptions, they will be asked to develop their own theory of why objects fall in the way they do.

Class 4: Have students share developed theories (30 mins). Teacher will place students in "Aristotelian" or "Galilean" groups according to their predictions from last class. Have students in each group explain/debate why they made this assumption, and share the results of each experiment (30 mins). While discussing, students should work to prepare a short comparison and contrast between Galileo and Aristotle. They can use the method of their choice to record this (table on paper, make a short video clip, audio recording, sketch of each character with text, or Fakebook profile (see my example: http://www.classtools.net/FB/1492-zuV3pc) for each scientist, for example This class will close with a short video clip: https://youtu.be/2HR5UmG0q0s while students work through their summaries (30 mins).

Class 5: Have students share their presentation of compare/contrast Aristotle and Galileo's beliefs on freefall (2-3 mins each). Each group will have 20 minutes at the start of class to research Aristotle's views or Galileo's views on Free Fall, based on their grouping. The objective is for students to question or refute points following the presentations, so that students get to experience some of the peer/society doubt that was present as Galileo moved through his developments.

Class 6: Have students perform inclined plane experiment as per attachment. For extra authenticity (if materials are available), perform lab with a water clock, with set-up as below:



Class 7: Have students look at data collected from experiment. Emphasize for students to come up with a meaningful way of representing their data, given what they know about their values and the experimental situation. Explain

that graphing, using equations they are familiar with, and relationships from Science 1206 will help. As the teacher, it will be my job to help facilitate this activity, as derivation/pattern detection is not something they often get to work with. As the class progresses, I will ask groups strategic questions like:
Is your data linear?
What would it look like on a graph?
Based on the numbers in your chart, if you were to do a little rounding, would you be able to find a mathematical relationship?
Create a classroom display of graphs/equations derived and praise any relationships discovered, even if not as Galileo found. Check relationship to student data. Provide written feedback to students that will help explain differences between Galileo's findings and theirs, should there be any, so that they appreciate the process and factors involved rather than a right vs wrong approach.

Class 8: Introduce class by showing a light swaying back and forth (suspend from ceiling or stand, as necessary). Ask students what they observe. If answers are scarce, after a few minutes, prompt with questions like, "Does it keep swaying? What is its path? Will it ever stop?"

I would then use a second pendulum next to the first (same set-up) and do the following:
1. Change the mass of the bob (light) and ask them if they observe any changes

2. Change the displacement of the swing and observe the result (with same mass bobs). Release one at 10 degrees and one at 25 degrees from the vertical.

3. Change the length of the pendulum (one at 50cm and one at 80cm, for example) and leave the mass of the bob the same.

For the remainder of the class, students should record their observations and work in pairs to predict what would happen if the angle of the swing were increased (to say, 65 degrees from the vertical).

As a little "hook" close the class by explaining that Galileo defended the notion that regardless of angle of release, pendulums stay in sync using only mathematics.

Class 9: Using http://phet.colorado.edu/en/simulation/pendulum-lab have students test out their predictions. Ensure that they select the "show second pendulum" option, and then have them design their own experiment to test what happens when the length of the pendulum changes but the bob stays the same. Point out that they can manipulate the amount of friction applied in this lab.
Once students test their experiment and record numerical values used for their test, ask them if they are able to identify any mathematical/graphical relationships in their data. Additionally, ask students to write down one or

two places they may see pendulums in reality.

Class 10: With data collection done on free fall, inclined planes and pendulums, students should be prepared to defend their observations and findings to their peers and teachers. Students, in groups if they wish, should prepare a brief summary of their findings (collect all work and put it into one location; a website, binder, poster, portfolio, etc) of their choosing. Their work will be cumulative and should be presented as such next class. For those in groups, each member is expected to explain some portion of the project, and how it unfolded/related to the unit. I would like to see things like why Galileo was punished by the church, and why he chose to continue his work/publications despite this included.

Class 11: For this class, I will have 1-2 additional science and/or social studies teachers in the room (ideally). As students present their work in about 5 minutes, the guest teachers will ask questions to prompt students to defend their findings, and to check their understanding of the circumstances in Galileo's time. The objective is for students to feel confident about their findings and to be able to back-up whatever results they found, even if they disagree with Galileo (or any other known science). This will be a challenge for many students as it is not something they often experience or are given permission to do. The presentation will give them opportunities to explain their process, discuss new ideas, or things that came out of their experimentation/discussions/research. Evaluation will be based on the ability to explain their findings rather than what their findings were.

Class 12: Debrief. Here I would like to commend students to approaching science without set procedures or methods each class, and to spend some time debunking the myths of science. I would like that discussion to include topics like:

a. Whether they would continue pursuing something they were passionate about, even if their peers disproved (cultural/societal influences on progression)

b. How each person came to their conclusions during the unit. Was there just one way we discovered relationships?

c. Review laws, theories and relationships

d. Note the creative approaches taken for both finding information and presenting it throughout the unit

e. Point out how science and technology are interrelated but not the same thing

I would like to close the class asking them exactly what I ask you, "Why, as scientists, do we feel the need to see all of our results before believing they may be there?"

Conclusions

By diversifying the learning, incorporating different methods of hands-on, interaction, presentation and teaching, I would hope to encourage students to break-free of the traditional step-wise science in a progressive way. I would love for students moving through the unit to develop confidence in their work, findings, and presentations while recognizing there are many ways of reaching conclusions.