Writing scheme teaches science to non-scientists

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Writing-intensive activities can be made use of to implement a 'narrow-but-deep' approach in an undergraduate introductory physics course for non-science majors. In this approach, a carefully selected number of topics are treated not only in more detail but also with attention to developing them logically and rigorously.

We teach a course that utilizes parts of an interdisciplinary text by Alan Lightman [1] and focuses on three subjects: (i) the conservation of energy, (ii) the second law of thermodynamics and (iii) the special theory of relativity. Lightman's text is complemented by a series of take-home minilabs based on household objects or 'toys', such as dice (for the second law of thermodynamics), a coffee mug (suspended to form a simple pendulum), a radiometer (a simple heat engine) and a slinky spring (a medium for waves)—see figure 1. Through a progression of writing assignments and their revisions, students practise reasoning with and applying the concepts that they are learning. In order of increasing depth and complexity, the assignment types are: a report on a take-home minilab, a response to a conceptual problem and an extended essay.

Figure 1. *Some of the household objects or toys that can be used in minilabs: a five-ball pendulum, a radiometer and a slinky spring.*

Reports on minilabs

Minilabs utilize both toys and guiding questions to promote enquiry and encourage exploration. 'Good' toys are simple and accessible (in that all parts of them can be observed), as well as inexpensive and reusable so that every student can be provided with one. For example, we have used a simple toy made from wood and plastic and containing two marbles (figure 2) to illustrate the concepts of centripetal and centrifugal force. It was purchased from a craft shop in a nearby Amish community for just a few dollars.

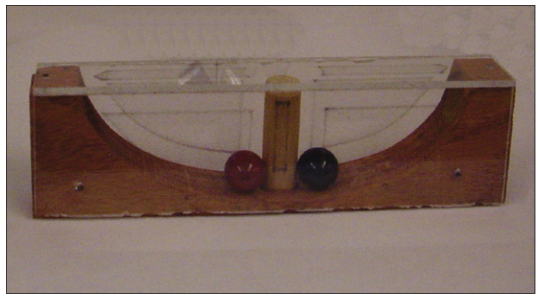

Figure 2. *This simple marble toy can be used to illustrate centripetal and centrifugal force.*

By taking the toy home, students have an opportunity to conduct the minilab throughout the week in a more relaxed environment. Many of the minilabs require the help of an assistant (a roommate or friend not enrolled on the course). For example, the assistant might be needed to measure the period of a pendulum, to time the speed of a pulse along a slinky or to hold the end of a slinky to make standing waves. Frequently, this person will ask questions, requiring the student to explain the reason for doing a measurement as well as various concepts related to it. This offers the potential of greatly extending the learning experience beyond a one- or two-hour lab conducted in the specialized laboratory in a physics building, which is occupied only by other students on the course and the instructor.

At the end of the week, students hand in a one- or two-page report on the minilab, which includes short-answer responses to a series of guiding questions. These culminate in formulating an explanation for the phenomenon under investigation. Some minilab reports include data collection as well as simple algebraic manipulations, such as computing the average speed of an object moving in a circle. These computational exercises acknowledge the limitations of a strictly qualitative presentation of the physics concepts.

In general, we find that toys provide a vivid and tactile experience that feeds mental images created by the students in solving conceptual problems. They focus the students' attention on a small number of concepts of interest. Their simplicity can serve to emphasize the generality of a concept being developed. This results in an intensified learning experience that facilitates concept retention.

Conceptual problems

Some of the conceptual questions are taken from Hewitt's text [2]. Students are asked to respond, by writing up to a page, to hypothetical situations or scenarios. They must develop their solution through a logical and rigorous argument. Though students may use mathematical relationships between physical quantities in their responses, algebraic manipulations are not required.

The question challenges students to reason on their own to reach a conclusion or make a prediction. An effort is made to sensitize the students to the mental images that they construct as they begin the solution process. They become aware that writing can be used to focus and intensify these mental images in order to conduct thought experiments.

An example problem might be: 'You're on a rooftop, and you throw one ball downward to the ground below and another identical ball up with the same initial speed. The second ball, after rising, falls and also strikes the ground below. If air resistance can be neglected, how do the speeds of the balls compare on striking the ground? Use the conservation of the ball's gravitational and kinetic energy to arrive at your answer. Give the logical steps in your argument, not just your conclusion.'

Essays

Most essay assignments are based on excerpts from Lightman's book [1]. For example, one deals with parts of an essay that Count Rumford read before the Royal Society of London in 1798 on the nature of heat. The student is expected to follow Rumford's attempt to interpret heat based on the then-current theory of a fluid called 'caloric'. The student has an opportunity to assess a theory (i.e. to determine which aspects of it hold up under the test of observation and which do not). In their essay, the student must first demonstrate an understanding of the concept of specific heat and then follow the logic of Rumford's arguments by which he inferred that heat is a form of motion. As the 19th century physics terminology differs somewhat from that used today, the student must rethink the meaning of each term in light of our modern theory of heat.

Students revise their essays after receiving the instructor's comments on a first draft. Comments target three domains: conceptual understanding, structure and organization of the argument, and grammar and conventions of writing. A code system facilitates commenting within each domain [3].

By using the language—English—that the majority of US university students have practised the most, all three types of writing assignments promote a depth of thinking and engagement that is difficult to achieve by other methods.

References

[1] Lightman A 2000 *Great Ideas in Physics* (New York: McGraw Hill) 3rd edn

[2] Hewitt P G 2002 *Conceptual Physics* (Glenview: Scott, Foresman) 9th edn

[3] Patton M D 2004 Research for faculty development? A study of WI faculty commenting *Writing Program Administration: Journal of the Council of Writing Program Administrators* **28** 75–91

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