

Physics Myth Busting: A Lab-Centered Course for Non-Science Students

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There is ongoing interest in how and what we teach in physics courses for non-science students, so-called “physics for poets” courses. Art Hobson has effectively argued that teaching science literacy should be a key ingredient in these courses.¹ Hobson uses Jon Miller’s definition of science literacy, which has two components: first, “a basic knowledge of key scientific concepts,” and second, “an understanding of the process of science.”² In preparing to teach our course for non-science students, I found that the majority of textbooks and courses focus on the first component. However, I wanted a lab-centered course that would give students hands-on practice doing science. I describe in this article a course I designed and implemented at Wabash College that focused on teaching students “the process of science.” The course was titled “Adventures in Physics: Mythbusters” and was based loosely on the popular Discovery Channel show “MythBusters.”³

The “MythBusters” TV show serves as a model for what is essentially the scientific enterprise. The structure of a MythBusters investigation, depicted graphically in Fig. 1, contains

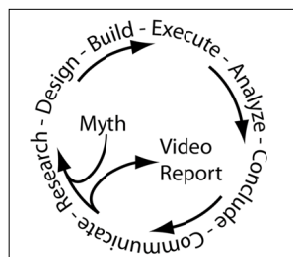


Fig. 1. The experimental method used in this course is based on the Discovery Channel’s “MythBusters” and is an iterative process beginning with the “myth” and going several times around the cycle, ending with a video report describing the entire process.

nine elements. The show’s production team begins by introducing a *Myth*, or primary research question. They *research* the myth, forming hypotheses about the conditions and processes involved in the myth. Then they *design, build, and execute* experiments that test their hypotheses. Finally, they present their analysis of the experiments, draw conclusions about their hypotheses, and communicate those to the audience. They often go through several iterations of experiments on the show, beginning with “preliminary experiments” that consist of doing small-scale model experiments or other initial experiments that test key pieces of the myth. Then they “scale up” their experiments based on the results of the preliminary experiments, testing the conditions of the myth as closely as possible. In doing this, they model the iterative nature of the scientific process. The cycle ends with the production of a video report of their experiments, similar to the way a scientist publishes results in a journal. Although the show is primarily intended as entertainment, the teams still use and communicate key aspects of the process of science, making it a reasonable model for a course for non-science students.

I began my course by introducing the experimental method (Fig. 1) to the students. I gave the students, who worked in teams of four, a simple “myth,” or research question, and guided them through each step of the method. The process of investigating the question posed in the myth typically consisted of two iterations of the experimental method. The first iteration was spent on small-scale “preliminary experiments”; the second iteration involved “scaling up” the experiments, both of which are described in more detail below. The student teams began the first iteration by researching physics models related to the concepts in the myth and designing experiments to test their models. They then built and executed their experiments, recording them using digital video cameras. The student groups then analyzed their data, drew conclusions as to the relevance of their models to the question posed in the myth, and communicated their results to the whole class. I guided the students through the second “scaled-up” iteration of the method, working to answer the same research question, as closely as possible to the conditions described in the myth. After the second iteration of experiments, the student groups put together a short video report of their work. We called the entire process from the introduction of the question to the production of a video report a “myth cycle.”

The remainder of the semester consisted of six more myth cycles, each following a similar pattern. I designed the myth questions so that each one was a bit more challenging than the last. As the students got more experienced at each of the steps in the experiment method, I provided less explicit guidance. Each student group proposed their own research question for the last myth cycle. They then had three weeks to work on their final project and present their final video report. I utilized a content theme each of the two semesters that the class was taught, shown in Table I. I chose themes that related to everyday student experiences in order to reduce the complexity of the physics models needed to begin designing experiments. This made it possible for the students to become quickly involved in the experiment method, designing and executing their own experiments. There was a definite trade-off between content and process; I covered only a small fraction of the content that is typically covered in science classes for non-majors. Because of this trade-off, I would not expect this course to stand alone as the only exposure a student might have to science; it would serve better as a companion course to a more traditional content-based course where “a basic knowledge of key scientific concepts”² can be covered.

The preliminary experiments for each myth cycle consisted of preparing for and then doing small-scale model experiments or other initial experiments that tested key pieces of the myth. I often suggested parts of these experiments, based

Table I. The myth questions for each semester were based on a general theme. The “Build-off” was a mini-competition between groups that helped transition from instructor-led experiments to the student-directed work.

Fall 2009: Theme “Momentum”	Spring 2010: Theme “Friction”
Do “crumple zones” on cars do anything more than make repairs more expensive?	Could a stone-age person really stop his “car” with his feet?
Which type of ball hits harder: rubber or clay?	Do football cleats affect how hard a player can push?
Can a skateboarder jump over a car with his board traveling under and land back on the board?	Could a Ping-Pong ball be thrown across a basketball court?
Build-off: Egg drop challenge (drop an egg off of the roof and get it to the ground safely)	Build-off: Pinewood derby car challenge (run a model car for the longest distance across a flat surface)
Can a grain car speed up by dumping its load?	What is the best way to get a truck unstuck from the mud?
Final myth: student-generated	Final myth: student-generated

on kinesthetic learning methods from Workshop Physics⁴ as a way of introducing the students to key physics concepts relating to the myth. For example, in doing the myth “Could a stone-age person really stop his ‘car’ with his feet?” (as in the “Flintstones” cartoon), the preliminary experiments were focused on learning the concepts of velocity, acceleration, force, and kinetic friction. Students began work grappling with the myth in a discussion session that included doing initial research through a variety of online materials.⁵ We discussed these concepts in class and talked about how a kinetic friction model could be used to describe the myth. Each student team then designed several small-scale tabletop experiments using blocks of wood and force probes to test the key concepts of the kinetic friction model. On the day of the lab, the students built their own experiment apparatus using parts and materials on hand, but not assembled or configured for their use. Because each student group designed their own set of experiments, there was a variety of experiments and models tested. In a discussion session following the lab, each group shared their results. The groups then worked together to analyze their results based on the initial physics models and came to a conclusion about whether or not (and to what degree) the physics models applied to the myth. Each group communicated back to the class as a whole their conclusions. Since each group had focused on a slightly different piece of the model, this enabled the entire class to benefit from the different experiments and form a more complete picture of the physics models associated with the myth.

The next iteration of the myth cycle involved “scaling up” the experiment based on the results of the preliminary experiments. In the case of the kinetic friction myth, the students designed a set of experiments where one student rode on a

kinesthetic cart and stopped himself with his feet. Because there was a new set of concepts involved in this experiment, the students went back and researched the physics models of kinetic energy and work. The groups then designed their experiments to test key elements of the myth based on these new models, e.g., stopping distance, material dependence, speed dependence, or mass dependence. On the lab day they built and executed their experiments (this time in our indoor fieldhouse space). The students again analyzed their results in the context of their physics models. The students then connected both their preliminary experiments and scaled-up experiments back to the original question posed in the myth and drew a conclusion about the myth based on their results. Finally, each team prepared a video communication of their experiments and turned their video report in for instructor evaluation. The best reports (based on instructor evaluation) were then posted to YouTube.⁶

Following the “MythBusters” model, the course relied heavily on video recording and analysis. Students were required to purchase small video recorders (in the sub-\$100 range) for the class instead of a textbook.⁷ The visual nature of these myths made it possible to record key details with the cameras. Students were directed to review the video footage of experiments and piece together the dynamics and interactions described by their physics models. They also used video footage in their analysis of the experiments, using particle tracking software to find object velocities and accelerations.⁸ Because of this reliance on video capture of the experiments, it was natural for the students to edit and combine their video records into a finished “video lab report” that communicated the key aspects of their experiments. I refined the purpose and evaluation of these student videos over the course of the two semesters, and a grading rubric is included in the supplemental materials.⁹ Advances in the power and simplicity of video editing software¹⁰ made it possible for students who had never done video editing before to put together a simple video report of their work.¹¹

While evaluating final student projects and feedback from student surveys at the end of the first iteration of the class, I found that the students did not retain well the concepts associated with the myths, nor did they have a clear understanding of the process of science. I added several components to the second iteration of the course that I believe improved the course outcomes. First, I presented the students with regular homework assignments, both conceptual and quantitative, in order to give them practice working with the formulas and models used in their experiments. I tested the students weekly with short in-class quizzes over this material. Second, I gave them a variety of texts describing the process of science that we then discussed in class.¹² I evaluated their final grades using a combination of their homework and quiz scores, their participation (in discussion and lab), and their video report grades. Compared to the first semester, my evaluation of the final student projects and student surveys for the second semester indicated that the students had a bet-

ter grasp of the basic physics concepts and had a much better understanding of the process of science. In order to measure the overall effectiveness of this new course, I gave the spring class the Colorado Learning Attitudes about Science Survey (CLASS)¹³ as a pre- and post-test. The results were analyzed using the analysis tool available from the survey authors and are shown in Fig. 2. The students from this class ($N=19$) showed significant improvements in the “Real World Connection” category (Cohen’s $d=0.72$, large effect), with positive shifts also in the “Problem Solving General” ($d=0.59$, medium effect) and “Problem Solving Confidence” ($d=0.49$, medium effect) categories. These three categories are, arguably, the most important indicators that the students had improved in their understanding about how to ask questions from a scientist’s perspective outside the physics classroom, a key goal for the course. Although the students did not show significant improvement in the “Conceptual Understanding” or “Applied Conceptual Understanding” categories, the primary goal of this course was not focused on physics concepts, but rather on understanding the process of science. The overall favorable scores showed a shift of +8.6% (with a standard deviation of 2.6%), results that are similar to other successful physics courses for non-science majors that have favorable score shifts from +4% to +14%.¹⁴

Student feedback from the course was overwhelmingly positive. The students particularly found the myth approach useful in thinking about science outside of the classroom. One student commented, “I feel like it takes science from a nontraditional perspective and possibly from a more real-life view. I felt like I could better apply the things I learned in

this class to everyday situations and thus learned more than I would have in a typical physics class setting.” The students were engaged in the role of investigators and enjoyed that role. Another student noted at the end of the class, “I really felt like a MythBuster and felt that most of our experiments were dealing with important and useful topics.”

Several questions remain as to the effectiveness of this course in teaching the process of science: What other strategies are effective in teaching students the process of science? Are the results I found teaching this class repeatable for other instructors or institutions? There have been dramatic improvements in conceptual physics courses designed for non-science students reported in the literature.¹⁴ What are similar successful strategies for teaching the process of science? Future versions of this course could be used to answer these questions and clearly identify the most important strategies.

Although I taught this course with two relatively small classes ($N=39$ and $N=19$), I believe it is possible to implement the course with a larger number of students by breaking the class up into small groups and focusing on simple physics concepts. The SCALE-UP environment would work well for this kind of independent group work for larger classes.¹⁵ Furthermore, there is a broad range of other themes that could be used, including myths focused on rotational motion (like on a children’s merry-go-round), buoyancy myths (like the conceptual battleship-in-a-bathtub), or energy myths (questions about energy production and consumption).

I began by looking for a lab-centered course that would give students hands-on practice doing science. I have described a course based loosely on the popular Discovery Channel show “MythBusters” that I designed and implemented at Wabash College. Preliminary results from the CLASS instrument and from student feedback from two iterations of the course indicate that it was successful in meeting the goal of teaching students “the process of science.”

References

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2. Ibid.
3. dsc.discovery.com/tv/mythbusters.
4. Priscilla Laws, “Workshop Physics: Learning introductory physics by doing it,” *Change* **23**, 20–27 (July-Aug. 1991).
5. I directed students to physics concepts on www.wikipedia.com, the reference material at Georgia State University’s hyperphysics.phy-astr.gsu.edu/hbase/hframe.html, and general Internet searches.
6. www.youtube.com/user/WabashCollege#g/c/8BA92EC3B24957A0.
7. These cameras, for the most part, worked well and the students did not object to buying them as they got to keep them after the course finished. I did have to remind them regularly to bring fresh batteries and flash memory to lab. I recommended the students use the Kodak Zi6 model, though there are better models now available in the sub-\$100 range.

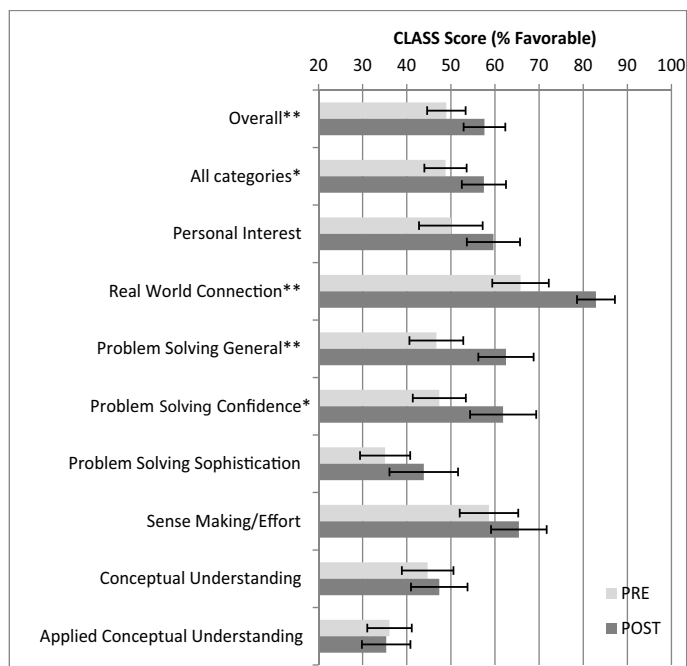


Fig. 2. Average favorable responses for the pre- and post-test of the CLASS. These results are for the spring 2010 semester ($N=19$). Error bars reflect the standard error of the mean. * <0.05 , ** $p < 0.005$.

8. We used Vernier's Logger Pro software to analyze the motion of the videos.
 9. See supplementary material at <http://netserver.aip.org/cgi-bin/epaps?ID=E-PHTEAH-49-022107> for a copy of the simple "Handbook" that outlined the different video recording and editing responsibilities for group members.
 10. We used a combination of QuickTime Pro and Final Cut Pro to edit the videos.
 11. I dedicated the first lab period of the semester to teaching the students the basics of video editing by having them film and edit short personal introductions.
 12. I gave students the following short texts to read: Richard Feynman, *The Pleasure of Finding Things Out*, 1st ed. (Perseus, Cambridge, 1999), pp. 1-5, 13-15, 23-25. W. Thomas Griffith, *The Physics of Everyday Phenomena*, 5th ed. (McGraw-Hill, Boston, 2007), pp. 2-5. Richard Feynman, *Surely You're Joking, Mr. Feynman* (W.W. Norton, New York, 1997), pp. 338-346. Henry Gee, *The Science of Middle-Earth* (Cold Spring Press, Cold Spring Harbor, NY, 2004), pp. 212-219. Chris Mooney and Sheril Kirshenbaum, *Unscientific America* (Perseus, New York, 2009), pp. 1-12.
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 15. M. Oliver-Hoyo and R. Beichner, "The SCALE-UP Project," in *Teaching and Learning through Inquiry: A Guidebook for Institutions and Instructors*, edited by V. S. Lee (Stylus Publishing, Sterling, VA, 2004).
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