

# Feedback With Web-based Homework And PADs

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**Abstract.** The Physics Applets for Drawing (PADs) allow students to interactively make graphs and other physics diagrams on the Web and have them evaluated. PADs are able to evaluate qualitative as well as quantitative drawings and to give customized feedback. These features greatly expand the range of exercises possible in a web-based homework system and make the latter more able to support research-based curricula. While feedback is an important component in learning, it is a challenge to provide enough feedback so that students do not become stuck and frustrated while at the same time not so much that it enables students to avoid thinking, particularly in an on-line environment. In this paper six different approaches to computer-based feedback are discussed along with how PADs could be used for different approaches. Participants are invited to discuss and make suggestions as to how PADs could be best used to support research-based curricula.

## INTRODUCTION

Two significant trends in physics instruction are Physics Education Research (PER) and the use of web-based homework. The latter is often driven by economic and logistical motivations, but could support a key principle of PER-based curricula: providing immediate, formative feedback to the student. The challenge is to provide the right level of feedback.

If insufficient structure and feedback are provided, weaker students will flounder and become frustrated. If too much structure and feedback are provided, students can use it as a crutch and avoid thinking. Balancing the structure/feedback needs of different students in the classroom is a significant challenge for a good human instructor. Web-based implementation exacerbates the challenge, reasons including limited communication (no facial expressions) and the difficulty of anticipating all possible responses. Over the years different approaches have been used for computerized feedback. Some general approaches will be discussed below with an eye towards lessons that can be learned and applied to the PADs project.

The Physics Applets for Drawing (PADs) project<sup>1</sup> is sponsored by the National Science Foundation for a suite of Java Applets for making qualitative and quantitative graphs, vector diagrams, and other

diagrams on the web. PADs can be used in static web pages or within web-based homework. They are currently supported by WebAssign. PADs have an internal grading engine with the ability to give conditional feedback customized to a particular exercise. I would like to engage in discussion with other members of the PER community on how to best use these features to support PER-based curriculum. The first curricular application was to code homework questions from RealTime Physics Module 1<sup>2</sup> (which uses many graphs) into WebAssign.<sup>3</sup> WebAssign is reviewing the questions and obtaining permissions to add RealTime Physics 1 as a supported textbook.

## TYPES OF FEEDBACK

Different approaches have been used over the years to try to provide correct levels of computer feedback. They can be divided into six major categories with different advantages and disadvantages.

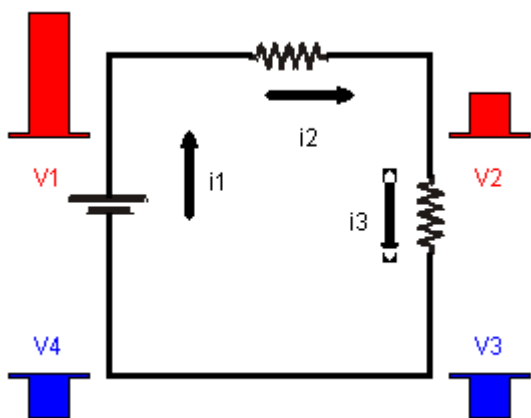
### Poll

The poll type offers no direct feedback about what is right or wrong. Examples include Just-in-Time-

Teaching<sup>4</sup> (JiTT) and Peer Instruction.<sup>5</sup> In this approach the instructor eventually gives feedback in the discussion of student answers, resolving the structure/feedback dilemma by passing the buck to the instructor. Since the instructor must provide feedback, it may be delayed and it may not meet the needs of a particular student.

### Right Or Wrong

This is a common mode for web-based homework because of its ease of implementation. The system simply tells the student whether the response is correct or not, with no other information. Students can learn from their own mistakes as they figure out the error that was made, but a student working alone without enough resources to identify the error may spend hours in frustration. The straight right/wrong feedback may also lead some students to focus more on getting things “right” compared to understanding.



**FIGURE 1.** An example of a qualitative circuit PADS exercise. The student adjusts the bars to represent the voltage at each point, and the arrows to indicate direction and magnitude of current through each element. The applet will grade correct any diagram in which  $V_2$  is halfway between  $V_1$  and  $V_4$ ,  $V_3$  is the same as  $V_4$ , and the currents are clockwise and the same magnitude. This example uses VectorPAD, illustrating both vector and bar forms of objects.

### Help On Demand

This approach makes additional help available to students when they ask for it. However, there needs to be some sort of disincentive for using help when the student doesn't really need it. The first web-homework system I used, CyberProf,<sup>6</sup> often included hint and help links in the text of the exercise that students could expand for additional suggestions and pointers. In practice, many students would expand all

of the hints and helps in the page before even reading the problem. CyberProf's replacement, the Tychos<sup>7</sup> system, provides additional help not in statements but through a series of extra questions and steps the student goes through if they chose; help is available at the cost of having to answer additional questions. Another approach is to assess a point penalty for asking for extra help. However, I heard of students at my school partially defeating this penalty in Mastering Physics<sup>8</sup> by one person in a group sacrificing the point and then passing the hint on to the rest of the group.

### Reactive Help

This approach provides help when students submit an incorrect answer. A simple approach (employed by CAPA<sup>9</sup>) is to simply provide a hint from a list. Students have been known to randomly submit wrong answers until they had received the whole list of hints provided.<sup>10</sup> A more sophisticated and challenging approach is for the system to try to figure out the cause of the mistake and provide appropriate feedback. A student worker of mine told me about a light refraction problem in which Mastering Physics kept telling him there was a sign error when in reality an additional index of refraction had been left out.<sup>11</sup>

### Simulated Results

Students receive feedback from simulated results by observing a simulation of the result. An example might be an object moving according to the equation of motion that was entered. Examples of computer programs that use this are Graphs and Tracks<sup>12</sup> and Electric Field Hockey.<sup>13</sup> This type of feedback tends to emphasize the physics in the problem and requires the student to judge for himself/herself whether the goal was achieved, and what errors would have lead to an undesired result. However, not all problems easily lend themselves to this type of feedback.

### Structured guidance

The alternative to trying to help students figure out their mistakes is to help them do it correctly in the first place. This may be less discouraging as it focuses on what is right instead of what is wrong. It is also easier to code the exercise, being easier to anticipate all the responses the student might make at one particular point than in trying to reconstruct the error from a final answer. The simple approach is to break a large, complex exercise into a series of smaller exercises, an

example being the program Freebody<sup>14</sup>. A more sophisticated approach is to give initial guidance and then allow the student some flexibility in taking larger or smaller steps through the material. As the students' skills progress, the assisting structure needs to be reduced. The challenge is to provide enough guidance and feedback for the weaker student without putting a straightjacket on a stronger one, especially on exercises with multiple valid approaches to solving. The more sophisticated approach reduces the straightjacket problem at the cost of a more complex exercise/program that requires more effort to write.

## FEEDBACK IN PADS

The internal grading engine of PADS provides the exercise author great flexibility in establishing what counts as correct and providing various levels of feedback. This is necessary for the wide range of possible applications of PADS, from qualitative to quantitative exercises, from kinematics graphs to force diagrams to voltage bar charts, all of which have different criteria to be evaluated. The goal of the discussion here is to simply give a sense of what is possible to do in PADS, and the interested reader is referred to additional information on the website<sup>1</sup> for additional information.

The key aspect of the PADS approach to grading is the ability to nest criteria and values inside each other, providing a way to construct complex evaluations and messages with a set of simple statements. For example, the value of V2 in figure 1 should be halfway between that of V1 and V4. PADS has a statement that instructs it, "Return the set of the objects that are labeled 'V1,'" and another, "Return the height of all objects in this set." Combined, it instructs the applet to return the height of all objects labeled 'V1.' A similar statement can be made to obtain the height of V4. These can be nested in yet another statement that says, "Add these two values together and divide by 2," to get the average of V1 and V4. This can then be nested in another statement that compares two values (e.g. the average and the height of V2) and returns one message if they differ by less than a tolerance, and a second if they do not. This is illustrated in Figure 2. The messages themselves can be compound statements of nested criteria and values that depend on almost any aspect of the current status of the diagram.

Selection criteria can depend on almost any property of an object—labels, position, height, width, magnitude, direction, style, size, color, others—or any combination thereof. Both numerical and string

comparisons are available. A wide range of mathematical operations can be specified, along with store/recall functions and limited conditional operations. Not only can the grading criteria and feedback messages depend on any combination of nested statements, they can also be used to specify properties of the objects themselves, such as displayed label, style (e.g. vector, bar, line, etc.) or color. Note that in Figure 1, the color of the bars depends on whether the height is positive or negative.

## Possible Modes For Using PADS

PADS can be used in most of the feedback modes described above. A PAD can return whether or not it is correct, the feedback message, or both. For a Poll exercise, the feedback would simply describe the student work, e.g. on a simple graph it might return "Increasing line," "Horizontal line," or "Decreasing line". In a Right or Wrong exercise, the messages specified could be either empty strings or omitted altogether. Figure 1 illustrated a Reactive response. Feedback can range from very general ("Double check all the voltages.") to very specific ("Current i2 should have a value of 1.5 A."). Simulated exercises are enabled through inter-PAD communication. GraphPAD can plot how a student moved an object in MotionPAD or vice versa. Structured Guidance can be achieved by specifying a task (e.g. construct a freebody diagram) that requires a number of steps and providing the student a button to periodically click. Each time the button is clicked, the PAD determines where the student is in the process based on the configuration of objects, and the feedback message provides instructions for the next step.

## LOOKING TO THE FUTURE

What are the most fruitful ways to use PADS to support research based curricula? The overriding question of this paper is how to best provide feedback for all students, from the weakest to the strongest. I invite discussion on that as well as more specific questions, including:

**Polling systems:** PADS could be used in class poll situations. It would be possible to conduct Interactive Lecture Demonstrations<sup>14</sup> (ILDs) in which the class results of student graphs were collected and viewed before the experiment. However, this would require students to have some sort of computer access in the classroom, as well as the software for such a system to

be developed, both of which could require substantial resources. How valuable would this be to undertake?

**Feedback and coding:** Complex exercises with good feedback may be more beneficial for student learning. However, they require significantly more effort to code (can take several days compared to less than an hour). What is the value of some complex exercises with good feedback versus many simple, limited feedback ones?

**Tying in with curricula:** Many research-based curricula have similar activities, such as making position and velocity graphs. One could develop generic problems that could be used for a variety of curricula to make more available. However, generic may not fit perfectly with a curriculum and could lead to uncertainty on what to use when. How important is it to have problems written for a particular curriculum?

**Appropriate scaffolding:** A valuable method for teaching skills is scaffolding, initially providing extra support to the learner, which is gradually removed. One approach would be to place high-feedback exercises at the beginning of an assignment, followed by similar, low-feedback exercises. Another would be to spread these across several assignments. Another would be to assign only low-feedback exercises, but make high-feedback ones available for students who are struggling. There are advantages and disadvantages for different approaches.

**Problem-solving:** Problem-solving is a major goal of physics instruction. Teaching students to take the time to carry out important intermediate steps is common to most efforts to teach problem solving. PADs allow students to carry out and receive feedback on such steps, such as drawing free-body diagrams. Implementation in a web-based system raises tricky issues. Does one make the student choose what kind of diagram before they get the applet for drawing? If so, how does one grade the energy diagram for an exercise that requires a force diagram? However, simply handing the student an applet for making a force diagram could provide a major clue as to how to solve it. Does the student get to choose variable names? How does one get them to enter equations? Do we need a PAD for that?

## CONCLUSION

The PADs project is an on-going effort to bring important capabilities to web-based homework. Graphical responses and customized feedback enable

it to support curricula based on Physics Education Research. However, there are important questions to be discussed as to the best way to achieve this goal

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