

# Interactive Problem Solving Tutorials Through Visual Programming

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**Abstract.** We have used LabVIEW visual programming to build an interactive tutorial to promote conceptual understanding in physics problem solving. This programming environment is able to offer a web-accessible problem solving experience that enables students to work at their own pace and receive feedback. Intuitive graphical symbols, modular structures and the ability to create templates are just a few of the advantages this software has to offer. The architecture of an application can be designed in a way that allows instructors with little knowledge of LabVIEW to easily personalize it. Both the physics solution and the interactive pedagogy can be visually programmed in LabVIEW. Our physics pedagogy approach is that of cognitive apprenticeship, in that the tutorial guides students to develop conceptual understanding and physical insight into phenomena, rather than purely formula-based solutions. We demonstrate how this model is reflected in the design and programming of the interactive tutorials.

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## INTRODUCTION

Our work in devising an interactive problem solving environment originated from the well-known realization that even the best lectures can play only a partial role in student learning of physics. While ‘active engagement’ lecture techniques have been shown to enhance student engagement and the learning that occurs during ‘class contact’ periods, the time and effort that students spend outside the classroom are vital. Office hours, tutoring sessions and cooperative learning are valuable options that a serious student will seek, but still, even students trying to take responsibility for their own learning will often find themselves alone with a blank sheet of paper, hoping for some insight into a homework question or problem. Receiving non-intrusive and friendly guidance and feedback at just this time might be a real lifesaver for such potentially frustrated or discouraged students.

Problem solving is an important part of learning physics and developing expertise, but it is a complex and demanding task. Solving physics problems is often regarded as one of the most difficult learning enterprises, for good reasons: there is such a richness and diversity of phenomena, and so many

interconnections. Many introductory physics students see the domain as an impenetrable wall, and may (mistakenly) identify physics with mathematics and physics problem solving with equation matching and manipulation. Critical thinking, physical insight and conceptual understanding are often neglected in courses and end-of-chapter exercises.

The goal of our project is to offer an interactive, computer-assisted tutorial that emphasizes qualitative reasoning involving multiple representations in problem solving, thus fostering conceptual understanding in physics. Computer-assisted problem solving is a thriving field in physics education; several quality resources are web-available<sup>1</sup>. Arguably the most successful web-based homework tutor is MasteringPhysics<sup>2,3</sup>, which aims to provide a degree of Socratic dialog with the objective of improving students’ performance on final exams<sup>4</sup>.

## DESCRIPTION OF OUR APPROACH

The novelty of our approach resides in both the pedagogy and the software used to build the tutorials.

First of all, the design of the adaptive help sequences concentrates on the challenging initial step

in problem solving: understanding the problem properly. Visualizing, translating and interpreting the problem help the learner to a conceptual understanding of the essence of the phenomenon, and to decipher the situation presented. Next we pose questions and tasks to guide the learner to a conceptual understanding of the entire physical system and its behavior, before searching for a particular quantitative solution.

Some existing interactive tutorials<sup>4,5</sup> aim primarily to prepare students for exams; but our main focus is to first improve their conceptual understanding, because we strongly believe that progress in student learning will be a natural consequence.

The software (LabVIEW) used to construct both the tutorial pedagogy sequence and the problem solution uses visual programming as opposed to syntax programming. Manipulating program elements graphically offers incredible flexibility in designing the applications, as well as in modifying them. The logic flow is evident visually and easily modified. Instructors with little knowledge of LabVIEW can easily personalize the tutorials by accessing subparts of the program.

## PEDAGOGY DESIGN

We choose a ‘cognitive apprenticeship’<sup>6</sup> pedagogy which guides students to develop conceptual understanding and physical insight into phenomena, rather than purely formula-based solutions. Note that we see our tutorials as representing two important aspects of cognitive apprenticeship, namely promoting physical insight and conceptual understanding of a problem prior to mathematical formalism, and the use of multiple representations; both of these are characteristics of expertise. However we do not claim to address cognitive apprenticeship more broadly.

It is widely recognized that good problem-solving strategies are essential, supported by a solid knowledge base<sup>7</sup> and use of multiple representations<sup>8,9</sup>. We adapted a strategy<sup>10</sup> specifically suited to physics, comprising the following main stages: problem translation (into one’s own words), visualization of the situation, redescription in terms of physics concepts involved, solution planning, solution process and evaluation.

To avoid the potential ‘plug and chug’ tendency of many novice students<sup>11</sup> the interactive tutorial advises users to stay away from calculators when beginning. In the first translation phase the student is asked to understand the problem, to see if the situation and stated facts make sense; distinguish between relevant and irrelevant information, identify key words, restate information in his or her own words and decide if the aim of the problem is reasonable. At a user’s request,

the tutorial will provide the translation; for example, relevant/irrelevant information will appear in different colors in the text. To help students visualize the problem, the tutorial can also offer a sketch of the situation or appropriate diagrams. In the redescription phase, the students’ own understanding of the problem is converted into applicable physical principles. Typical questions asked here are: What are the basic physics principles involved? What are the associated physical quantities? Depending on the type of the problem (mechanics, electricity, etc) subsequent specific questions follow, for example: What is the state/type of the motion? What is the reason for that particular state/type of motion? Etc. The next step is planning: what the problem asks for must be connected to the situation and the given information. This requires relationships between physical quantities previously identified. The tutorial can help the user to recognize the important physical quantities, but will not provide equations or help in solving the problem algebraically. To carry out the plan and reach the solution the student uses paper and pencil and may consult notes or textbook. However, if the translation and visualization phases are done properly, the student has achieved a good basis of understanding for producing the solution. In the last step the tutorial will confirm if the student’s solution is correct, but ask additional questions to prompt the student to think about the answer: is the solution reasonable? Is this a special case? How does this relate to common experience? How would the answer change if one or other of the variables changes? What about extreme cases where a variable becomes very small or very large, and does this make physical sense?

In order to solve the problem, students don’t have to go through all the steps and guidance offered by the tutorial. They can provide a solution whenever they feel confident enough, or work independently until they feel they need guidance.

## PROGRAMMING TOOL

The graphical development tool offered by LabVIEW has radically changed the way engineers and scientists design data acquisition and control applications. Its visual programming environment, although not originally designed with the creation of interactive web-accessible problem solving tutorials in mind, turns out to be a versatile and flexible tool for doing so.

A LabVIEW program is called a VI (virtual instrument) and a subroutine (a smaller VI embedded in a larger one) is called a subVI. The user interface, called the front panel (Figure 1), contains a combination of controls and indicators (numerical and Boolean) that facilitate communication with the

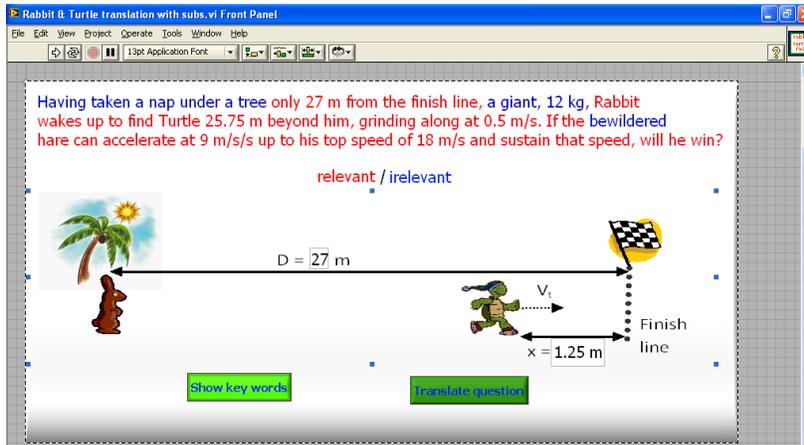


FIGURE 1. Screenshot of a simple LabVIEW program, showing the front panel of a translation VI.

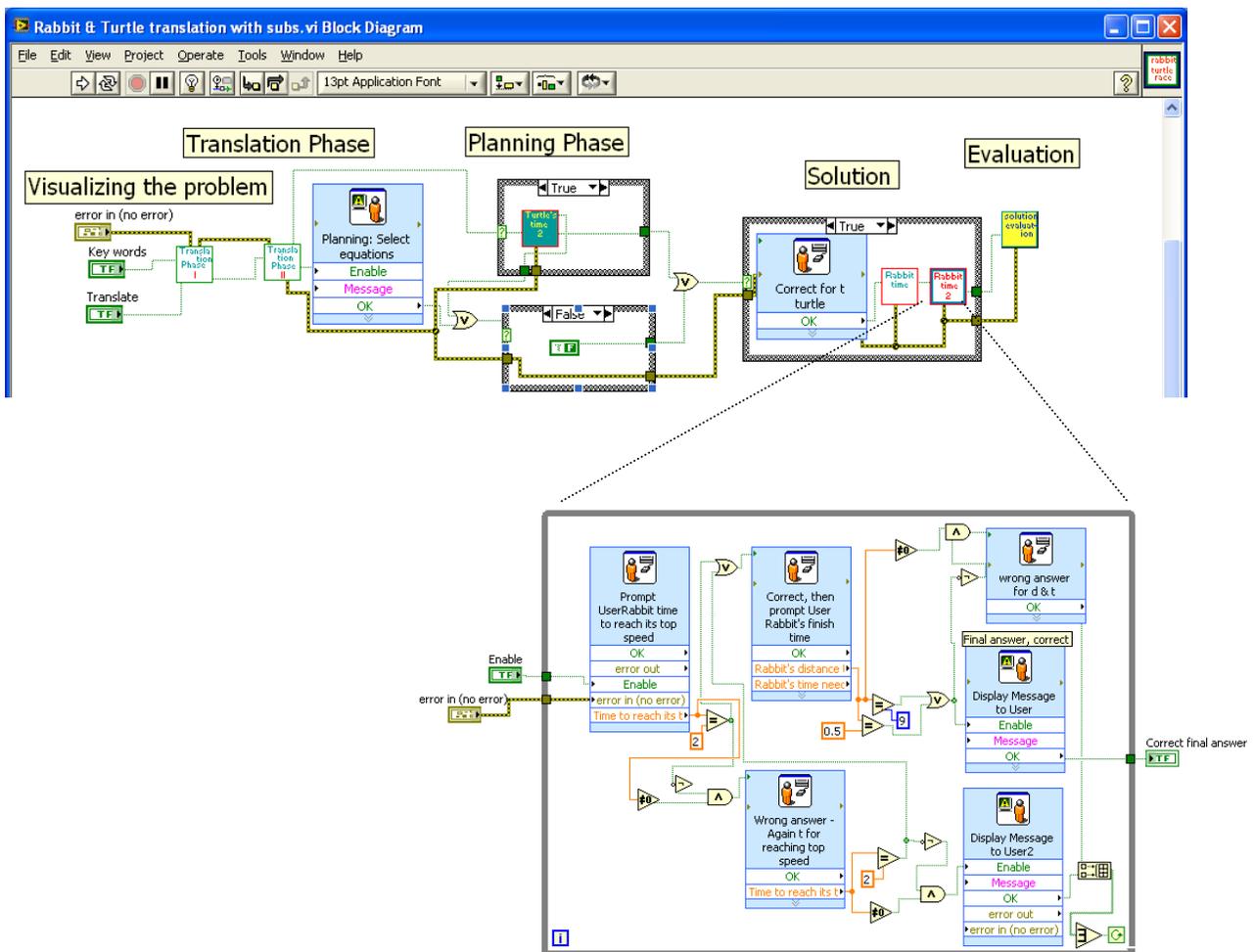


FIGURE 2. The block diagram of the VI shown in the previous figure is shown in the upper part. Displayed in the lower part is the blow out of the block diagram of a component subVI. Each symbol on the block diagram represents a LabVIEW subroutine (subVI) corresponding to a particular step from the problem-solving strategy.

program. The heuristic dialog is performed through pop-up dialog boxes (prompt user and display message).

The graphical source code of a VI is contained in the block diagram (Figure 2), which is the programmatic interface. Instead of writing the program, the programmer builds a block diagram by connecting various objects with specific functions in a ‘wire-like’ fashion. Components involved are: terminals (corresponding to the controls and indicators from the front panel) and nodes (these can be functions, VIs, or structures).

This modular structure allows the creation of “specialized VIs”, responsible for executing fragments of a larger program, which therefore act as subroutines. Each step in a problem solving strategy can correspond to (and be executed by) a specific subVI. This division of the program into dedicated subroutines not only simplifies the application as a whole, but also allows the creation of templates, which assist in making changes to an existing program, or creation of a new one. The programs are thus ‘open’ to users, rather than closed as for proprietary programs.

Web-accessibility is provided through LabVIEW Run-Time Engine, software offered free by National Instruments. This Engine would allow students to run executables or view LabVIEW Remote Panels by accessing a remote server. Only the server needs to have LabVIEW installed.

## CONCLUSION

We have shown that LabVIEW can serve as a versatile and accessible visual programming environment for the creation of web-based interactive tutorials for physics problem solving. We have developed such tutorials for a limited number of problems so far, to try out in practice and at the same time help refine both pedagogical strategies and visual programming techniques for the purpose.

Formal evaluation will come at a later stage, but the response to preliminary trials with students has been positive; they enjoyed solving physics problems assisted by our tutorial sequence and learned from them. Early results and progress were presented at the University of Virginia’s College at Wise, at the Fellowship In the Natural Sciences (FINS) Annual Conference in October 2007, with favorable feedback.

Future work includes the creation of a library of interactive problem-solving tutorials, the assessment of the project and its products, and evaluation of its impact and sustainability. We intend to develop a web page that will allow open access to our interactive tutorials for interested instructors and students.

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