

## Coach: A New System for Interactive Learning

John H. Ristroph  
University of Louisiana at Lafayette

### **Abstract**

Coach is an interactive learning system originally designed for engineering economics, and then extended to be useful to other disciplines. It provides professors with a comparatively easy way to implement computer-based tutorials, examples, or problem solving sessions.

### **Introduction**

Interactive learning systems encourage active learning, but they have proven to be very difficult to implement. Professors who have developed such systems [1, 2, 3] understand the benefits to students, but the development time can be prohibitive. This paper describes an Excel-based system named Coach that uses Visual Basic for Applications to provide a single platform for both implementing and conducting interactive learning sessions.

There are two levels to the design of such a system. The first consideration is how the final end product will appear to students, and the second dimension is to provide an effective developmental environment for professors. The next section shows the system from a student's viewpoint using a fairly basic example. Then the following section explains a professor's implementation, and provides an overview of the system. The last section provides a brief summary and discusses potential impacts of the system on engineering education.

### **Student's Perspective**

Students see a display area with a question followed by graphics and text, including equations using typical engineering notation. Beneath the display area are steps consisting of prompts or other instructions provided by a professor. Initially, only the text of the first step is visible, and then other steps appear as the student progresses. Students respond to these, and then feedback occurs using text, graphics, screen effects, or sound. Figures 1 through 7 on the following pages show this process. Students can revisit steps and experiment, or press Clear and start over. Pressing Mute toggles sound effects on and off, and Help provides assistance in using Coach.

**Interactive Process.** Figure 1 illustrates using a dropdown box to respond to a prompt. Other response mechanisms are screen hot spots and the traditional method of typing followed by pressing Enter. Figure 2 shows the result of a wrong answer to Step 1 in which the response background becomes red and a feedback box makes a suggestion. The cursor is placed back on the incorrect response cell for another try.

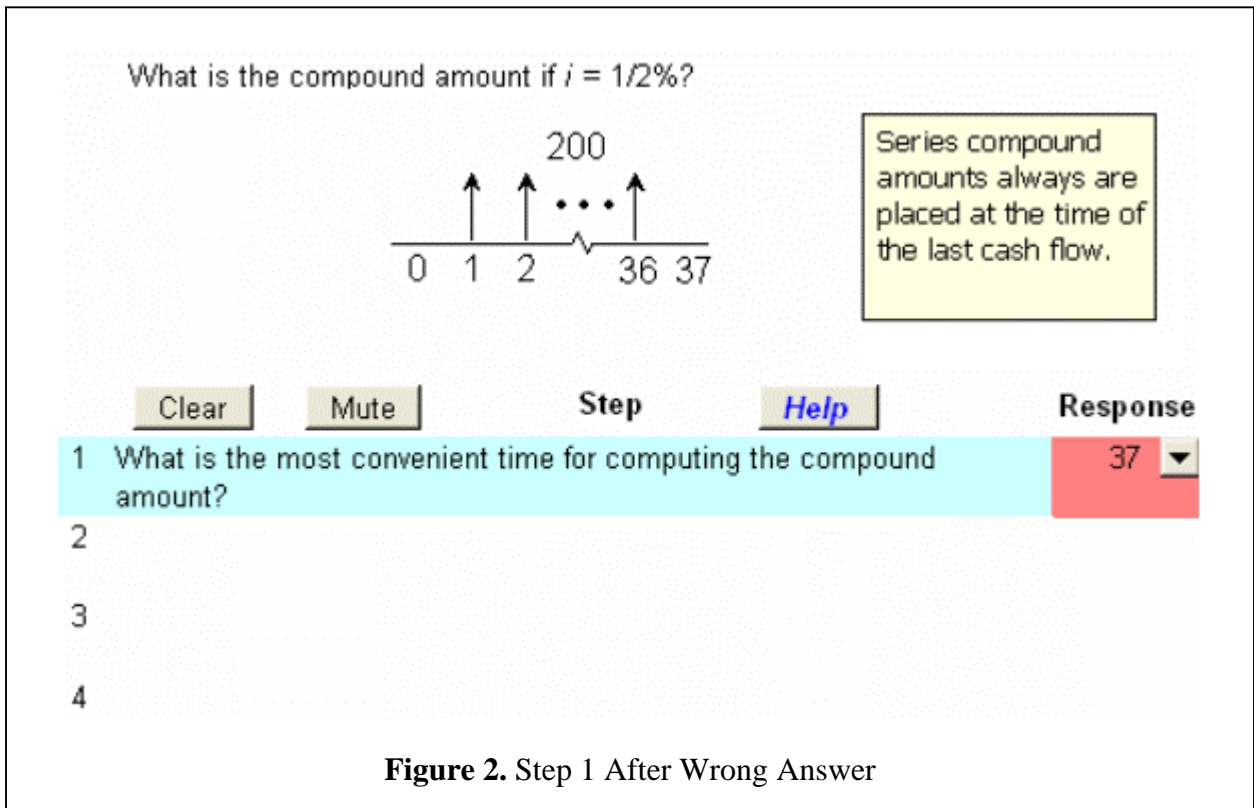
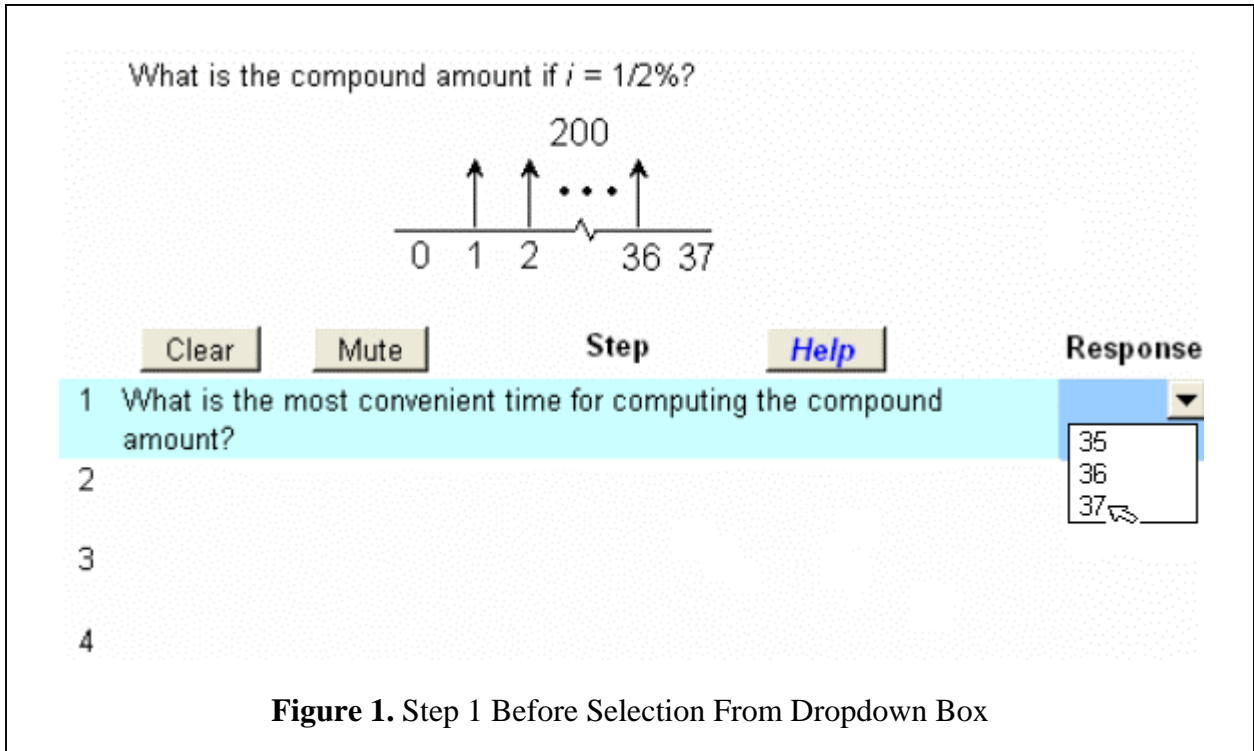
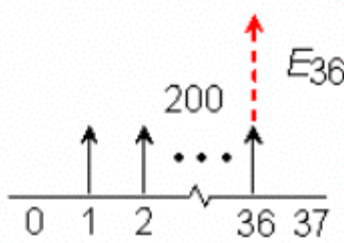


Figure 3 is a correct answer to Step 1's dropdown box, with a green response background and positive feedback. Also the display blinks; a red arrow now shows the position of the equivalent; and the cursor advances. Figure 4 is the result of a correct answer to Step 2's dropdown box.

What is the compound amount if  $i = 1/2\%$ ?

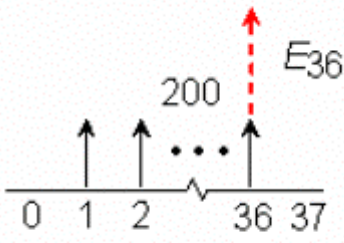


Yes, at the time of the last cash flow. Notice the equivalent arrow on the diagram.

	Clear	Mute	Step	Help		Response
1						36
2						▼

**Figure 3.** Step 1 After Correct Answer With Equivalent Arrow

What is the compound amount if  $i = 1/2\%$ ?



Nice going!

	Clear	Mute	Step	Help		Response
1						36
2						F A
3						▼

**Figure 4.** Step 2 After Correct Answer

Figure 5 results from a correct answer to Step 3's drop down box; notice that the display now includes an equation with subscripts. More complex equations can be entered as figures using Microsoft's equation editor. Notice that there is no dropdown box for the reply to step 4 since the professor wants to be sure that the student actually can do the computations.

**Round-Off.** Directly typed entries usually cause a problem due to round-off errors. For example, student who uses a calculator will compute \$7,867.22, whereas an answer based on tables would differ slightly. Coach addresses this problem with functions that accept an answer if it is within either an absolute error or absolute percent error specified by the professor, in this case 0.02 or 0.025%. Entering 7,867 is acceptable although its absolute error is too large, since its absolute percent error is within limits.

**Personal Touches.** Coach can reflect a professor's classroom persona, or lack thereof. When the student types 7,867 and presses enter, the computer groans audibly and displays the notice shown in Figure 6. After this wakes the student up, then he or she can click the notice covering the response to remove the offending warning to see the final screen displayed in Figure 7.

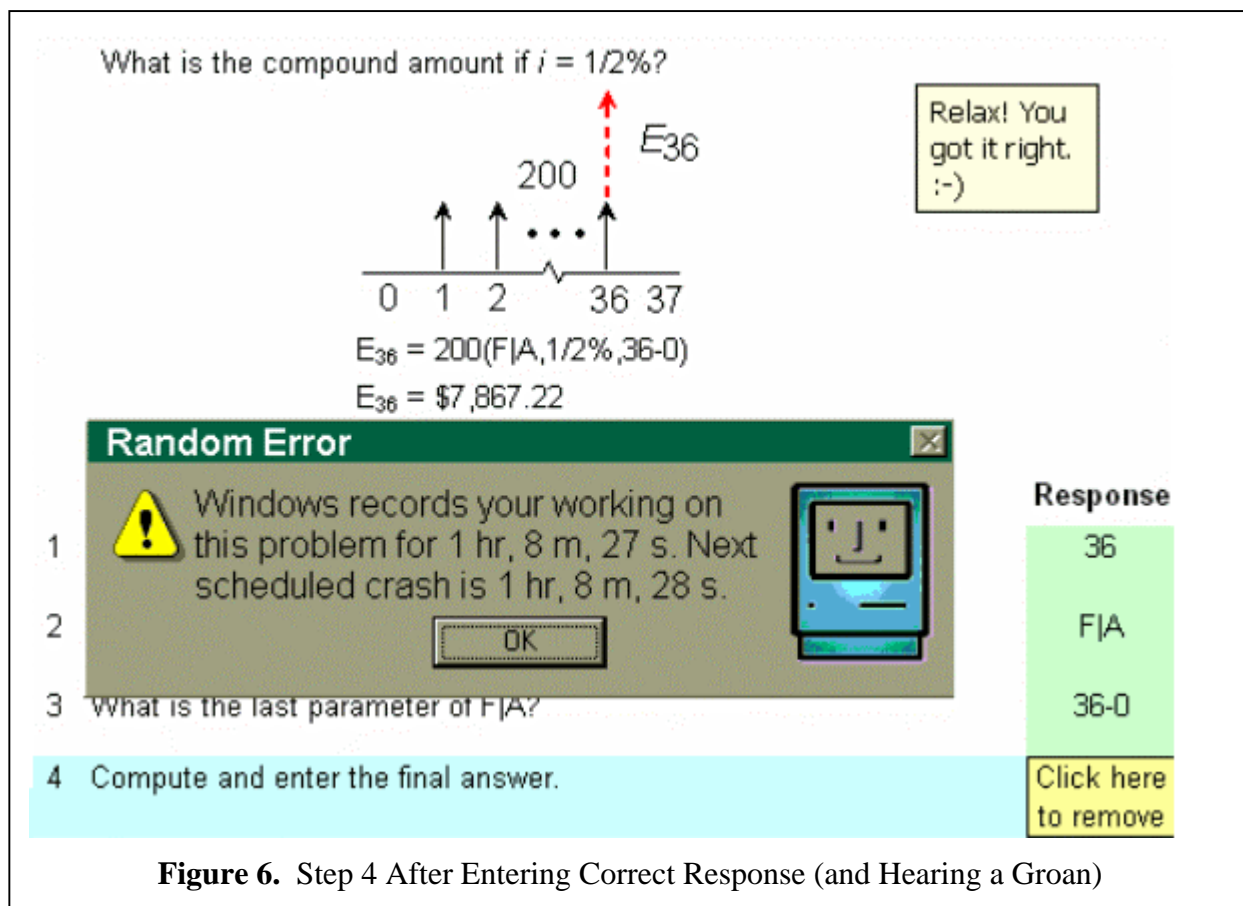
In summary, students have a full interactive experience that they have come to expect from a computer, using text, graphics, screen effects, sounds, point-and-click, and typing. They can learn at any time or place, a definite bonus for students with jobs or taking distance courses.

What is the compound amount if  $i = 1/2\%$ ?

$E_{36} = 200(F|A, 1/2\%, 36-0)$

	Clear	Mute	Step	Help	Response
1					36
2					F A
3					36-0
4					

**Figure 5.** Step 3 After Correct Answer With Equation

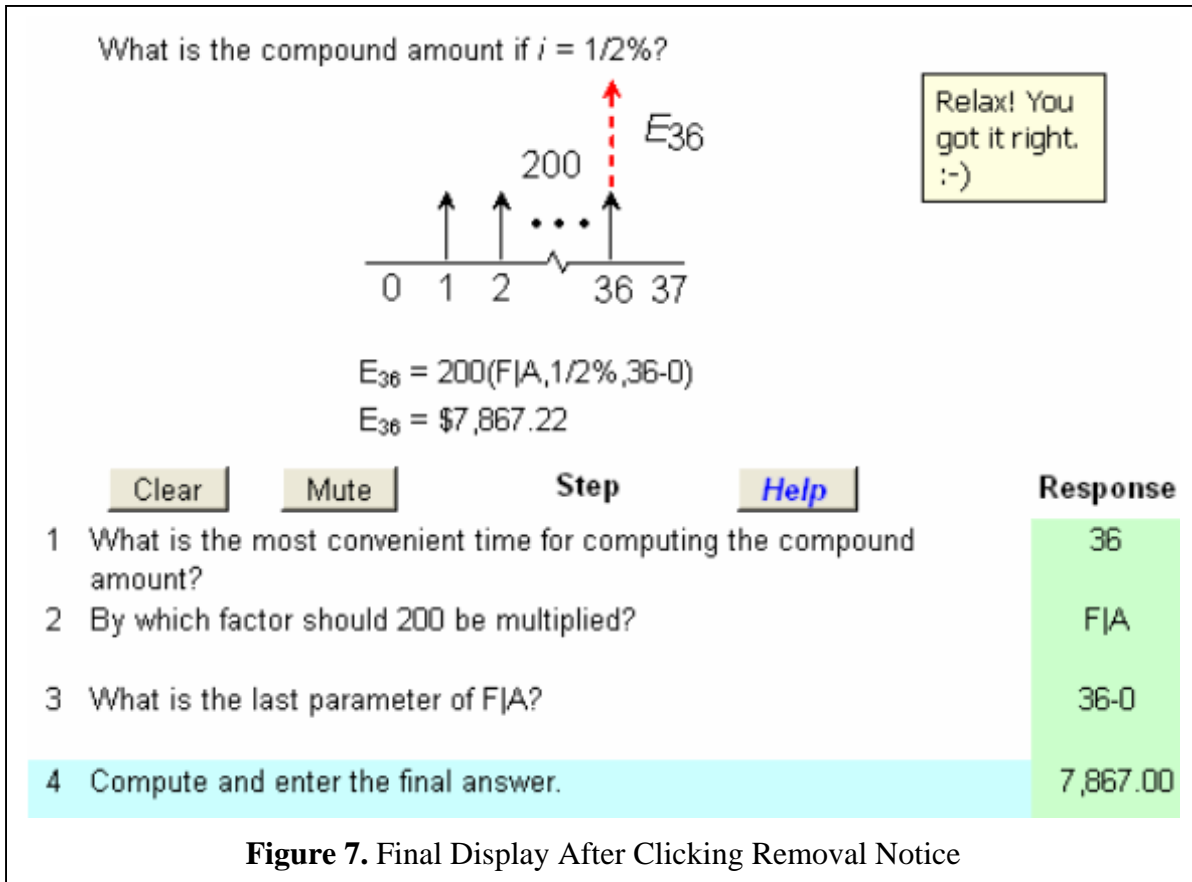


### Professor's Perspective

Professors know that once the novelty wears off, students will realize that they've been tricked into learning. To this end, Coach collects performance statistics so that professors can see how much students worked, which problems they solved, and how much experimentation they engaged in. Interesting, but there is still the bottom line: How much of a professor's time will the system require? Also how does the system work?

**Time.** Interactive sessions like the preceding example usually are implemented on a website by someone with a fairly high degree of expertise and/or plenty of time. Coach merely assumes that a professor is reasonably familiar with Excel and can use a graphics program, such as MS Graph via the graphics toolbar of Excel or MS Paint. Coach provides a simple structure and an easy-to-master command language that offers professors dropdown selections and other aids. Persons very familiar with Excel can use many of its features for additional enhancements.

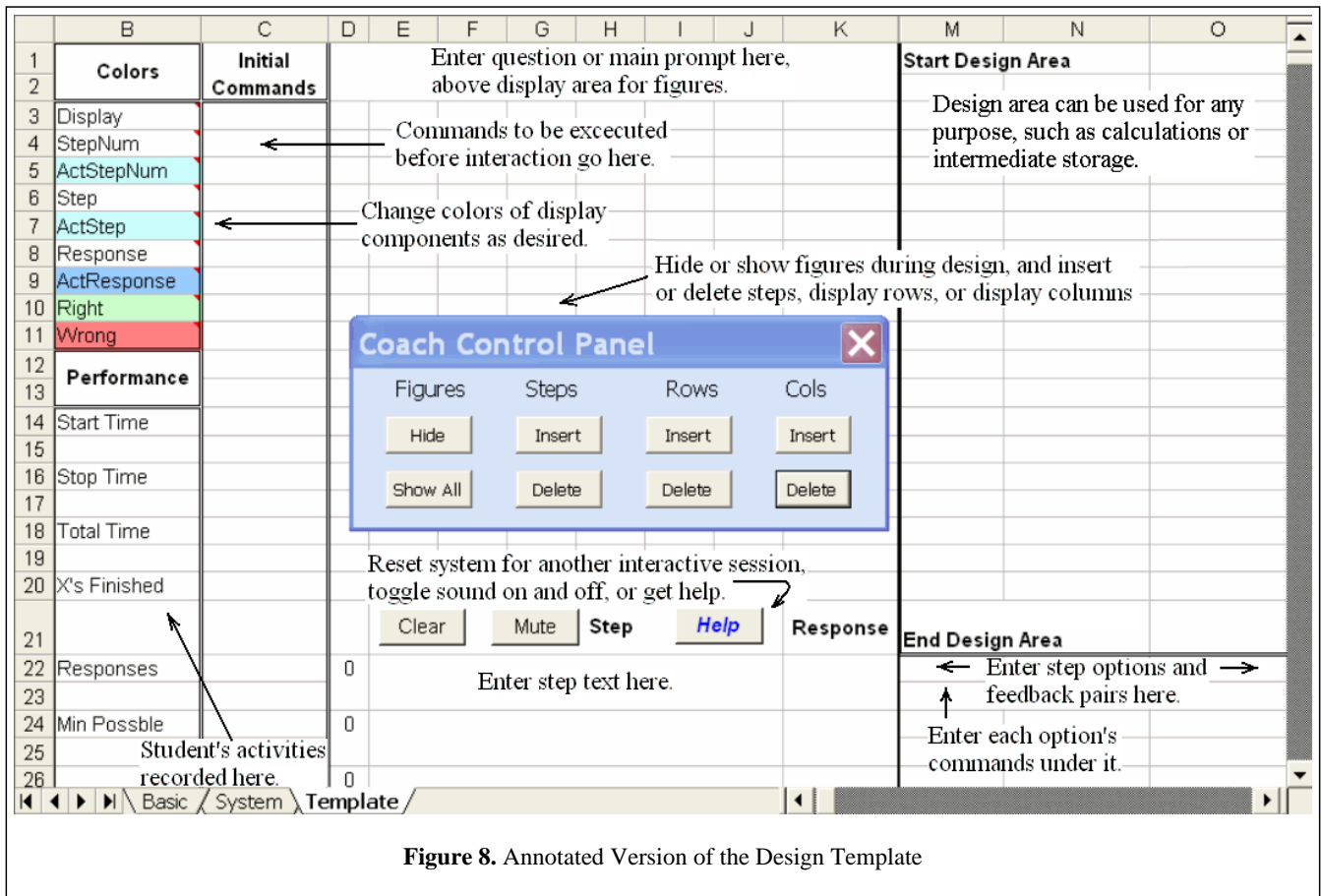
Like anything else, Coach has a learning curve, but professors should rapidly progress to implementing a problem like the example in 20 to 40 minutes; and thereafter times would depend upon the individual. This assumes that the professor is doing his or her own technical graphics, but is using freely available sound and humor files. The remainder of this section illustrates how Coach works by providing an overview of the example's implementation.



**Template.** The implementation begins by using Excel's *Edit / Move or Copy Sheet* menu to create a copy of a sheet named Template. Then change the name of the new sheet (say, to *Basic*) by double-clicking its tab. Figure 8 shows an annotated version of the design template, with its control panel activated. The buttons on the movable Control Panel allow showing and hiding figures during design, as well as inserting and deleting steps, display rows, and display columns. For example, clicking *Insert* under *Col* twice would move the start of the design area to column O.

**Graphics.** Usually one of the first activities is to create whatever graphics are necessary, either by using the graphics toolbar or the *Insert / Picture / From File* menu. The graphics toolbar provides a surprisingly extensive set of drawing tools. When it is used to create a figure, select all of the individual elements of the figure and group them using the *Draw* dropdown on the toolbar. After creating each figure, select it and type its name into Excel's name box. Finally, position the figures as desired on the display area and enter the question, as shown in Figure 9.

**Initial Commands.** Coach goes from design mode to the run mode used by students when the Clear button is pressed. Clearing hides all figures in the display area, deletes any text there, and applies color schemes, among other things. Column C contains initial commands that are executed after clearing. Typical commands include showing figures and hiding unused display rows. The final initial command is Start, and it puts the cursor in the first response cell. Thereafter Coach keeps the cursor in the response cells, but it does allow clicking on screen hot spots to provide responses to prompts. Figure 10 shows the initial commands for the example.



**Figure 8.** Annotated Version of the Design Template

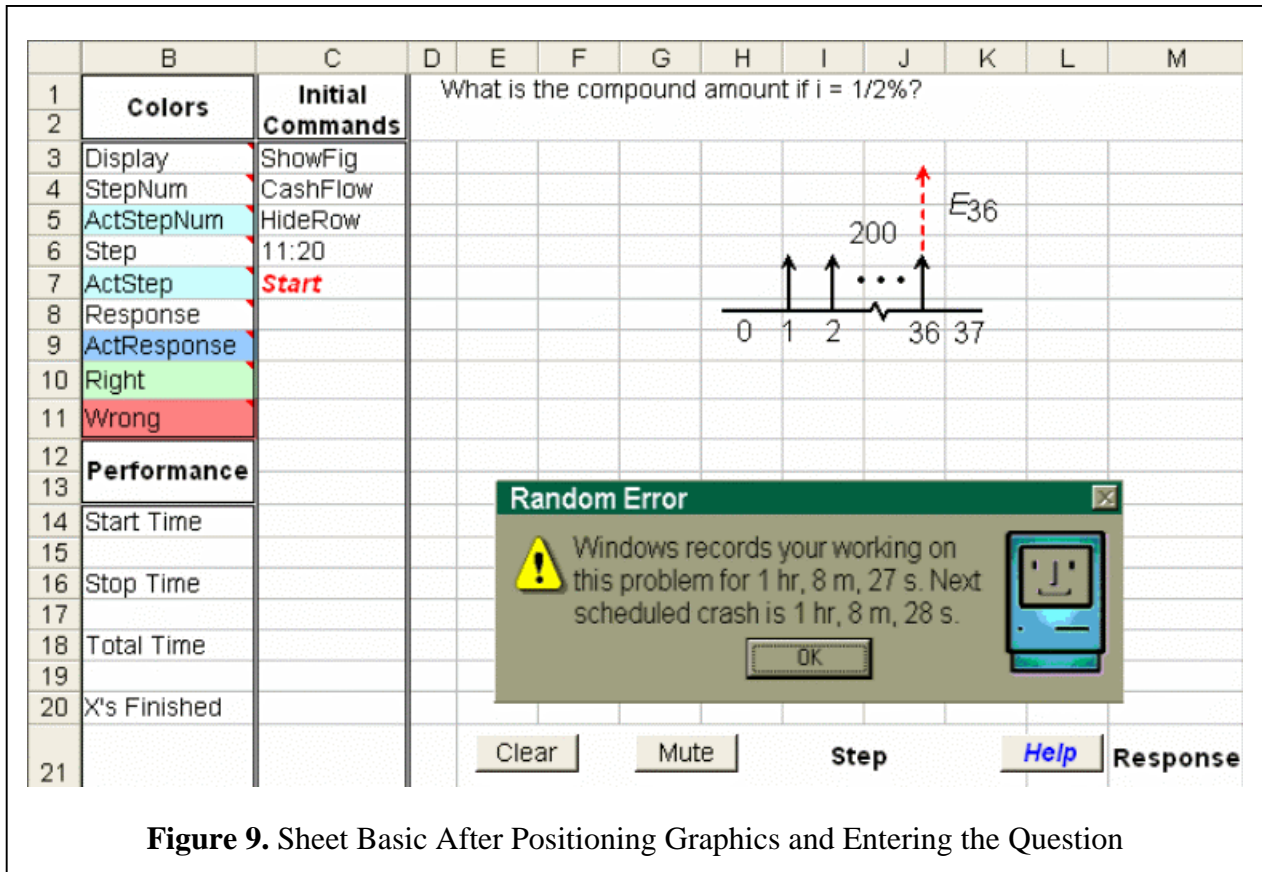


Figure 9. Sheet Basic After Positioning Graphics and Entering the Question

**Command Entry.** Coach always uses two cells for each command: one for the name of the command and a second cell for the command's argument, if any. The commands in Figure 10 show the figure named CashFlow, hide rows 11 through 22 since they will not be used, and then start the user interaction. Commands that must appear last in a sequence of commands always have a red color to make it easier to be sure that the sequence is properly terminated. Figure 11 shows the automatic, context-sensitive dropdown box of command names, and Figure 12 illustrates the use of context-sensitive dropdown boxes, prompts, and/or partial entries to assist entering arguments.

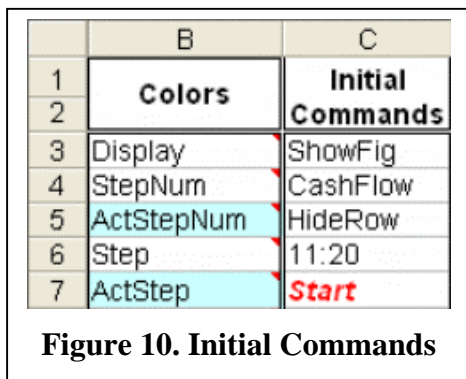


Figure 10. Initial Commands

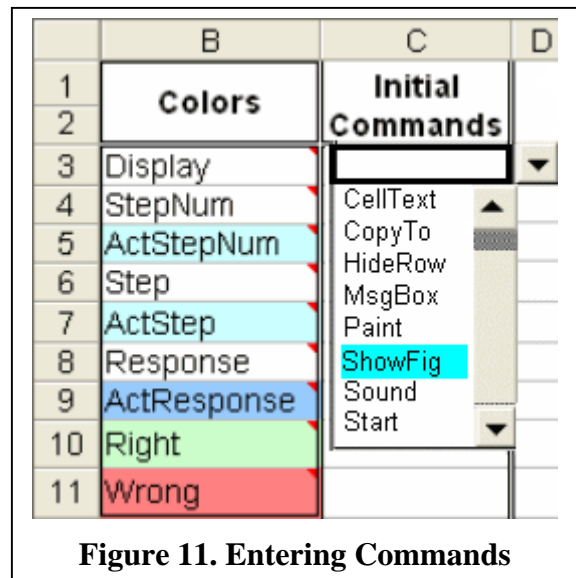


Figure 11. Entering Commands



**Prompts and Options.** Next type in the prompt for the first step at the start of the step area, cell E22 in Figure 14. On the same row enter the options for the step, in this case 35, 36, and 37 beginning in column O and moving one cell to the right for each different option. There can be up to 30 options, and Coach keeps track of how many are actually entered for each step, and then automatically creates a dropdown box for the response cell. If this dropdown is not wanted, then select the response cell and uncheck the dropdown option on the *Settings* tab of the *Data / Validation* menu.

	B	C	D	E
1	Colors	Initial		
2		Commands		
3	Display	ShowFig		
4	StepNum			▼
5	ActStepNum			
6	Step			
7	ActStep			
8	Response			

**Figure 12. Entering Arguments**

**Option Feedback and Commands.** Beneath each option, type in the feedback message to be displayed if it is selected. Then under each option enter as many command-argument pairs of cells as needed. Several of the arguments use custom functions, such as the Approval( ) feedback function that randomly generates positive feedback messages like “Good!” or “Nice going!” The Insert Step button allows editing via adding extra step rows to accommodate additional command-argument entries, and similarly unneeded step rows can be deleted with the Delete Step button. The system automatically updates cell references after deletions, and command-argument entries can be dragged to different locations with automatic updating. Several commands are illustrated in Figure 14, and Table 1 provides a complete alphabetical listing with terminators shown in red. Each sequence of command-argument entries must end with a terminator.

**Design Area.** The right side of Figure 13 is the design area. Use this area to dynamically perform calculations depending upon a student’s responses, or for any other purpose. In this case, it contains formatted equations in cells P10 and P11 that steps 3 and 4 copy into cells G9 and G10.

	B	C	D	E	O	P	Q
1	Colors	Initial	What is		Start Design Area		
2		Commands					
3	Display	ShowFig					
4	StepNum	CashFlow					
5	ActStepNum	HideRow					
6	Step	11:20					
7	ActStep	Start					
8	Response						
9	ActResponse						
10	Right					$E_{36} = 200(F A, 1/2\%, 36-0)$	
11	Wrong					$E_{36} = \$7,867.22$	

**Figure 13. Design Area**

O42													=IsClose(N42,7867.22,AE,APE)			
D	E	F	G	H	I	J	K	L	M	O	P	Q	R	S	T	
21	Clear		Mute		Step			Help		Response	End Design Area					
22	1		What is the most convenient time for computing the compound amount?						35	36	37					
23	1								Series con	Yes, at the time	Series compound amounts always are placed at the time of					
24	1								Wrong	ShowFig	Wrong					
25	1								Equivalent							
26	1								Blink							
27	1									3						
28	1								Next							
29	1															
30	2		By which factor should 200 be multiplied?						FJP	FJA	PJA					
31	2								This factor	Nice going!	This factor computes an equivalent one period before the s					
32	2								Wrong	ShowFig	Wrong					
33	2								Equivalent							
34	2								Next							
35	2															
36	3		What is the last parameter of FJA?						36-1	37-0	36-0					
37	3								The last p	The last pararr	Sweet!					
38	3								Wrong	Wrong	CopyTo					
39	3										G10=P10					
40	3										Next					
41	3															
42	4		Compute and enter the final answer.						7867.22	0						
43	4								Relax! You Ouch!	Ever have trouble balancing a checkbook? Please try again.						
44	4								Finish	Wrong						
45	4															
46	4								CopyTo							
47	4								G11=P11							
48	4								Sound							
49	4								Groan							
50	4								ShowRow							
51	4								11:20							
52	4								ShowFigOK							
53	4								FakeCrash							
54	4								Paint							
55	4								M42							
56	4								Same							

Figure 14. Prompts, Options, and Commands

Table 1. Commands and Arguments		
Command	Description	Argument
Blink	Blink the display area.	Number of blinks.
CellText	Put unformatted text into cell(s).	=CellText(??,"??"), where first ?? is the target and the second ?? is the text.
CopyTo	Copy to cell(s) from cells(s).	=CopyTo(??,??), where arguments are first the To cell(s) and then the From cell(s).
Finish	Record the finish time.	None.
GoTo	Go to another step.	=XLCells(??), where ?? is the cell containing the target step number.
HideFig	Hide a figure.	Figure name.
HideRow	Hide row(s).	=XLRows(??), where ?? is the target.
MsgBox	Display an "OK" message box.	Text of message.
Next	Proceed to the next step.	None. Turns current response correct color.
OKCancel	Display an "OK/Cancel" box.	Text of message.
OKCancel	Paint cells.	=XLCells(??), where ?? is the target . Use formatting toolbar to paint argument cell the desired color.
Same	Stay on the same response.	None. No automatic response color change.
ShowFig	Show a figure.	Name of figure.
ShowFigOK	Show figure w/ removal button.	None.
ShowRow	Unhide rows.	=XLRows(??), where ?? is the target.
Sound	Play a sound.	Primary name of .wav file.
Start	Begin interaction and mark time.	None.
Wrong	Stay on the same response.	None. Turns current response wrong color.
YesNo	Display an "Yes/No" box.	Text of message.

**Testing.** Now all that remains to be done is to click the Clear button to enter the interactive run mode and test the system. Two special key combinations facilitate testing. The Ctrl+Shift+I key interrupts the run mode and puts the system in design mode. Then entering Ctrl+Shift+R resumes the run mode. When testing is complete, pressing Ctrl+Shift+P puts the system in password mode. Coach hides the Template and System sheets, puts all remaining sheets in run mode, and requests a password that must be used to re-enter the design mode. Now students cannot enter the design mode to examine performance records or determine which options are correct, so the workbook is ready for distribution.

**Performance Tracking.** Coach tracks a student's performance by recording usage data for each sheet. It stores the most recent start and stop times, as well as the total time. It also records the

number of responses, the number of successful session completions, and the minimum number of responses required for those completions. This information is stored in the performance area of each sheet in design mode, as shown in Figure 15. The number of responses can be expected to exceed the minimum due to normal mistakes. Also Coach allows revisiting prior steps to experiment, resetting the display to its appearance when the step was first visited. Nonetheless, a very high number of responses indicates that a student probably is having difficulty. When a student completes a workbook, it can be emailed to the professor who supplies the password. This instructs Coach to re-enter design mode and create a performance summary on sheet System for all of the sheets in the workbook.

### Summary, Conclusions, and Future Directions

The current example only uses Coach's commands to control step-by-step progress from the first step to the last step, provide feedback, and affect the display area, but Coach is not limited to simple interactions. For example, the GoTo command allows alternative solution procedures, and for complex situations Excel's If() function permits conditional prompts and commands.

The use of Excel as Coach's platform allows incorporation of its extensive capabilities, such as drawing transparent polygons to serve as screen hot spots that serve as hyperlinks to return responses to prompts. In the example, the student could have been asked to click the time on the diagram at which to place the compound amount. Similarly, this technique can be used to select cash flows by clicking, or even regions in a statics free-body diagram.

An extremely promising future direction utilizes Excel's random number generation capability to provide each student with individualized problems. This benefits students and helps professors address the age-old problem of homework copying. The structure of the system has been designed with this expansion in mind, as well as the capability for automated grading.

Professors control the extent of help that Coach provides. Detailed step-by-step, point-and-click interactions can guide a student initially. Then a later problem can require students simply to type in intermediate results, and only notify them if their input is correct or wrong. This requires the students to do their own work, but it pinpoints where difficulties occur and lets the students use their time more effectively. In short, the system can adapt to each professor's own style.

The challenging aspect of creating Coach lay in its conceptual design, imagining the framework, determining its major structures and components, such as the command language, and then developing a seamless system meeting the needs of both students and professors. Hopefully, it will

	B
1	<b>Colors</b>
2	
3	Display
4	StepNum
5	ActStepNum
6	Step
7	ActStep
8	Response
9	ActResponse
10	Right
11	Wrong
12	<b>Performance</b>
13	
14	Start Time
15	
16	Stop Time
17	
18	Total Time
19	
20	X's Finished
21	
22	Responses
23	
24	Min Possible
25	

Figure 15. Performance Area

provide an organized, easy-to-use method for professors to offer high quality, convenient, active learning sessions for their students. Such an outcome would serve engineering education in general and specifically deal with growing trends of distance learning and students with jobs.

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### ***Author***

JOHN H. RISTROPH is jointly appointed as a professor of Engineering and Technology Management and as a professor of Economics and Finance at the University of Louisiana at Lafayette. His doctorate is in industrial engineering and operations research, and his non-academic experience includes service to the Louisiana Department of Natural Resources first as Head of Economics and Statistics and then as Director of Policy and Planning.