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Bothered by Abstraction: The Effect of Expertise on Knowledge Transfer and Subsequent Novice Performance

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Abstract

Although experts should be well positioned to convey their superior knowledge and skill to novices, the organization of that knowledge, and particularly its level of abstraction, may make it difficult for them to do so. Using an electronic circuit wiring task, we found that experts as compared to beginners used more abstract and advanced statements and fewer concrete statements when providing task instructions to novices. In a second study, we found that beginner-instructed novices performed better than expert-instructed novices and reported fewer problems with the instructions when performing the same task. In study 2, we found that although novices performed better on the target task when instructed by beginners, they did better on a different task within the same domain when instructed by experts. The evidence suggests that the abstract, advanced concepts conveyed by experts facilitated the transfer of learning between the different tasks.

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Bothered by Abstraction: The Effect of Expertise on Knowledge Transfer and Subsequent Novice Performance

We live in a knowledge-based economy in which work is increasingly knowledge work. "What an organization and its employees *know* is at the heart of how the organization functions" (Davenport and Prusak, 1998: x). However, there are problems inherent in the location and transfer of knowledge and skill across boundaries inside organizations (e.g., Hansen, 1999). "Managers are realizing that "inside their own organizations lies, unknown and untapped, a vast treasure house of knowledge" that if tapped, "could drop millions to the bottom line and yield huge gains in speed, customer satisfaction, and organizational competence" (O'Dell & Grayson, 1998: 154). Davenport and Prusak (1998) observed that most of the knowledge companies need is already inside these organizations. To capitalize on this knowledge, organizations must figure out how to transfer the expertise from those that have it to those who need to know.

In a knowledge-based economy, training to develop additional skill and expertise is important. Although estimates are that U.S. companies spent almost $60 billion on formal training programs in 1997 (Bartel, 2000), on-the-job-training may be as important or even more important a way in which people learn how to do their work. That is because doing the work itself—learning from experience—and, of course, calling on co-workers and supervisors to provide insight and guidance, is one of the most important and effective ways people learn how to do things (e.g., Lazear, 1995; Pinfield, 1995). "Most people…consult a few knowledgeable people when they need expert advice on a particular subject" (Davenport and Prusak, 1998: 12).

In both the case of on-the-job training and in instances of transferring knowledge across boundaries within an organization, experts are often called upon to share their expertise with novices. For example, experts may be asked to produce "white papers" or to embed their knowledge within databases that can be made available to others throughout the organization. Experts also may be asked to participate in programs in which they transfer knowledge to others with less expertise who are in the same domain. However, there may be problems in transferring knowledge and expertise to those less knowledgeable because the very characteristics that constitute expertise may interfere with experts' ability to effectively convey their knowledge to novices. In particular, experts may have trouble overcoming the cognitive differences between themselves and novices to effectively instruct those less expert than themselves. For instance, Bechky's (1999: 17) ethnographic study of a production floor revealed interactional difficulties between assemblers and engineers: interactional trouble resulted because "the engineers had an abstract understanding while the assemblers had a concrete one." In this paper we examine how experts as compared to beginners, defined as those with some task knowledge but not nearly as much as the experts, convey instructions to novices. We also explore the effect of these differences in instructions on novice performance in both stable and dynamic task environments.

Instructing Novices

Intuitively, one might expect that experts will be the best teachers – those most suited to convey their superior knowledge to those with less expertise. However, characteristics that differentiate experts from beginners may interfere with experts' ability to effectively transfer their domain-specific knowledge to novices. Experts organize and access knowledge differently than those with less expertise (see Sternberg, 1997 for a review). Expertise comes with experience and with the acquisition of tacit knowledge in the domain (see Polanyi, 1966). For the purposes of this study, we consider experts to be those with both knowledge and experience in applying this knowledge to a variety of problems within the domain. In contrast, beginners are those with some exposure to, but little experience in the domain. Beginners, as compared to experts, are less adept at performing tasks within the domain and have less mastery of the concepts and theories in the domain.

One robust finding in studies of experts is that, as expertise increases, mental representations become more abstract. For example in a electronics trouble-shooting task, Gitomer (1988) found that more skilled electronics technicians viewed an electronic device as a system of components, and conducted trouble shooting by following a conceptual model of the circuit. Less skilled technicians assumed that "there must be a short somewhere" and spent more time switching , using a trial-and-error procedure. Similarly, Chi and her colleagues (Chi, Glaser, & Rees, 1982) found that experts in physics used a deeper, more conceptual structure to sort physics problems whereas novices sorted problems using a superficial structure. Langer and Imber (1979) found that expert's lists of task components contained fewer and less specific steps than those with less task experience. These studies along with others (i.e. Ceci, & Liker, 1986; Gobet & Simon, 1998; Johnson, 1988; Lamberti & Newsome, 1989; Chase & Simon, 1973; McKeithen, Reitman, Rueter, & Hirtle, 1981) suggest that experts encode and process information in a more conceptually abstract way than do those with less expertise.

Experts, by definition, also have more knowledge within a domain than do those with less expertise. In many fields, expertise is hierarchical. That is, one cannot understand more advanced concepts unless provided with the foundation on which to build. For example, it may be extremely difficult to learn calculus without the foundation of understanding multiplication. Consistent with this idea, theories of cognitive skill development suggest that acquisition of declarative knowledge must precede acquisition of procedural and strategic knowledge (see Ackerman, 1987; Anderson, 1982; Kraiger, Ford, & Salas, 1993). Thus, it is likely that in the process of gaining expertise, experts have acquired not only more knowledge but also more advanced knowledge than they had as novices.

There are two reasons to suspect that experts may have difficulty effectively instructing novices. First, there is evidence that experts are likely to articulate their superior knowledge at a more advanced, abstract level. Second, experts may face cognitive limitations when attempting to adjust their level of presentation downward to a level appropriate to novice learners.

Although little work has focused specifically on the articulation of expert knowledge, studies of expertise often ask experts to describe the process they use to think through a problem or generate a solution. For example, in work examining how people learn to skip steps in solving problems as they gain expertise, Blessing and Anderson (1996) asked participants to describe their thought processes as they solved 200 algebra-like problems. Such work equates the thought process of experts with experts' articulation of their thought processes. From this work, it appears that experts not only organize their knowledge differently, but that they articulate it differently than those with less expertise. Consistent with extensive work examining the organization of expert knowledge, experts can be expected to use more abstract concepts and demonstrate a more advanced understanding of the domain when articulating their knowledge. Although this research does not tell us whether or not experts will actually explain their understanding differently when asked to instruct novices, we posit that they will.

Previous research suggests that experts can have difficulty anticipating novices' experience. Experts may suffer from an availability bias that leads them to rely upon their own, more recent experience when anticipating the experience of novices (Hinds, 1999). Hinds describes a process whereby experts attempt to predict the experience of novices by anchoring on the experts' own novice experience and using this as a basis from which to estimate novice performance. However, the accuracy of this anchoring and adjustment process is disrupted by experts' inability to recall their own novice experience. Experts, therefore, rely more heavily on their own recent experience and have trouble imagining the lack of knowledge with which novices start. In the same study, those with an intermediate level of expertise were more accurate than were experts in their estimation of novices' experience (Hinds, 1999). Those with less expertise were more able to understand the experience of novices because their most recent experience was closer to that of the novices and therefore less adjustment was required.

We expect that experts as compared to beginners will experience a similar bias when instructing novices. That is, when instructing novices, experts will not adequately adjust downward and will convey information at a level and degree of abstraction that does not account for the novices' lack of domain knowledge. Therefore, we predict that experts, as compared to beginners, will make more statements that assume an advanced understanding of the domain and more statements containing abstract conceptualizations of the problem.

H1: Experts, as compared to beginners, will make more abstract and fewer concrete statements when instructing novices.

H2: Experts, as compared to beginners, will use more advanced concepts and fewer basic concepts than beginners when instructing novices.

The Effect of Instruction on Novice Performance

Assuming that experts, as compared to beginners, convey instructions to novices using more advanced, abstract statements, the next question is whether or not this difference in behavior affects novice performance. One reason to think that the level of instruction would affect performance is that novices are likely to need concrete, basic knowledge as a foundation for understanding how to perform the task. For example, Kalyuga, Chandler, and Sweller (1998) demonstrated that, although trade apprentices were distracted by labels on the diagrams, the less experienced trainees benefited from the labels. Novices may have needed concrete labels to explain the abstract diagrams, whereas experts were able to understand the diagrams and found the labels distracting. This suggests that novices may need the additional concrete information to help them interpret more abstract aspects of the task.

Another reason to think that the level of instruction would affect performance is that communicating successfully depends upon partners adjusting to each other’s level of understanding. For example, Isaacs and Clark (1987) had pairs of people who were or were not familiar with New York City landmarks sort pictures of New York City by talking about them. They found that both partners adjusted to the others’ level of understanding – the experts relied less on the use of proper names and provided richer descriptions whereas the novices began using proper names more. When instructing others, communication accuracy and performance increase if the instructor adjusts their instruction to their partner's level of knowledge (Harris, Begg & Upfold, 1980). But experts may not be as capable as beginners in understanding, anticipating, and adjusting to the level of understanding possessed by novices. This suggests that instructors closer to the novices' level of expertise may be more effective at instructing novices on a task than will be experts in that domain.

H3: Novices instructed by beginners will perform the target task better than novices instructed by experts.

Transferring Knowledge Between Tasks

Although concrete instruction may be most effective in situations in which tasks are repeated, we argue that more abstract instruction may be more effective when the parameters of the problem change and tasks are somewhat different. In extensive research on analogic transfer – situations in which learners transfer knowledge from base tasks to a related task – it appears that distilling the learnings from base tasks into abstract concepts facilitates the transfer of learning between tasks (e.g. Bassok, 1990; Bassok & Holyoak, 1989). In a review of the work on analogic transfer, Reeves and Weisberg (1994) concluded that people are strategic in their use of analogic tasks. They use previous problems to solve new problems by comparing similarities between tasks. Most of the studies on analogic thinking present multiple base tasks to participants. This facilitates comparisons among tasks and the opportunity to abstract from multiple examples. However, single analogies can be effective when learners actively process the more abstract principles (Ahn, Brewer, & Mooney, 1992). These findings are consistent with research on expertise that demonstrates that experts' more complete representations help them to adapt to surface level changes in bridge games (Frensch & Sternberg, 1989).

Abstract or conceptual knowledge may also assist novices in the selection of variables while working on a problem. Applying solutions to problems without domain-specific conceptual knowledge will typically lead to inadequate solutions (Voss & Post, 1988). Novices frequently attend to irrelevant information in solving problems. It is possible that acquiring conceptual knowledge will increase novices' ability to determine which information adds value and which does not, thus making them more effective performers (see Sonnentag, 1998). Therefore, although we predict that expert-instructed novices will perform worse than beginner-instructed novices when performing the same target task, we expect them to perform better when doing different (non-target) tasks within the same general task domain because the more abstract knowledge conveyed by experts may enable novices to better transfer their understanding to the new task.

H4: Novices instructed by experts will perform better than novices instructed by beginners on different (non-target) tasks within the same domain.

Overview of Studies

To test our hypotheses, we conducted two experiments. In study 1, we tested whether electronics experts used more abstract, advanced statements and fewer concrete and basic statements than those with less electronics experience (beginners) when instructing novices. The beginner and expert participants completed a simple electronics construction task and described their understanding of how the circuit worked. All participants then provided videotaped instructions to a novice on how to complete the task. Study 2 was composed of two rounds. In round one, we used videotapes from study 1 to instruct novices on the target task. To test hypothesis 3, we measured the performance of novices on the target task after having received either beginner or expert instructions via videotape. To test our hypothesis about the transfer of knowledge between tasks (H4), round two manipulated the task (same vs. different). We measured the performance of the same novices as they built either the same or a different electronic circuit.

Study 1

Method

Study 1 was designed as a test of hypotheses 1 and 2 about differences in how experts and beginners would instruct novices to perform a task. We asked beginners and experts in electronics to videotape instructions to novices about building an electronic circuit and coded these videotapes for concrete, abstract, basic, and advanced statements.

Participants

Twenty-eight junior and senior Stanford University undergraduates earned $20 for their participation in the study. Four expert and two beginner participants were dropped from the study because they did not meet our criteria for level of expertise. Eleven beginners and eleven experts remained in the study.

Task and Materials

An electronic project lab kit was used for this task. The kit was designed as a tool for teaching simple electronics concepts and contained materials for completing over 200 different electronic circuits. Circuits are completed by connecting wires between the spring-coil connectors on the board of the device to make the electronic guts of various devices (e.g. light telegraph, radio, and motion detector). Our choice of task was inspired by a radio assembly task used by Moreland, Argote, and Krishnan (1996). While Moreland and his colleagues' task allowed the construction of a simple radio, ours allows for the presentation of multiple tasks within the same task domain.

Participants followed directions on how to complete an electronic circuit. The instructions included a schematic of the circuit, a wiring sequence stating which spring coils should be connected, and the goal of the task. The circuit was a "light telegraph." When completed, pressing a button illuminated a light and allowed signaling by Morse code. Completing this circuit required participants to connect four wires to different spring-coil connectors on the board in order to connect the batteries, a resistor, a control key, and a light emitting diode (LED). When the wires were properly attached and the key was depressed, the circuit was completed and the LED illuminated.

Expertise

Experts and beginners were initially recruited based upon their majors and the number of college level engineering and physics courses they reported taking. To ensure that experts had a broad understanding and experience in the domain of electronics, junior and senior engineering and physics students who had either taken the course "introduction to electronics" or "electricity and magnetism" were recruited as experts. As a validation of expertise, experts completed 5 different electronics circuits in session 1 which took place 7-10 days prior to session 2. This "training session" had the added advantage of familiarizing experts with an electronic project kit.

Junior and senior humanities majors who had not taken either of these courses were recruited to be trained as beginners. Beginners also came to the lab a week before, but did not use the electronic project kit in session 1. Their training took place during session 2. Prior to being considered beginners for the purposes of this experiment, these participants completed the target electronic circuit (the light telegraph) once and explained their understanding of the task to the experimenter. This level of training ensured that the beginners in the sample had some basic experience with and understanding of the target task.

Procedure

In session 1, the participants signed a consent form and completed a demographic questionnaire. Experts completed 5 different electronic circuits from the electronics project kit, answered questions about the tasks, and returned again 7-10 days later for session 2. Beginners left after completing the questionnaire and returned 7-10 days later.

In session 2, all of the participants completed the "light telegraph" circuit. The experimenter recorded whether the participant requested a hint, errors made during construction, and the amount of time required to complete the project. After completing the circuit the experimenter asked the participant to describe how they understood the electronic project to work in order to get the participant to think about what they just constructed and deepen their understanding of how the light telegraph worked. Next the participant was asked to disconnect the wires and rebuild the electronic project while giving instructions to a novice who would later perform the same task using their instructions. Participants were told that the primary purpose of the video recording was to instruct a freshman or sophomore humanities student on how to complete the light telegraph circuit. Participants were also informed that the novices would not have the wiring sequence or instructions available and that they would have to complete the electronic project using just the videotaped instructions. They were informed that the novice would also complete another electronic project without their help. A written test of their electronics knowledge was administered after their instructions were videotaped. The participants were paid for their participation and debriefed.

Measures

The primary dependent variables of interest in this study were the number of concrete, abstract, basic and advanced statements used by the instructors. These variables were coded from the transcriptions of participants' videotaped instructions. Each statement was coded for whether or not it was concrete vs. abstract and whether or not it was basic vs. advanced. Concrete statements were those that were specific, measurable, or tangible whereas abstract statements were those that were more conceptual. For example, stating that the exposed tip of the wire should be placed into the spring connector was coded as concrete whereas describing the circuit as being open was coded as abstract. Basic statements were those that required no foundation in electronics to understand whereas advanced statements required such a foundation. For example, mentioning the role of the battery in the system was basic, but identifying the specific number of ohms in the resister was coded as advanced. A coding key was created prior to running the experiment and was later augmented based on a sample of the transcripts. A coder blind to the experimental hypotheses but knowledgeable about electronics coded each statement for level of abstraction (concrete vs. abstract) and for level of information (basic vs. advanced). Finally an experimenter coded 10% of the transcripts. Inter-rater reliability for each specific segment was quite high ($R=.91$, $p<.01$).

While expert and beginner status were our primary independent variables, we wanted a continuous measure of expertise for a secondary analysis. We also were concerned that teaching experience and experience providing computer advice might lead to using more concrete, basic instructions independent of level of expertise, as experienced instructors might have learned how to pitch their information to a level appropriate for novices. To check this, we asked participants to complete a questionnaire containing a test of their electronics knowledge and questions about their experience teaching and providing technical advice. The questions used for each of these scales are provided in figure 1. The electronics knowledge test was scored by someone blind to condition but knowledgeable about electronics. Respondents received a score between 0-3 based on the accuracy and completeness of their response to each of the items (because there was only a single right answer for question 3, it was scored as 0-1). These scores were then summed for a possible high score of 10 and a low score of zero. The questions on self-reported teaching skill and providing technical advice were rated on a 5-point scale with 1=strongly disagree and 5=strongly agree. The teaching skill items were averaged to create a scale of self-reported teaching skill.

Figure 1 About Here

Results

Table 1 contains descriptive statistics (means and standard deviations) for and correlations among the variables of interest in this study. As can be seen from table 1, beginners in this study were a little over 20 (20.7) years old on average and over half of them (68%) were female. Most experts (73%) also were female and were about the same age, 20.6 years old. Experts reported having significantly less teaching skill (M=3.18 vs. M=4.00, t[20]=2.65, p<.05), but also reported significantly more experience providing technical advice (M=3.55 vs. M=1.45, t[20]=-4.16, p<.001).

Insert Table 1 About Here

Manipulation Check

Expert instructors did have greater electronics knowledge as measured in a variety of ways. As expected, experts had taken a significantly greater number of electrical engineering courses (M=4.45 vs. M=0) and fewer English courses (M=1.36 vs. M=3.45). As can be seen from table 1, expertise was highly correlated with our measures of performance and knowledge in the domain (performance time, errors, and electronics knowledge). Experts completed the electronic project in significantly less time (87 vs. 239 seconds, t[19]=6.83, p<.001) and were significantly less likely to make an error (10% vs. 91%, t[19]=4.14, p<.001) compared to beginners. Furthermore experts got more answers correct in a test of electronics knowledge (M=6.91 vs. M=2.82). Experts also were more likely to have previously used an electronic project kit (82% vs. 9%).

Novice Instruction

The instructional videotapes were 2 minutes 39 seconds (SD=62 seconds) long on average and contained an average of 315 words. Overall, a majority of the statements made by participants were concrete and basic. Approximately 55% of the statements were concrete versus abstract and over 76% of the statements were basic versus advanced. However, only 49% of the statements were both concrete and basic, suggesting that many of the statements may have been at a level above the knowledge of the novices being instructed.

To test hypotheses 1 and 2, we compared the statements made by beginner and expert instructors. Although beginners and experts used about the same number of words (M=308 vs. 322) in their instructions to novices and recorded instructions of about the same length (M=158 vs. M=160 seconds), beginners made fewer statements (M=14.26) than did experts (M=18.09). As indicated in table 2, beginners included 3.81 (SD=2.99) abstract statements and 10.45 (SD=4.82) concrete statements as compared to experts who included 10.82 (SD=4.81) abstract statements and 7.27 (SD=4.43) concrete statements. A series of regression analyses were conducted to test hypotheses 1 and 2 (see table 3). To account for number of words and for teaching skill, these variables were included in the model along with expertise. Our first regression confirms that experts made significantly more abstract statements than did novices, $t[3,18]=4.02$, $p<.001$. Although beginners made more concrete statements than experts, this difference was not significant, $t[3,18]=-2.04$, $p<.10$. These analyses provide partial support for hypothesis 1. As indicated in table 1, beginners used more basic statements (M=13.18, SD=5.88) and fewer advanced statements (M=1.09, SD=1.64) than did experts (M=11.55, SD=5.88

and M=6.55, SD=4.06). The results of a regression analysis suggest that although experts made significantly more advanced statements than beginners (t[3,18]=3.72, p<.01), there was no significant difference in the number of basic statements made between the two groups, t[3,18]=-.69, n.s. These data provide partial support for hypothesis 2.

Insert Table 2 and 3 About Here

As expected, the regression analyses reported above suggested a positive relationship between number of words and number of concrete (t[3,18]=4.37, p<.001) and basic statements (t[3,18]=3.82, p<.001), although the relationship between number of words and advanced (t[3,18]=1.39, n.s.) and abstract statements (t[3,18]=1.80, p<.10) was weak. These analyses suggest that instructors who speak more tend to provide more concrete and basic details in their instructions. Self-reported teaching skill was not significantly related to number of concrete, abstract, basic, or advanced statements in the instructional tapes.

The above analyses used a dichotomous indicator of expertise (beginner vs. expert). To examine expertise more precisely, we further tested hypotheses 1 and 2 using regression analysis with participants' performance (time to complete task and number of errors) predicting types of statements they used in their instructions (see table 3). Examining number of errors as an indicator of participants' skill in the task domain and including number of words and teaching skill as control variables in the model, we found that those with less skill made fewer abstract statements (t[3,17]=-2.46, p <.05), more concrete statements (t[3,17]=2.79, p <.05), and fewer advanced statements (t[3,17]=-

3.15, $p < .01$). Although less skill also predicted more basic statements, the difference between groups was not significant ($t[3,17]=1.87$, $p < .10$). Time to complete the target task was used in a similar series of regressions with the same pattern of results. Taken together, these data suggest that those with more expertise use more abstract, fewer concrete, and more advanced statements when providing instructions to novices, providing support for hypothesis 1 and partial support for hypothesis 2[1].

In an additional analysis, we looked at whether or not expertise affected the number of statements that were both concrete and basic – a level that someone completely unfamiliar with the domain could easily understand. A regression analysis with expertise predicting concrete, basic statements and controlling for number of words resulted in a significant effect ($\beta=-5.21$, $t[2,19]=-3.43$, $p<.01$) suggesting that experts as compared to beginners were less likely to provide concrete, basic statements in their instructions to novices ($M=5.45$ vs. $M=10.45$).

Discussion

Consistent with our arguments outlined in the first two hypotheses, the data suggest that experts communicate different information than beginners when instructing novices. In comparison to beginners, experts used more abstract and more advanced statements. Of course, these results are not surprising. Beginners, by definition, do not have advanced knowledge or an abstract understanding of the task. More interesting is that experts provided fewer concrete statements in their instructions to novices. Thus, they gave novices less specific detail to guide their performance of the task. For example, properly connecting the wires to the spring-coils is required for an electrical connection to be completed. However, only 9% of the experts as compared to 90% of the beginners included this concrete information in their instructions. Our analysis of teaching skill indicates that after controlling for the number of words, self-reported teaching skill does not predict use of concrete, abstract, basic, or advanced statements in instructions to novices.

Study 2

Method

In study 2, we tested the effect of beginner versus expert instruction on novice performance. Study 2 consisted of two rounds. In the first round, we presented novices with either beginner or expert instructions prior to completing the target task. This allowed a test of hypothesis 3 which argued that novices instructed by beginners would perform better on a target task than novices instructed by experts. In the second round of the experiment, the same novices were asked to complete a second electronic circuit. Half of the participants completed the target task a second time while the other half completed a different circuit. This allowed a test of hypothesis 4 which argued that novices instructed by experts would perform better than novices instructed by beginners when the particulars of the problem changed.

Participants

Seventy-two freshman and sophomore Stanford University students majoring in humanities were paid $10 for their participation. To ensure that we had novices in the domain of electronics, we used a screening survey to recruit participants who had never taken college physics or an engineering course that included relevant instruction in electronics. Most (62) of the participants had taken physics in high school, thus giving a basic exposure of electronics to most participants. However, our test of electronics knowledge confirmed that our novices had less knowledge (M=2.37, SD=1.48) than either our experts or our beginners from study 1. Participants were randomly assigned to either the beginner instruction or the expert instruction condition. For round two of the study, half of the participants in each of the instruction conditions (beginner vs. expert) were randomly assigned to compete the target task a second time while the other half were assigned to complete a new task within the same domain.

Task and Materials

The electronics project kit described in study 1 was used again. The novices were randomly assigned to receive videotaped instructions from one of the experts or one of the beginners. Next, they completed the target task – the “light telegraph” circuit. Finally, they either completed the target task (the light telegraph) a second time or an electrical meter circuit – a circuit with a meter that measured the electricity flowing through the circuit. In the meter task, participants connected the circuit, then switched connections in order to increase and decrease the amount of electricity flowing through the circuit.

Instruction Manipulation

Videotapes of 2 experts and 2 beginners from the first study were used as stimuli for study 2. We chose the 2 experts with the highest electronics knowledge score and the 2 novices with the lowest electronics knowledge scores to ensure that our manipulation varied along the dimension of expertise.

Novices were shown the videotaped instructions prior to beginning the first task (round 1).

Task Manipulation

In round two of the study, half of the participants from each of the instruction conditions were randomly assigned to perform the target task a second time and the other half were assigned to perform the new task (the electrical meter circuit).

Procedure

The participants completed a consent form and a demographic survey. They were told that they would be completing an electronics task after watching the instructional video and encouraged take notes and prepare for the task. After watching the video, they were instructed to complete the "light telegraph" circuit. If the participant requested a hint, the experimenter provided one after 3 minutes into the project. If the hint was requested earlier the experimenter instructed them to keep trying and provided them the hint after 3 minutes into the project if still required. All hints were pre-determined based on the known problems that novices had in pre-tests. The experimenter discretely recorded the number of seconds needed to successfully complete the circuit, the number of errors made, and number of hints required. After completing round one, participants filled out a post-task survey containing questions about their perceptions of the videotaped instructions they received.

In round two of the study, participants were asked to engage in a second task – either completing the same circuit or completing a new circuit. In both cases, participants were provided with written instructions that were derived from the electronic kit instruction manual. These included a schematic diagram of the circuit with a list of specific numbered points that needed to be connected with wires. Again, the experimenter recorded time to completion, errors, and the number of hints provided.

Measures

The primary dependent variables in study 2 were novices' performance on the target task and on the new (non-target task). Time required to complete the task and errors made were used as indicators of performance. Variables were measured using the same methods as in study 1. In the post-test survey, participants also were asked to rate the quality of the videotaped instruction that they received. The 6-item scale for instruction quality is presented in figure 1.

Results

In table 4, we report the descriptive statistics (mean and standard deviation) for and correlation between the measures of novice performance (completion time and errors), novices rating of the quality of instruction, characteristics of the novices in the sample (gender, age, and electronics knowledge), characteristics of the instructor[2] (expertise, completion time, self-reported teaching skill, and gender), and characteristics of the videotaped instructions (concrete, abstract, basic, and advanced statements, and number of words). Sixty-two percent of the participants in study 2 were female and the average age was 18.83 (SD=.75) years old. All 72 of the participants completed the two rounds in the experiment. For the first round, it took novices an average of 5 minutes and 2 seconds (SD=68 seconds) to complete the circuit with an average of 1.11 (SD=1.08) errors.

Insert Table 4 About Here

Manipulation Check

At the end of the first round, all participants were asked to rate the quality of the instructions they were provided. These rating were recorded on a 1 to 7 scale with 1=strongly disagree and 7=strongly agree. On these ratings, expert-instructed novices as compared to beginner-instructed novices described the instructions as too technical (M=3.89 vs. 2.08), too abstract (M=3.67 vs. M=2.25), and without enough details (M=4.36 vs. 3.36). Beginner-instructed novices as compared to expert-instructed novices rated the instructors as understanding their skill level better (M=4.81 vs. 2.64), providing more practical information (M=5.11 vs. 3.89), and providing clearer instructions (M=5.17 vs. 3.36). An ANOVA analysis with instructor expertise predicting overall instruction quality resulted in beginners as compared to experts being rated as significantly better instructors, $F[1,70] = 31.04$, $p<.01$. These results suggest that the novices perceived differences in the way that beginners and experts conveyed instruction on the videotapes.

Novice Performance

To test hypothesis 3, we compared the performance of novices instructed by beginners and novices instructed by experts. As expected, we found that novices instructed by experts made more errors (M=1.64 vs. .58) and required more time to complete the project (M=368 vs. 237 seconds) than novices instructed by beginners (see table 5). Because of the strong correlation between expertise of the instructor and teaching skill of the instructor, we included self-reported teaching skill as a covariate in our ANCOVA models[3]. An ANCOVA analysis with level of instructor (expert vs. beginner) predicting task completion time resulted in a significant effect, $F[2,68]=21.78$, $p <.001$, confirming that beginner-instructed novices performed significantly better than expert-instructed novices. A similar analysis with instruction predicting errors on the task also resulted in a significant effect for level of instruction, $F[2,68]=15.39$, $p <.001$. These results provide strong support for hypothesis 3 which argued that beginner-trained novices would perform better than expert-trained novices on the target task. Teaching skill also was significantly related to novice task completion time, $F[2,68]=4.42$, $p >.04$ such that novices instructed by those who reported more teaching skill took longer to perform the task. However, teaching skill was not significantly related to the number of errors novices committed on the task, $F[2,68]=.61$, n.s.

Insert Table 5 About Here

In hypothesis 4, we argued that the benefits of beginner instruction would not necessarily obtain when novices were asked to perform a different task of the same type. The data from study 2 provide support for hypothesis 4. The new, non-target task was completed by 36 participants – 17 beginner-instructed novices and 19 expert- instructed novices. A second round of the target task also was completed by 36 participants – 19 beginner-instructed novices and 17 expert-instructed novices. Because the tasks were different, we could not directly compare participants' performance between the two tasks. Therefore, we examined participants' performance on the target task and on the new task separately. To control for participants' performance on round one of the experiment, repeated measures ANOVA were used.

Although not statistically significant, expert instructed novices as compared to beginner instructed novices took less time to perform the non-target task (see table 6). In a repeated measures ANOVA controlling for participants' performance on round one, expert-instructed novices performed significantly better on the non-target task in time, $F[1,34]=11.58$, $p < .05$, and in errors, $F[1,34]=20.03$, $p < .001$, than did beginner instructed novices. This analysis suggests that expert as compared with beginner instructed novices improved significantly more between the target task in round one and the non-target task in round two. A closer look at the data indicates that expert-instructed novices improved their performance time by an average of over 5 minutes while the beginner instructed novice improved by an average of less than 3 minutes. The results of these analyses provide some support for our hypothesis that expert-instructed novices may be better able to transfer their knowledge to analogous tasks.

Insert Table 6 About Here

An examination of the second round of the target task shows that expert instructed novices improved their performance by 3.48 minutes as compared with beginner instructed novices who improved by 1.6 minutes on average. In a repeated measures ANOVA controlling for round one, the completion times of expert as compared with beginner instructed novices was no longer significantly different, $F[1,34]=1.82$, n.s. This analysis suggests that the benefit of receiving instructions from beginners as compared to experts may diminish with practice on the task.

Novices were exposed to videotape instructions from one of two beginners or one of two experts. To determine the effect of the different instructors, we examined the characteristics of each videotape and novice performance data by instructor. For ease of exposition, we will refer to the two beginner instructors as B1 and B2 and the two expert instructors as E1 and E2. Although the two beginner instructors had similar knowledge scores and electronics background, one of the beginners (B1) reported more extensive teaching experience (4.67 vs. 3.67). B1's as compared to B2's instructions also contained more words (406 vs. 193), more concrete statements (19 vs. 8), more basic statements (21 vs. 10) and more statements that were both concrete and basic (19 vs. 8). B1 and B2 both provided two abstract statements and no advanced statements in their instructions to novices. Using the logic of our argument, we would expect novices instructed by B1 to exhibit better performance than novices instructed by B2. As expected, novices instructed by B1 performed significantly better on round one than novices instructed by B2, $F[1,34]=6.13$, $p <.05$. A comparison between the two expert instructors, E1 as compared to E2 reported a higher level of teaching skill (3.67 vs. 1.00) and more electronics background (3 vs. 1). E1's as compared to E2's instructions to novices contained more words (710 vs. 281), more abstract statements (16 vs. 13), and more advanced statements (14 vs. 8). However E1 also provided more concrete (13 vs. 7) and more basic (15 vs. 12) statements. Because E2 provided fewer abstract and fewer advanced statements, we expected that novices instructed by E2 would perform better than novices instructed by E1 on round one. An ANOVA with instructor (E1 vs. E2) predicting performance on round one, supports this prediction, $F[1,34]=17.00$, $p<.01$. This analysis further shows that the number of words and teaching skill are not adequate explanations for the effect of expertise on task performance.

General Discussion

The results from the two studies reported here suggest that experts, as compared to beginners, provide instruction at a level and degree of abstraction that may be difficult for novices to immediately absorb. However, the abstract, advanced concepts conveyed by experts appear to facilitate the transfer of learning to other, similar tasks. This finding is consistent with research on analogous problem solving (see Reeves & Weisberg, 1994) that suggests that an abstract, conceptual understanding of a domain is important in being able to transfer knowledge between tasks.

Because experts and beginners tend to encode and process information differently, we tested whether or not instructions intended for novices would differ by level of expertise. In our comparison of expert and beginner instructions given to novices, we found that experts used more abstract and advanced concepts, while beginners tended to use more concrete statements. Beginners also used more statements that were both concrete and basic. The novices following expert instructions made more errors and took more time on the task than beginner instructed novices.

In study 2, it is difficult to separate the contribution of abstract versus advanced statements because experts consistently provided more of both in their instructions to novices and both appear to contribute to poorer novice performance. We have some evidence that the number of concrete and basic statements may contribute to performance on the target task. However, systematically varying the number of each type of statement presented in instructions to novices might help to establish the independent contribution of each to novice performance. This could be accomplished by presenting videotaped instruction that provides exclusively either concrete and basic, concrete and advanced, abstract and basic, or abstract and advanced statements. Such knowledge might help to determine the best method for conveying knowledge to novices. We leave this ambitious task for future research.

We do not interpret our results to mean that experts are invariably worse at transferring information than beginners, those with less expertise. In fact, we were encouraged by the improved performance of expert instructed novices on an analogous task. However, we believe that experts may be prone to a bias toward the abstract and toward their own, more advanced understanding of the task. It is possible that experience in sharing expertise with novices may alleviate this bias, but the data presented here on self-reported teaching skills does not support this. Further, previous research suggests that experts' bias toward relying on their own experience may be difficult to eliminate (see Hinds, 1999). There was not enough variance in teaching experience among experts in our sample and we did not have objective measures of teaching skill, so we were not able to test the extent to which experts adjust their instruction based on experience teaching novices. We suspect that training experts to be more concrete may help them in transferring knowledge to novices and believe that this could be incorporated into "train the trainer" programs, but how to do so successfully must be explored in future research.

There are several limitations to and cautions in interpreting the result of the studies we report. First, to ensure that participants in study 1 had different levels of expertise, we recruited from different populations – engineering students and humanities students. It is possible that differences in the populations other than expertise with electronics may have contributed to the differences we detected. To control for those characteristics that we thought might be associated with instruction quality, we included teaching skill in our analyses. It did not affect the results. However, future research that manipulates expertise would more convincingly address this concern.

Second, for study 2, we intentionally selected on expertise rather than manipulating the type of statements in the instructions received by novices. We believe that this provided a better test of the effect of expertise on novice performance. The disadvantage of this strategy is that we do not have a clean test of the effect of each statement type. We believe that research may benefit from such precise testing of different statement types. Further, we were not able to equate instructions on both expertise and other characteristics of the instructor and the instructions. Therefore, we can not fully control for the effect of number of words, teaching skill, and other differences between the expert and novice tapes shown in study 2. We have attempted to eliminate alternative explanations in our analysis, but further research that holds constant in the presentation everything except type of statement (concrete, abstract, basic, and advanced) is warranted. This could be accomplished by providing instructional tapes recorded by confederates rather than relying on beginners and experts to provide instructions.

Finally, to control for information presented, we relied on one-way videotaped instruction. Although attempts to transfer expertise inside organizations occasionally use face-to-face communication, this is not invariably the case. In many instances, novices are expected to learn from information on intranets, databases, instruction manuals, and videotapes, or are instructed in such large numbers that interactive communication is precluded. Our results suggest that one-way communication media such as instruction manuals, videotapes, and databases may not adequately convey the tacit knowledge, exceptions, wisdom, and mistakes, which must be learned on the job in order to be effective. Interactive sessions might result in different effects as experts have the opportunity to receive verbal and non-verbal feedback from novices and adjust their communication style to fit novices' needs.

Several recommendations follow from our study. First, the results support the idea of leveraging the potential contributions of those whose knowledge falls short of full expertise. When novices need to know how to perform a specific task, beginners may be just as good or even better candidates for instructing novices. Second, matching skill level between instructor and the person being instructed more closely may facilitate the transfer of learning between employees. This is consistent with the idea of peer-to-peer learning. For example, in a study of Xerox copier repair technicians, Brown and Duguid (1991) found that most of the learning takes place through the narrative with other technicians and customers, rather than the detailed instruction manuals. Furthermore they suggest that you must become part of a community in order to learn. Finally, if novices will need to perform in a variety of contexts or the environment is volatile and frequent changes are expected in the dimensions of the task, then relying on those expert enough to convey abstract, advanced knowledge that can be transferred between tasks would appear to be more a more effective training strategy.

References

Ackerman, P. L. (1987). Individual differences in skill learning: an integration of psychometric and information processing perspectives. Psychological Bulletin, 102, 3-27.

Ahn, W., Brewer, W. F. & Mooney, R. J. (1992). Schema acquisition from a single example. Journal of Experimental Psychology: Learning, Memory, and Cognition, 18, 391-412.

Anderson, J. R. (1982). Acquisition of cognitive skill. Psychological Bulletin, 89, 369-406.

Bartel, A. (2000). Measuring the employer's return on investments in training: Evidence from the literature. Industrial Relations, 39, 502-524.

Bassok, M. (1990) Transfer of domain-specific problem-solving procedures. Journal of Experimental Psychology: Learning, Memory, and Cognition, 16, 522-533.

Bassok, M. & Holyoak, K. J. (1989). Interdomain transfer between isomorphic topics in algebra and physics. Journal of Experimental Psychology: Learning, Memory, and Cognition, 15, 153-166.

Bechky, B. (1999). Creating shared meaning across occupational communities: An ethnographic study of a production floor. Paper presented at the annual meeting of the Academy of Management, Chicago, Illinois.

Blessing, S. B. & Anderson, J. R. (1996). How people learn to skip steps. Journal of Experimental Psychology: Learning, Memory, and Cognition, 22, 576-598.

Brown, J. S., & Duguid, P. (1991). Organizational Learning and Communities-Of-Practice: Toward a Unified View of Working, Learning, and Innovation. Organizational Science, 2(1), 40-57.

Ceci, S. J., & Liker, J. K. (1986). A day at the races: A study of IQ, expertise, and cognitive complexity. Journal of Experimental Psychology: General, 115(3).

Chase, W. G., & Simon, H. A. (1973). Perception in Chess. Cognitive Psychology, 4(1), 55-81.

Chi, M., Glaser, R. & Rees, E. (1982). Expertise in problem solving. In R. J. Sternberg (Ed.), Advances in the psychology of human intelligence (pp.7-75). Hillsdale, NJ: Erlbaum.

Davenport, T. H., & Prusak, L. (1998). Working knowledge: How organizations manage what they know. Boston: Harvard Business School Press.

Frensch, P. A., & Sternberg, R. J. (1989). Expertise and intelligent thinking: When is it worse to know better? In R. J. Sternberg (Ed.), Advances in the psychology of human intelligence, (pp. 236). Hillsdale: Lawrence Erlbaum Associates Inc.

Gitomer, D. H. (1988). Individual differences in technical troubleshooting. Human Performance, 1(2), 111-131.

Gobet, F., & Simon, H. A. (1998). Expert chess memory: Revisiting the chunking hypothesis. Memory, 6(3), 225-255.

Hansen, M. (1999). The search-transfer problem: The role of weak ties in sharing knowledge across organization subunits. Administrative Science Quarterly, 44, 82-111.

Harris, G., Begg, I., & Upfold, D. (1980). On the role of the speaker's expectations in interpersonal communication. Journal of Verbal Learning & Verbal Behavior, 19(5), 597-607.

Hinds, P. J. (1999). The curse of expertise: The effects of expertise and debiasing methods on prediction of novice performance. Journal of Experimental Psychology: Applied, 5(2), 205-221.

Isaacs, E. A., & Clark, H. H. (1987). References in conversation between experts and novices. Journal of Experimental Psychology: General, 116(1), 26-37.

Johnson, E. J. (1988). Expertise and decision under uncertainty: Performance and process. In M. T. H. Chi, R. Glaser, & M. J. Farr (Eds.), The nature of expertise. (pp. 209-228). Hillsdale: Lawrence Erlbaum Associates Inc.

Kalyuga, S., Chandler, P., & Sweller, J. (1998). Levels of expertise and instructional design. Human Factors, 40(1), 1-17.

Kirschenbaum, S. (1992). Influence of experience on information-gathering strategies. Journal of Applied Psychology, 77, 343-352.

Kraiger, K., Ford, J. K., Salas, E. (1993). Application of cognitive, skill-based, and affective theories of learning outcomes to new methods of training evaluation. Journal of Applied Psychology, 78, 311-328.

Lamberti, D. M., & Newsome, S. L. (1989). Presenting abstract versus concrete information in expert systems: What is the impact on user performance? International Journal of Man-Machine Studies, 31(1), 27-45.

Langer, E. J., & Imber, L. G. (1979). When practice makes imperfect: Debilitating effects of overlearning. Journal of Personality & Social Psychology, 37(11), 2014-2024.

Larkin, J. McDermott, J., Simon, D. P. & Simon, H. A. (1980). Expert and novice performance in solving physics problems. Science, 208, 1335-1342.

Lazear, E. P. (1995). Personnel economics. Cambridge: MIT Press.

McKeithen, K. B., Reitman, J. S., Rueter, H. H., & Hirtle, S. C. (1981). Knowledge organization and skill differences in computer programmers. Cognitive Psychology, 13(3), 307-325.

Moreland, R. L., Argote, L., & Krishnan, R. (1996). Socially shared cognition at work: Transactive memory and group performance. In A. M. B. E. Judith L. Nye (Ed.), What's social about social cognition? Research on socially shared cognition in small groups. (pp. 57-84): Sage Publications, Inc, Thousand Oaks, CA, US.

O'Dell, C & Grayson, C. J. (1998). If only we knew what we know: identification and transfer of best practices. California Management Review, 40, 154-174.

Pinfield, L. T. (1995). The operation of internal labor markets: Staffing practices and vacancy chains. New York: Plenum.

Polanyi, M (1966). *The Tacit Dimension*. New York, NY: Doubleday.

Reeves, L. M. & Weisberg, R. W. (1994). The role of content and abstract information in analogical transfer. Psychological Bulletin, 115, 381-400.

Seifert, Colleen, & Hutchins, E. L. (1992). Error as opportunity: Learning in a cooperative task. Human-Computer Interaction, 7(4), 409-436.

Sonnentag, S. (1998). Expertise in professional software design: A process study. Journal of Applied Psychology, 83, 703-715.

Sternberg, R. J. (1997). Cognitive conceptions of expertise, Expertise in context: Human and machine. (pp. 149-162). Cambridge Menlo Park: The MIT Press American Association for Artificial Intelligence.

Voss, J. F., & Post, T. A. (1988). On the solving of ill-structured problems. In M. T. H. Chi, R. Glaser, & M. J. Farr (Eds.), The nature of expertise. (pp. 261-285): Hillsdale, NJ: Erlbaum

Table 1

Descriptive Statistics and Correlation Table for Study 1 (n=22)

Variable	Mean	Std. Dev.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Instructor expertise[a]																
2. Performance time (in seconds)	166	92	-.84**													
3. Errors	.52	.60	-.69**	.90**												
4. Electronics knowledge	4.86	2.59	.81**	-.69**	-.61**											
5. Teaching skill	3.59	.82	-.51 *	.30	.15	-.42*										
6. Advising experience	2.55	1.50	.68**	-.80**	-.77**	.51*	-.41									
7. Number of engineering courses	2.23	3.56	.64**	-.46 *	-.30	.56**	-.08	.28								
8. Number of English courses	2.41	2.11	-.51 *	.52 *	.50 *	-.47*	.12	-.36	-.25							
9. Experience with project kit[c]	.45	.60	.29	-.43	-.24	.73**	.04	.29	.73**	-.38						
10. Age	20.68	.72	-.06	.25	.25	-.10	.06	-.01	-.05	-.04	-.09					
11. Gender[b]	.68	.48	.10	-.16	-.23	> .01	-.27	.12	-.04	-.15	-.30	.11				
12. Concrete statements	8.86	4.80	-.34	.44 *	.46 *	-.30	.45*	-.38	.28	-.16	-.03	.44 *	-.37			
13. Abstract statements	7.32	5.30	.67**	-.58**	-.47 *	.65**	-.13	.59**	.36	-.11	.48 *	.14	-.20	.05		
14. Basic statements	12.36	5.80	-.14	.32	.36	-.09	.38	-.24	-.10	.18	.10	.54**	-.33	.92**	.32	
15. Advanced statements	3.82	4.11	.68**	-.69**	-.57**	.62**	-.19	.66**	.27	-.22	.44 *	-.07	-.22	-.06	.90**	.07

[a] Instructor expertise was coded with “expert” = 1 and “beginner” =0.

[b] Gender was coded with female = 1 and male =0.

[c] Project kit experience was coded as 0,1 with 1 indicating that the participant had used a similar hobby kit in the past.

** $p < .01$, * $p < .05$

Table 2

Mean Number (Standard Deviation) of Statements by Type by Expertise of Instructor (n=22)

	Expertise of Instructor		Effect Size *d*
Type of Statement	Beginner	Expert	
Abstract	3.81 (2.99)	10.82 (4.81) ***	1.32
Concrete	10.45 (4.82)	7.27 (4.43)	.66
Advanced	1.09 (1.64)	6.55 (4.06) ***	1.33
Basic	13.18 (5.88)	11.55 (5.88)	.28
Total words used	308	322	.08

*** $p < .001$, ** $p < .01$, * $p < .05$

Table 3

Results of regression analyses predicting number of each type of statement in study 1 (n=22)

	Type of Statement Predicted											
	Abstract	Concrete	Advanced	Basic	Abstract	Concrete	Advanced	Basic	Abstract	Concrete	Advanced	Basic
Number of words	.48 *	.61**	.42 $^{+}$	.65**	.30 $^{+}$	.70 **	.25	.68**	.47 *	.59 **	.40 *	.63 **
Teaching skill	-.30	.24	-.33	.16	.14	.02	.09	.08	-.24	.18	-.26	.11
Expertise (expert vs. beginner)					.73**	-.36 $^{+}$	.72 **	-.13				
Skill (number of errors)									-.46 *	.40 *	-.55 **	.30 $^{+}$
Adj. R^2	.14	.48	.11	.47	.52	.56	.47	.45	.32	.60	.39	.51

Note: Entries are standardized beta coefficients.

*** $p < .001$, ** $p < .01$, * $p < .05$, $p < .10^{+}$

Table 4

<u>Descriptive Statistics and Correlation Table for Study 2 (n=72)</u>

Variable	Mean	Std. Dev.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Novice completion time (task 1, in seconds)	302	68														
2. Novice errors (task 1)	1.11	1.08	.85**													
3. Instruction quality	4.45	1.43	-.53**	-.46**												
Novice Characteristics																
4. Gender [b]	.62	.49	.13	.13												
5. Age	18.83	.75	.09	.16	-.24 *											
6. Electronics knowledge	2.37	1.48	.05	-.03	.02	-.15										
Instructor Characteristics																
7. Expertise [a]			.46**	.49**	-.55**	.03	.22									
8. Completion time on task	2.96	1.83	-.44**	-.47**	.54**	-.03	-.23	-.39 **	-.99**							
9. Teaching skill	3.50	.97	-.17	-.28 *	.23	-.09	-.14	-.09	-.70**	.66**						
10. Gender [b]	.50	.50	-.11	>.01	.15	.09	-.04	-.199	>.01	.06	-.70 **					

Video Characteristics																
11. Concrete statements	11.75	4.80	-.18	-.27 *	.14	-.06	-.04	.06	-.37**	.29 *	.83 **	-.89**				
12. Abstract statements	8.25	6.38	.52**	.52**	-.60 **	.01	.22	.33 **	.99**	-.98**	-.58 **	-.12	-.29 *			
13. Basic statements	14.50	4.18	-.22	-.28 *	.14	-.04	> -.01	.09	-.24 *	.16	.67 **	-.84**	.97**	-.19		
14. Advanced statements	5.50	5.94	.57**	.54**	-.63 **	-.02	.21	.34 **	.93**	-.93**	-.43 **	-.25 *	-.18	.98**	-.13	
15. Number of words	387	197	.45**	.34**	-.48 **	-.80	.13	.31 **	.50**	-.53**	.27 *	-.82**	.47**	.62**	.44**	.75**

[a] Instructor expertise was coded with "expert" = 1 and "beginner" =0.

[b] Gender was coded with female = 1 and male =0.

*** $p < .001$, ** $p < .01$, * $p < .05$

Table 5

Novices Performance on Round 1 of Study 2 by Expertise of Instructor (n=72)

	Expertise of Instructor			Effect Size *d*
Novice Performance	Beginner	Expert		
Time to complete project (in seconds)	237	367	**	1.91
Errors made during project construction	.58	1.64	**	.98

*** $p < .001$, ** $p < .01$, * $p < .05$

Table 6

Novices Performance on Non-Target and Target Tasks on Round 2 by Expertise of Instructor

	Non-Target Task (n=36)		Effect Size *d*	Target Task (n=36)		Effect Size *d*
	Expertise of Instructor			Expertise of Instructor		
Novice Performance	Beginner	Expert		Beginner	Expert	
Time to complete project (in seconds)	132	107	.48	110	103	.22
Errors made during project	.05	.06	.03	.06	.05	.03

*** $p < .001$, ** $p < .01$, * $p < .05$

Figure Caption

Figure 1. Survey questions used in studies 1 and 2.

Teaching Skill (alpha = .80)
1. I am a good teacher.
2. Verbal communication is one of my strengths.
3. I am good at explaining difficult concepts.

Technical Advice
1. I regularly provide computer/technical advice.

Electronics Knowledge (alpha = .75)
1. Why does the light go on when you press the key?
2. Please list as many ways you can think of to make the light brighter using the electronics kit.
3. How could you make the light stay on without the button being pressed?
4. What do you think would happen if you used a 50ohms resistor instead of a 100ohms resistor?

Instruction Quality[a] (alpha =.85)
1. The instructions were clear.
2. The instructions were too technical. (reverse scored)
3. The instructor understood my electronics skill level.
4. The instructor provided practical information .
5. The instructions did not have enough detail. (reverse scored)
6. The instructions were too abstract. (reverse scored)

[a] Instructor Quality was only measured in study 2.

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[1] These analyses were also conducted with teaching skill in the model and produced a similar pattern of results.

[2] Because there were only four videotapes selected (two beginner and two expert), some characteristics of the instructors (e.g. age and gender, expertise and electronics knowledge) were 100% correlated with others and were therefore not reported in the correlation table.

[3] Number of words on the videotaped instructions was also highly correlated with expertise, but we could not include expertise, teaching skill and number of words in the models concurrently. Therefore, we ran separate models with expertise and number of words predicting novice completion time and predicting errors. Both resulted in the same pattern of results reported. Number of words was positively and significantly correlated with novice completion time, but not with errors on the task.