Procedural Instructions, Principles, and Examples: How to Structure Instructions for Procedural Tasks to Enhance Performance, Learning, and Transfer

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Objective: The goal of this article is to investigate how instructions can be constructed to enhance performance and learning of procedural tasks.

Background: Important determinants of the effectiveness of instructions are type of instructions (procedural information, principles, and examples) and pedagogical goal (initial performance, learning, and transfer).

Method: Procedural instructions describe how to complete tasks in a stepwise manner, principles describe rules governing the tasks, and examples demonstrate how instances of the task are carried out. The authors review the research literature associated with each type of instruction to identify factors determining effectiveness for different pedagogical goals.

Results: The results suggest a trade-off between usability and learnability. Specific instructions help initial performance, whereas more general instructions, requiring problem solving, help learning and transfer. Learning from instructions takes cognitive effort, and research suggests that learners typically opt for low effort. However, it is possible to meet both goals of good initial performance and learning with methods such as fading and by combining different types of instructions.

Conclusion: How instructions are constructed influences their effectiveness for the goals of good initial performance, learning, and transfer, and it is therefore important for researchers and practitioners alike to define the pedagogical goal of instructions.

Application: If the goal is good initial performance, then instructions should highly resemble the task at hand (e.g., in the form of detailed procedural instructions and examples), but if the goal is good learning and transfer, then instructions should be more abstract, inducing learners to expend the necessary cognitive effort for learning.

Keywords: instructional materials, procedures, principles, examples

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learning or transfer, and vice versa (Schmidt & Bjork, 1992; Schneider, 1985).

What Are Instructions?

Instructions are messages that guide people to perform procedural tasks; they indicate how the task can be accomplished through some action by describing the steps or rules required for completing the task (Andrews, 2001; Farkas, 1999; Guthrie, Bennett, & Weber, 1991; Lannon, 2008). Defining instructions as messages implies that instructions involve a dialogue between an expert and a novice, or an instructor and a learner. Indeed, instructions usually represent an authority instructing someone with less experience on how to accomplish a task (Lannon, 2008; Mayer, 2001).

Instructions accompany most products and systems (e.g., computer software, appliances, toys). They can appear on the product itself, on the box containing the product, or in a separate manual, brochure, booklet, online user guide, or help system (Andrews, 2001; Farkas, 1999; Guthrie et al., 1991; Lannon, 2008; Wright, 1981). They are also often provided in textbooks (e.g., on programming or math), do-it-yourself books (e.g., cake decorating for dummies), and handbooks (e.g., how to do a task analysis). However instructions are provided, they are most commonly available as written text, with accompanying diagrams or pictures. There is an active field of research concerning how best to design the lay out or graphically implement instructions, but that is outside the scope of this analysis, and the focus here is on written instructions. However, the conclusions reached might apply to all media types used to deliver instructions.

Instructions are important not only to reduce error and facilitate performance but also to make sure that the user can get the task accomplished at all. Wright (1981) made the point that as products or systems get more sophisticated and complex, the limiting factor might not be the technology itself “but the ability to explain to the user how to make use of the many and varied facilities available” (p. 131). In addition, the potential for improved performance, often the reason for purchasing or using systems or products in the first place, can be sacrificed if the product is used incorrectly or inefficiently. Providing instructions can in those cases mean the difference between a satisfied customer and an unhappy one.

When defining instructions it is necessary to also note what kind of information they do not contain. Instructions usually do not have information about the environment that the task is being carried out in or any information about the current state of the system, although they might provide information on what the state should be after a step is carried out. Real-time assessment of the environment and state of the system remains the responsibility of the users (e.g., initiating a step, completing a step, and examining feedback from the environment to confirm that the step has been carried out correctly). It follows that instructions are different from feedback and knowledge of results that are by definition information about some aspect of performance (Adams, 1987; Kluger & DeNisi, 1996). Instructions, as they are defined here, are not contingent on the behavior of the user or performance.

Three Types of Instructions

In this article, we distinguish among three different types of instructions: procedural instructions, principles, and examples. These three types represent different levels of abstraction and type of information. Procedural instructions describe how to carry out the task by describing and explaining each step. Principles provide information about rules and regularities governing the task and task domain. Examples demonstrate how a single instance of the task is carried out, usually without explanations.

Procedural instructions are at the heart of most instructions and explain how to complete a task by describing the steps or method of what to do (Bibby & Payne, 1993; Karreman, Ummelen, & Steedhoud, 2005). Procedural instructions describe system states and the actions that change these states. They usually consist of brief action statements that tell the user the condition for the action (e.g., when getting gas you need to pay and insert the nozzle before pumping), what action to take (e.g., pulling on the handle of the gas pump), and the expected consequences (e.g., when gas starts to flow, the counters—cost and quantity—will increase). They are most often organized as a series of successive steps that
need to be carried out to complete the task (Konsoke & Ellis, 1991). For example, instructions on how to send an international fax from the United States might be as follows: (a) place the document in the tray, text facing up, (b) dial 011, (c) dial the country and city code, (d) dial the number, (e) press start to scan and send the fax, and (f) check the display, which will indicate if the transmission was successful. Procedural instructions do not explain to the learner how or why the system or situation is structured as it is or functions the way it does, except to convey the immediate results of an action that the user performs. Procedural instructions also do not address the relationships between steps but focus on describing the actual steps (Konsoke & Ellis, 1991).

Principles or system-oriented instructions explain how the system is constructed and how it works; they provide information about the elements in the system and how these elements relate (thus both structure and function of the system). Principles describe the theory of operation, the cause-and-effect underlying tasks, and how different parameters affect the states of the system (Andrews, 2001; Houp, Pearsall, & Tebeaux, 1998; Konoske & Ellis, 1991). For example, instructions on how to send an international fax might include an explanation of the international access code, for instance, that it is used to dial out of countries and that the International Telecommunication Union recommends using the standard of 00. This information explains some of the principles of the system being used.

Examples are instances of the task; they illustrate how the task can be completed and therefore provide both an instantiation of more abstract instructions and a model of how to actually do the task. Examples resemble the task itself and therefore provide users with an opportunity to better understand what they should expect when doing the task themselves. However, examples do not, by default, provide explanations, and the users must infer general methods. An example of how to send an international fax would, for instance, demonstrate how a fax is sent to a Berlin number from a particular fax machine in Iceland: (a) place document in the tray on the right side of the machine, text facing up, (b) dial 00-49-30-5555, (c) press the start (green) button.

Generally, the three types of instructions described here provide information at different levels of detail. Principles are the most general; they provide information about common domain regularities or rules relevant to the task and can be applied to many tasks within that domain. Principles are therefore bound to be system oriented. Procedural instructions are less general and describe how to do a specific task (e.g., bake an apple pie) or class of tasks (e.g., formatting headings in a word processing program). Examples, however, are always specific; they involve a single instance of the task. The difference between task-specific procedural instructions, and an example therefore lies not necessarily in the details provided but in how the information is provided: procedural instruction tell the user what to do (i.e., describe the action steps), whereas examples show the user what to do (i.e., demonstrate the action steps). Some published instructions might have elements of all three types, but as research in this area has up to now not been reviewed in this context, one can only assume the combination is generally not based on research recommendations.

Why Provide Instructions?
Pedagogical Goals

Instructions can be provided for different reasons or pedagogical goals. Some instructions are meant to assist with initial performance only, to help the user get the task done as easily, quickly, and correctly as possible while using the instructions (regardless of whether there is any intention of repeating the task in the future). This is what would for example be expected from instructions on how to assemble furniture or toys. Other instructions are meant to assist with learning or skill acquisition. In that case the goal is not effortless immediate performance but effective retention of what was done at some later date when instructions are not available. In addition to learning, the goal might also be the generalization or transfer of learning. This means learners are expected to be able to complete tasks that are in some way different from the ones for which they received instructions.

The view taken here is that learning and transfer of learning are a continuum; learning is measured on tasks that are identical to the training
tasks (retention), whereas transfer is measured on tasks that are in some way different from the training tasks (Gick & Holyoak, 1987; Schmidt & Bjork, 1992). As Barnett and Ceci (2002) have pointed out, the difference between tasks can be defined across many different dimensions, making it difficult to determine the exact nature and level of transfer. It is beyond the scope of this article to analyze the exact dimension of transfer measured in the studies reviewed (e.g., whether it is near or far transfer). In addition, the pedagogical goals of learning and transfer will be discussed together below because in the literature the same issues are often found to apply to both learning and transfer, and factors influencing learning are often found to affect transfer and vice versa.

Different pedagogical goals require different emphasis in instructions. As Schmidt and Bjork (1992) and Schneider (1985) have pointed out, factors leading to effective performance initially (fast and accurate) do not necessarily lead to better learning, and conversely factors enhancing learning often make initial performance more difficult. Performance during initial practice is therefore often a poor indicator of the learning that actually takes place. When measuring training performance, temporary and permanent effects of practice are confounded, and to assess actual learning it is necessary to measure retention after training (Schmidt & Bjork, 1992). This means that when the goal is fast and accurate initial performance, the measure of interest reflects the combination of these permanent and temporary effects during initial task performance with the use of instructions. But when the pedagogical goal is learning or transfer, the interest is in the permanent effects only, separate from the temporary effects of practice, and retention and transfer need to be measured at a separate occasion without the aid of instructions.

**Research Question**

The goal of this article is to consider the factors that make instructions effective for different pedagogical goals and how these can be used to inform instructional design. More specifically, we consider how the three different types of instructions, procedural instructions, principles, and examples, can be made more effective for initial performance and learning and transfer.

This is, to our knowledge, the first attempt to aggregate and review research on these different types of instructions with the aim of understanding how they can be structured to induce learners to use strategies compatible to the pedagogical goal in questions. A secondary aim has been to identify where more research on the subject is needed. The criteria used to select studies for review were based on the relevance to the topic at hand with the main focus on factors pertinent to the structure of the instructions themselves. We decided to focus on the fundamental research where possible, and therefore in some cases much of the work cited is older, from the 1980s and 1990s. When applicable we tried to incorporate discussions of later research as well. It was a challenge to decide where to draw the line for inclusion and exclusion of research. Many relevant topics and follow-up lines of research could not be included because of the trade-off between depth and scope of analysis. The decision not to include topics was based on whether they added to the coherence of the analysis and whether it was deemed necessary for completeness.

**USING INSTRUCTIONS**

When and how do people use instructions? Each of the three instruction types, procedural instructions, principles, and examples, poses different challenges for those creating instructions.

**How Do People Use Procedural Instructions?**

Procedural instructions instruct the user to complete a task by describing how to carry out the steps of the task (Farkas, 1999; Rettig, 1991). Procedural instructions are what most people refer to when they use the term instructions (Bibby & Payne, 1993; Karreman et al., 2005). It is often assumed that users read procedural instructions before engaging with the task, but the evidence suggests that a substantial percentage of people are disinclined to read instructions when using various systems or devices, such as telephone systems (Szlichcinski, 1979), consumer products (Wright, Creighton, & Trelfall, 1982), household appliances (Schriver, 1997), and computer software (Carroll, 1990). Even if
instructions are designed from the perspective that users should read the instructions from beginning to end before starting the task, few users actually do so (Carroll, 1990; Ganier, 2004; Houp et al., 1998; Rettig, 1991; Schriver, 1997; Szlichcinski, 1979; Wright, 1981; Wright et al., 1982). Users who do read procedural instructions often scan large parts of the instructions and read carefully only when they need clarification. For example, Schriver (1997) found that only 23% of electronic product users said they read the instructions before they used the equipment; the majority said they read some of the instructions while using the equipment or referred to the instructions when they were confused.

Research on instructional use has often focused on familiar devices and products (e.g., pay phones and typical household devices), and Wright et al. (1982) showed that perceived simplicity of a familiar device is the main predictor of whether the instructions are read or not; the greater the perceived simplicity of use, the less likely people were to read the instructions. Instructional use might therefore be more likely when people are faced with an unfamiliar system.

Carroll and colleagues (Carroll, 1987, 1990; Carroll & Mack, 1987; Carroll, Mack, Lewis, Grischkowsky, & Robertson, 1985) extensively studied people using unfamiliar software and found that even if the participants had no experience or familiarity with the system they still resisted reading the procedural instructions. Their conclusions were that people do not necessarily have problems following the instructions; the issue is that they will not. They prefer to start doing the task, trying out things, and relating what they need to do to the system they are using. Carroll (1990) made the point that people are situated in a world that provides context and convention for everything they do, and they prefer to try to understand the situation through the effectiveness of their actions. However, even if Carroll’s participants did not have any software experience, they were professional secretaries using the software to complete secretarial tasks and could be said to be highly familiar with the tasks (Charney & Reder, 1986; Wiedenbeck & Zila, 1997). It is therefore unclear whether familiarity with tasks and/or familiarity with devices both work to decrease the probability that users will refer to instructions.

The preceding discussion suggests that people seldom read instructions from beginning to end before trying to use the system or device and that most users seem to use instructions only when they do not know what to do, preferring to use other methods before consulting instructions (Carroll, 1990; Redish, 1998; Rettig, 1991; Szlichcinski, 1979; Wright et al., 1982). There are a few possible reasons for this lack of enthusiasm.

First, people do not perceive instructions as being useful. Wieringa, Moore, and Barnes (1998) listed some of the various reasons people give for not using procedural instructions: They are inaccurate, out of date, confusing, unnecessary, too authoritative, difficult to understand, or difficult to use or treat the user as a child. The view of instructions as unhelpful can be taken to indicate that people do not have good experiences using them. This could be traced to the secondary status often assigned to instructional design in the product developmental process because of the attitude that instructions are a necessary evil. Many product developers treat instructional design as a separate ad hoc process, and the instructions are often developed or designed by documentation staff not involved in the product design process and not privy to the design decision rationale (Knaphide, 2000; Rettig, 1991). These realities of the design and development process make it quite unlikely that instruction usability is optimal, which is ironic given that instructions are often used to make up for compromises in design decisions (Knaphide, 2000).

The second reason that people tend to be reluctant to use instructions is cognitive effort. People generally prefer to use methods that require the least amount of effort (Ganier, 2004; Redish, 1998; Szlichcinski, 1979). Researchers have pointed out that using instructions is a difficult comprehension task because the user has to figure out what the instructions mean in their current context, how concepts and action descriptions map onto their own situation, and whether the changes they perceive correspond to the expected results (Rettig, 1991). People often find it easier to either ask someone or experiment through trial-and-error methods to get the tasks accomplished. This is
supported by research showing that even if useful information is available, people are unlikely to use it if it is too effortful to access and process (Fu & Gray, 2006). This problem is likely compounded if the instructions are not well designed or easy to use.

The idea that people often resist employing the effort of needed for effective learning is not new. The adaptive control of thought—rational (ACT-R) theory of skill acquisition is in part based on a rational analysis that suggests that people will engage in the behavior that is least likely to cost them in terms of time and effort while still obtaining the goal (Anderson, 1990). Fu, Gray, and colleagues (Fu & Gray, 2006; Gray, Sims, Fu, & Schoelles, 2006) have also found support for what they refer to as the “soft constraints hypothesis” derived from rational analysis: People select “interactive routines that tend to minimize performance cost while achieving expected benefits” (Gray et al., 2006, p. 463). This is problematic when learning and transfer are the pedagogical goals because these goals require an effortful engagement by the learner.

Whether the reason people are often reluctant to use procedural instructions is because they are badly designed and difficult to use, because they require more cognitive effort than users are willing to exert, or because they prefer to start attempting the task and figuring it out on their own, it seems evident that designing effective instructions poses a challenge. Instructions must be easy to use, take into account the user’s access of materials in a different order as the need arises, and somehow overcome the reluctance of people to invest cognitive effort if learning is the goal.

How Do People Use Principles?

Procedural instructions are at the heart of most instructions but another type of instruction commonly encountered is principles explaining how the system works. Principles describe internal workings of the system or device, the components of the system, and how they interact (Bibby & Payne, 1993; Karreman et al., 2005). For example, instructions on how to replace spark plugs in a car engine might include information about the role they play in the engine (ignite the fuel). This type of information in instructions has been called system information (Karreman & Steehouder, 2004), functional information (Smith & Goodman, 1984), figurative knowledge (Duff & Barnard, 1990), supportive information (Kester, Kirschner, Van Merrienboer, & Baumer, 2001), and principles (Catrambone, 1995b). Sometimes this type of information is referred to as “how it works” information in contrast with “how to do it” information that is indicative of procedural instructions (Bibby & Payne, 1993; Duff & Barnard, 1990).

Principles are not directly task oriented; instead, they describe how the system is constructed and the cause-and-effect mechanisms that determine the outcome when some variable is manipulated. By reading this type of instruction the user presumably gets more familiar with how the system works, understands why things operate the way they do, and is better able to figure out how to solve problems that come up by reasoning about the system and inferring what steps need to be taken (Kieras & Bovair, 1984). That is, the basic assumption for including principles in instructions is that they help people build a more comprehensive understanding or mental representation of the system, as compared to what might be derived from procedural instructions only. Having a better understanding of the system is expected to lead to better learning when using the system, specifically when it comes to transfer and problem solving. The idea that mental representation is the underlying factor determining the benefit of principles is central in the research literature on principles. Most commonly these mental representations are referred to as mental models (Barnett & Ceci, 2002; Bibby & Payne, 1993; Gott, Lajoie, & Lesgold, 1991; Karreman & Steehouder, 2004; Mayer, 1981).

It has been questioned whether principles should be included in instructions. One of the main tenets of the minimalist approach to instructions is that people are task oriented and tend to ignore principles when using instructions (Carroll et al., 1985; Mack, Lewis, & Carroll, 1987). However, it has been noted that users sometimes ask for more conceptual information after using a minimalist manual (Carroll, 1990; Van Der Meij, 2003). Research has also shown that users sometimes choose to study principles when they are provided. Ummelen (1997) and Steehouder, Karreman, and Ummelen (2000) found both novices and experts spent 20% to
40% of the time they used for instructions reading principles, indicating that learners can be interested in using principles. Even though there is some evidence that learners might want to use principles, it is still unclear what factors might contribute to the decision to use them, and research has not unequivocally shown whether studying principles helps learning and transfer.

How Do People Use Examples?

Examples are instances of the tasks and provide a model of how to do the task. They show exactly how a particular task is carried out and are therefore similar in appearance to the task itself, whereas procedural instructions most often are not. At the same time “pure” examples do not contain information or explanations about the task or how or why the particular method is used for carrying it out. The user must infer from the example the nature of the task, the purpose of steps, subgoals, organization, and rules (LeFevre & Dixon, 1986; Pirolli & Recker, 1994).

Examples can help instantiate more abstract task instructions and clarify general instructions by linking them to more concrete and specific concepts (Charney & Reder, 1987; Pirolli & Recker, 1994; Wiedenbeck, 1989). For example, the syntax definition of the “if” function in Microsoft Excel is “IF(logical_test, value_if_true, value_if_false).” From this description users might have difficulty understanding what is meant by the abstract term “logical_test,” but an example such as “A4<=$10” can help them better understand what the term means and how it can be applied.

In a similar manner, examples can be helpful by demonstrating how a rule or principle governing a task operates on a particular instance of the task it covers (Pirolli & Recker, 1994). Rules are usually described with general categories, and examples can be constructed by substituting these general terms with more specific terms (Charney & Reder, 1987). The Microsoft Excel help program has examples demonstrating how the “if” function can apply to different circumstances such as when the logical test compares a variable to a constant, another variable, or a string. These examples are all instances of the rule that governs tasks that involve the “if” statement; they help the user understand the different ways in which the rule applies and therefore define its scope and utility. Examples can also help learners deduce or infer the underlying principle or rule. If provided with only examples, learners can potentially extract the underlying rule the examples share.

Research on learning from examples has mainly focused on a category of examples called worked examples (also called worked-out examples; Atkinson, Derry, Renkl, & Wortham, 2000; Atkinson, Renkl, & Merrill, 2003; Catrambone, 1996; Chi, de Leeuw, Chiu, & LaVancher, 1994; Renkl & Atkinson, 2003). Worked examples are typically associated with well-structured domains, such as physics, computer programming, and mathematics. They consist of a problem statement, one or more solution steps, and the final solution to the problem. Worked examples therefore show the learner how one might solve a problem in the domain through a sequence of stepwise action statements without explaining why these actions were performed. Worked examples in textbooks are often accompanied by similar problems that the learners have to solve on their own for practice.

Research shows that people find examples useful and prefer them to procedural instructions, at least for simple tasks, probably because they are easier to map onto the task (LeFevre & Dixon, 1986; Pirolli & Recker, 1994; Reder, Charney, & Morgan, 1986). In a series of experiments, LeFevre and Dixon (1986) found that when faced with procedural instructions and examples, people tend to rely more on the examples even when they were explicitly told to rely on the procedural instructions.

Summary of How People Use Instructions

A common assumption made by creators of procedural instructions is that this information is read before a task is attempted. This is an unrealistic view of how people actually use instructions, and for various reasons it seems that people prefer to use instructions only when they cannot figure out what to do. The reluctance to use procedural instructions poses a difficult challenge and makes it even more important to carefully design instructions appropriate for the goal that the instructions are designed to support such as making one time use successful or aiding
learning and generalization. A significant element of this challenge is that people seem to prefer to use the method of completing tasks that involve the least amount of cognitive effort. Learning, however, is an effortful process. Therefore, instructions need to be structured to facilitate and encourage learning (when appropriate) without dissuading learners from using the instructions.

Principles clarify how a system works by explaining the purpose of components and how they work together (Bibby & Payne, 1993; Duff & Barnard, 1990). The goal of providing users with principles is to enhance their understanding of why the system operates the way it does and as a consequence better equip them to deal with unfamiliar or unexpected situations (Kieras & Bovair, 1984). There is evidence that people choose to study principles in instructions even if they do not provide exact information on the task they are trying to complete, but research also suggests that principles are more helpful if they relate explicitly to the operations and actions used to carry out tasks.

Examples provide learners with a model of how a task is carried out and can be useful to help people instantiate abstract concepts and provide them with an instance of how a rule governing the task applies to a particular situation (Pirolli & Recker, 1994; Reder et al., 1986). In addition, people seem to prefer examples to procedural instructions.

An important body of research focusing on instructions addresses how to structure them to influence the strategy and methods that people use to accomplish tasks with the aim of facilitating initial performance, learning, and transfer.

**INITIAL PERFORMANCE**

What influences initial performance? What information does the user need to get the task done quickly and with few errors? The research evidence suggests that the more the instructions resemble the task and the more details are provided on how to accomplish the task, the better the initial performance. This, however, seems to come with a cost, as learning is usually negatively affected by these same factors. The reason is most likely found in the cognitive strategies people employ when using the instructions. The more the instructions resemble the task, the more likely it is that learners will process them through analogical reasoning; the more specific the information is, the more likely it is that the learners will mimic the information with little cognitive engagement or effort. There is reason to believe both of these strategies—analogue reasoning and imitation—can be detrimental for learning when the learner is left to his or her own devices and is not provided with support for effective learning.

**Procedural Instructions**

One critical factor that determines the success of initial performance is the completeness and detail of stepwise instructions. Steps describe the actions for carrying out tasks and are most often presented as ordered steps that describe each action step of the procedural task in a sequential manner (Van Der Meij, Blijleven, & Jansen, 2003). The findings in this area have consistently shown that as learners are provided with more detailed information their initial performance improves but learning and transfer decline.

Detailed steps provide the exact details of how to accomplish the procedural task by describing the elements of each action and the objects involved. General steps however do not contain detailed information on what to do but describe the method for doing a broad category of tasks, and the users must infer the specific actions that are needed (Catrambone, 1990). For example, instructions such as “Select the File menu, select the Open command, select the file named ‘demo,’ and then select the Open button” are much more detailed than telling the user to “open the ‘demo’ file.”

The level of detail should be considered a continuum rather than a dichotomy, especially because it is difficult to determine the absolute level of specificity. Catrambone (1990) proposed a functional way to define level of detail by considering how many cases the instructions cover. For example, a general description of opening a file encompasses many different cases and could apply to different software programs, whereas more detailed instructions of how to open a particular file in one particular piece of software might not be accurate for others.

Catrambone (1990) compared performance of computer novices using word processing software
with the aid of either general or specific instructions. Using a production rule analysis to identify the procedures the learners needed to do the tasks, he found that specific instructions helped the participants complete the tasks more easily initially but led to more difficulty in transfer of learning. He argued that specific instructions were more beneficial because they provided detailed description of how exactly to do the task, whereas general instructions were difficult to follow because the learners lacked the experience necessary to easily infer action details. The general instructions, however, were more helpful for transfer because they helped the learner construct a procedure that could be more easily adapted to new tasks (Singley & Anderson, 1989).

These results are consistent with other studies showing that providing participants with instructions describing each step in detail leads to good initial performance but worse learning and transfer (Duff & Barnard, 1990; Hickman, Rogers, & Fisk, 2007). This supports the conclusion of Schmidt and Bjork (1992) that factors enhancing performance during training (i.e., giving detailed instructions) do not necessarily lead to better learning. Specific instructions seem to encourage learners to rely on the instructions, whereas more general instructions require learners to think about and actively engage in the task, which leads to better learning and transfer.

**Principles**

An implicit assumption of most researchers is that users focused on initial performance are not interested in using principles compared to users concerned with learning and transfer within a domain (Carroll, 1990; Karreman et al., 2005). In addition, according to the minimalist approach to instructions, principles are, at best, useless for people who wish to immediately start doing tasks (Carroll, 1990). As a consequence there is little research on whether principles are helpful for initial performance.

However, Catrambone (1995b) showed that initial performance could be improved when using general instructions by adding either examples or principles. The example presumably helped participants instantiate the general procedural instructions, whereas the principles helped them infer the steps needed initially. The finding that principles and general procedural instructions can help initial performance is interesting given that overall research indicates that general procedural instructions hurt performance and that principles are irrelevant for initial performance. Catrambone’s study suggests that principles can aid initial performance, but additional research is needed to identify factors that determine how and when the aid happens.

**Examples**

Examples help people do procedural tasks by showing the user exactly how to perform a task, effectively providing a model of how to do the task. Researchers have suggested that in such cases people use analogical reasoning to map the example to the task that they are trying to accomplish (LeFevre, 1987; Wiedenbeck, 1989). An implication of this conceptualization is that the similarity between the example and the current task becomes important. The more similar the example, the more likely it is that the user can effortlessly map the procedure of the example to the task. But as the example becomes more different from the task, this process will become more effortful.

Research has shown that examples with higher overall overlap with target problems facilitate performance (LeFevre, 1987; Pirolli, 1991). Similarity can be defined in different ways. Pirolli (1991), for example, defined similarity as how many production rules the example and the target problems had in common, whereas LeFevre (1987) defined similarity on the basis of surface features. An example with high surface similarity looked identical to a test item, but an example with low surface similarity did not, even when both examples had the same content. Both Pirolli and LeFevre found that higher similarity led to better initial performance, indicating that similarity has a positive effect on performance, whether defined based on content or surface features.

However, using an analogical strategy can be problematic because whereas users can infer the rules of the task, they often do not. Research suggests that when people are working from examples they tend to look for a direct correspondence between the task and the example and do not necessarily extrapolate from the examples they
study (Wiedenbeck, 1989). Analogical processing, even if it leads to good initial performance, often breaks down as soon as the learners are required to solve a new, slightly different problem (Catrambone & Holyoak, 1990; Wiedenbeck, 1989).

These findings indicate that examples can be used to assist performance without requiring users to understand the rule behind the procedure they are carrying out. This could in part explain why examples have only intermittently been found to be helpful for transfer of learning (Anderson, Farrell, & Sayers, 1984; Catrambone & Holyoak, 1990; LeFevre, 1987; Piroli, 1991; Reed, Dempster, & Ettinger, 1985; Ross, 1989; Wiedenbeck, 1989). For example, both Wiedenbeck (1989) and Piroli (1991) found that participants could successfully complete training tasks but could often not get started on transfer problems and seemed to lack the understanding needed to adapt their knowledge to the new situation. In both cases the authors concluded that using examples seemed to be mostly rote copying and memorization of procedures without actually abstracting or learning the principle involved in the tasks. Conversely, research has shown that examples can be used successfully for learning (Catrambone, 1998). As with principles, the features of the examples matter, and systematic research on these features is needed.

**Summary of Instructions for Initial Performance**

Generally, initial performance improves when instructions are specific and resemble the task itself. For example, specific step descriptions and a specific task goal help initial performance, and examples have been found to be effective for initial performance because they provide a concrete instance of how the task is carried out (Catrambone, 1995b; Reder et al., 1986).

The central issue of using examples to enhance initial performance is how easily the example can be mapped onto the current task. That is, the example is used as a model or analogy for a solution and the user tries to map elements of the example onto the task. This can be done through rote copying or analogical mapping without much cognitive effort. The similarity of the example to the task at hand is therefore important whether based on surface similarity or similarity of content.

Research suggests that when provided with information that resembles the task itself learners use analogical reasoning to figure out what to do. An analogical strategy does not necessarily require the user to infer the rule that governs the task or understand why the task is carried out in a particular way; thus, learners do not need to engage in more effortful cognitive processing necessary for learning. The same could be true for cases in which learners are provided with detailed procedural instructions; they simply carry out each step of the instructions without having to figure out what they are doing or why. These methods are successful for initial performance but not learning.

Examples and specific procedural instructions should be used in instructions where good initial performance is the primary objective. The downside of this recommendation is that if learning and transfer are also the pedagogical goals, specific instructions seem to be rather ineffective, and examples have been found to be problematic for transfer.

The role of principles in assisting initial performance has received little attention, mostly because the hypothesized benefit of principles is focused on learning and transfer. However, Catrambone (1995b) showed that adding principles to general procedural instructions helped initial performance, suggesting that principles can have beneficial effects on initial performance, but this issue needs further research.

**LEARNING AND TRANSFER OF LEARNING**

The evidence suggests that people often choose to use strategies that require little effort when using instructions but that these strategies are generally not conducive to learning. Instructions must therefore be structured to induce learners to use more effortful strategies that help learning and transfer of learning.

**Procedural Instructions**

Given that people often resist using procedural instructions, how do we structure them to encourage learning and transfer of learning? This can be accomplished by inducing the learner to expend
cognitive effort by providing more general information or a changing amount of support. The completeness or level of detail of the information influences whether learning takes place. Specificity of information can refer to either of the two basic components of procedural instructions: description of steps or goals of the task (Farkas, 1999; Van Der Meij et al., 2003). Research has focused on both of these elements as well as on whether different instructional types can be combined or whether specificity can be changed over time to help learning and transfer.

Step description specificity and combining instructional types. As was discussed earlier, the specificity of the step description in procedural instructions influences whether learning takes place: More specific step descriptions helped initial performance but were detrimental to learning and transfer outcomes, whereas the more general the steps the more they helped learning and transfer (Catrambone, 1990). However, Catrambone (1990, 1995b) also found that both general and specific procedural instructions could be structured to enhance initial performance and transfer outcomes, respectively. Adding either principles or examples to general instructions aided initial performance presumably because they helped the learners understand what they needed to do initially. Transfer was aided when examples were added to specific instructions, presumably by helping learners to generalize the procedure. Therefore, combining instruction types can capitalize on the strengths of both specific and general procedural instructions. Another method of doing so is fading.

Fading. Fading is based on the idea of scaffolding, which refers to methods that allow learners to successfully do tasks that they otherwise would not be able to do; the scaffolds change as the learner’s skill develops (Pea, 2004). In fading, learners are initially supported to accomplish a task, and then this support is gradually removed (faded) as they learn to do the task. Fading in the current context refers to giving the user incrementally less support for a repeated action (Carroll & Van Der Meij, 1998; Van Der Meij, 2003).

Fading can be implemented by decreasing the detail of the information, by giving more abstract information, and by combining steps (Van Der Meij, 2003; Van Der Meij et al., 2003). According to advocates of the minimalist approach to instructions (e.g., Carroll, 1990; Carroll & Van Der Meij, 1998), fading helps initial performance by giving users all the information they need to start but helps learning by requiring the users to gradually expend more mental effort to remember how to accomplish the task and to force them to stop relying on instructions (Carroll & Van Der Meij, 1998; Van Der Meij, 2003). Fading is also hypothesized to be successful from the perspective of the ACT-R theory of skill acquisition as it supports the gradual proceduralization of declarative knowledge (Leutner, 2000). Exactly how to implement fading needs to be studied further, but Leutner (2000) showed that slow fading resulted in better transfer than medium or fast fading.

Fading can be interpreted as capitalizing on the same factors that make both specific and general instructions beneficial for initial performance and transfer, respectively; initial performance is supported at first, but as support is faded out gradually, the instructions become less specific and more general and therefore start to emphasize learning.

The idea that information specificity is important for determining performance and learning outcomes is also reflected in research on goal specificity. As with step description specificity, the research on goal description specificity has shown that as learners are provided with more general goal information, their learning and transfer improve.

Goal specificity. Goals describe the state that the user is working toward, whether it is the end state or some intermediate state (subgoal), and thereby provide the criteria to which the user can compare the results of his or her actions in the task environment. The goals of a procedure are most commonly conveyed in the titles and subtitles of procedural instructions to assist the user in finding information and categorizing tasks; a picture showing the anticipated end results from following the instructions can also serve to provide the goal (Van Der Meij et al., 2003).

Goals can vary in specificity. For instance, asking someone to explore how formatting is done in a particular word-processing program is a nonspecific goal, but asking someone to bold a particular word provides a more specific goal.
Goal specificity therefore refers to the level of detail given about the end results of procedural tasks. Sweller and Levine (1982) showed that giving learners nonspecific goals led to better learning than when participants were given a specific goal. Providing a specific goal decreased learning about the problem structure in transformation problems (maze tracing and rule-based number series tasks) and led participants to adopt a means–end analysis, a method of problem solving focusing on reducing the difference between the current state and the desired goal state. According to Sweller and Levine, when people use a means–end analysis they focus on the attainment of goals, and this reduces their awareness of the relation between actions or elements in the system. Conversely, a nonspecific goal requires the learner to use other problem-solving strategies more conducive to learning, such as rule induction and schema acquisition. In addition, Sweller (1988) argued that means–end analysis is taxing for cognitive resources, and the learner consequently has fewer resources available for effective learning strategies. He showed that specific goals hurt performance on a secondary task more than when a nonspecific goal was provided, indicating that more cognitive resources were needed for the primary task under the specific goal condition.

Vollmeyer, Burns, and Holyoak (1996) compared different levels of goal specificity and found similar results. They had participants work on simulated biology lab problems that could be approached either as problem-solving tasks (reaching a goal state) or as hypothesis-testing tasks (discovering the rules of the system). They provided either a specific goal or a nonspecific goal, and provided half the participants with a learning strategy. The predictions were that participants in the nonspecific goal condition would be more likely to approach the tasks as hypothesis testing and as a result be more able to solve transfer tasks. Indeed, they found that participants in the nonspecific goal condition acquired better knowledge of the structure of the system and did better on transfer tasks, especially when provided with a learning strategy to help them organize their learning. Participants who received a specific goal performed well initially but had difficulty with transfer problems. These participants seemed to rely on a means–end strategy, whereas the participants in the nonspecific goal condition seemed to try to induce the rules governing the system’s behavior. It is interesting that the participants in the specific-goal condition who also received instructions on how to use the optimal learning strategy seemed to abandon this strategy in favor of a means–end strategy. These results indicate that providing learners with less specific task goals encourages them to use strategies that lead to more successful learning.

Exploration learning. Research focused on how to encourage people to learn by exploration when using instructions indicated that the nature of the learner’s goals is important. Exploration is not expected to replace procedural instructions but to be incorporated in them. In the minimalist account of instructions, encouraging exploration is believed to be important for two reasons. First, learners want to explore, and providing explicit invitations to explore helps to keep them motivated and relates the instructions to the tasks that they want to complete. Second, exploring encourages learners to formulate their own goals, to become actively engaged in what they are doing, and facilitates learning (Carroll, 1990; Van Der Meij, 2003; Wiedenbeck & Zila, 1997). The goals of increasing motivation and active engagement are important as people seem generally reluctant to use instructions, but when they do they often do not engage with the task enough to encourage learning.

Exploration results in better learning and transfer (Carroll et al., 1985; Charney & Reder, 1986). However, the success of exploration is bounded by how the learners interact with the task and learning materials and by the degree to which they can set meaningful goals.

Investigating what novice learners do during exploration, Wiedenbeck, Zavala, and Nawyn (2000) found that learners skipped parts of instructions, ignored whole practice sections, and rarely repeated practice of features introduced earlier. In addition, the goals that learners set themselves were always specific to the current section and almost never extended beyond procedures described explicitly in the manual. These observations suggest that although exploration
offers the learner an opportunity for innovation and meaningful learning, there is also the possibility that the learner will not or cannot take advantage of this. This is consistent with the idea that learners tend to select activities requiring the least amount of effort, to the detriment of learning and transfer.

Charney and Reder (1986) concluded that detailed stepwise procedural instructions are inadequate for learning and that it is necessary to require the learner to engage in some problem-solving activity for learning to take place. They later found evidence that it was not exploration per se but the problem-solving activity that led to better learning outcomes (Charney, Reder, & Kusbit, 1990). The authors pointed out that during exploration learners set their own goals and decide how to practice selecting and applying the operations. These might be fruitful activities for learning but could be problematic if the learner does not have the domain knowledge to invent the appropriate situation for practice.

This line of research suggests that although providing learners with nonspecific goals encourages problem solving and leads to better learning, there is a limit to how open-ended goals can be. The learner has to construct a meaningful task to work on, and this can depend on the experience the learner has with the task domain. But even learners with some domain experience can fail to take advantage of opportunities for practicing and working with the materials, thinking that they understand the material better than they actually do (Davis & Wiedenbeck, 1998; Wiedenbeck & Zila, 1997).

Overall, the results indicate that providing too much information is detrimental. However, providing too little guidance can also be ineffectual because learners can have trouble generating meaningful tasks or will not put the effort into engaging in meaningful tasks.

**Principles**

Research on principles has focused on whether adding principles to procedural instructions is helpful for learning and transfer, and so far the results have been mixed. Some studies have shown that adding principles is beneficial (Catrambone, 1995b; Kieras & Bovair, 1984; Smith & Goodman, 1984), whereas others have shown no effect at all (Berry & Broadbent, 1984; Reder et al., 1986).

Kieras and Bovair (1984) gave participants either procedural instructions or a combination of procedural instructions and principles. Participants who received principles demonstrated both better performance and learning. The authors hypothesized that these results occurred because participants were better able to infer the procedures for operating the system and did not have to rely on rote memorization; this idea was supported by results of follow-up studies using think-aloud protocols. Later studies have indicated an advantage for learning and transfer when principles were added to procedural instructions (Borgman, 1999; Catrambone, 1995b; Karreman & Steehouder, 2003, 2004). However, some studies have found beneficial effects only for transfer measures (Kontogiannis & Sheperd, 1999; Patrick & Haines, 1988; Smith & Goodman, 1984), and others have not found any benefit from providing principles (Berry & Broadbent, 1984; Morris & Rouse, 1985; Reder et al., 1986).

The reasons for these contradictory results are unclear, and it is difficult to compare the studies because of a wide variety of methods, instruction implementations, and tasks. Nevertheless, these results suggest that there are some still unidentified factors influencing the effectiveness of principles (Karreman et al., 2005).

**Methodological issues.** Two methodological factors could play a role in determining whether principles are helpful. First, a pervasive methodological problem in this literature is that many authors do not specify the method for creating the instructions and often do not provide an example of them (e.g., Borgman, 1999; Karreman & Steehouder, 2003; Patrick & Haines, 1988). If the goal is to compare the effects of different types of instructions, a method for creating these instructions should be defined to increase the likelihood that the instructions are helpful and relevant to the task. Using task analysis to define the information learners need to know to perform the experimental tasks is one way of increasing the chances that the instructions contain the necessary information (Catrambone, 1998). In the absence of any clearly defined method for creating instructions, it is possible that the quality
and relevance of instructions could be a confounding variable.

The second factor concerns how the principles are studied and used. In some studies the participants have limited opportunities to study the principles (e.g., Berry & Broadbent, 1984; Reder et al., 1986), whereas in other studies participants can use them during training (e.g., Karreman & Steehouder, 2003; Kontogiannis & Sheperd, 1999; Morris & Rouse, 1985). Aside from these differences in research design, it is often not known how participants study principles. Presumably, this could depend on the specific experimental instructions they are given or on their own study habits (Chi, 2009). One solution would be to ask participants explicitly to study the information in a particular way (e.g., by summarizing or highlighting). Another would be to measure how well the principles were studied independently of the learning outcomes (e.g., through study time or self-evaluation; Bujak, 2010).

Presence of other types of instructions. The presence and amount of other types of instructions could be important for determining whether principles are helpful. Duff and Barnard (1990) demonstrated a trade-off between providing procedural instructions and principles. In their experiment the participants, who were provided with both procedural instructions and principles, received a varying amount of procedural instructions for different task sequences (in a within-group comparison). They reported that beneficial effects of principles on transfer depended on the amount of procedural instructions for different task sequences. Participants benefitted from principles only if they were forced to use them during training. As more procedural instructions were provided, the participants were less likely to do well on transfer tasks because they did not use the principles. Duff and Barnard concluded, “Users only appear to benefit from such knowledge if they are forced to use it. Only then will the mental representation develop with the kind of form and content that can support inferences in novel task settings” (p. 65). Therefore, the presence of procedural instructions seems to influence whether learners use the principles effectively for learning and transfer.

Knowing and doing. It has been assumed that providing principles in instructions is effective because users develop a more complete mental model or understanding of the system compared to providing either procedural instructions or exploration. Furthermore, having a better and more complete mental model of a system leads to superior performance and subsequent learning within that system.

An early study on the effects of supplementing procedural instructions with principles of how the system works did not support these assumptions. Berry and Broadbent (1984) found that participants provided with principles had more knowledge of the system as measured on a knowledge test but did not show any benefits in controlling the system. In addition, they found that control of the system, but not system knowledge, improved with practice. These results were found for two different complex systems: controlling a sugar production plant and interacting with a computerized agent. Both systems had similar underlying structures, although the cover stories differed. The double dissociation between performance and knowledge indicated that even though principles might increase knowledge of the workings of the system (the mental model), they did not necessarily affect performance.

Morris and Rouse (1985) reported a similar pattern of results. They asked participants to control a simulated production plant, requiring them not only to control output but also to diagnose failures (transfer tasks). Even though the participants who received principles performed better on knowledge tests, their performance on transfer tasks was not improved. Morris and Rouse suggested that principles were not beneficial because knowledge of how the system works was not directly usable for operating the system. That is, using principles to apply knowledge of the system to its operation required deduction and reasoning, and participants either did not attempt to do so or tried but were unsuccessful. Even when people have the knowledge, they will not necessarily engage in the reasoning required to determine the correct course of action.

Kieras and Bovair (1984) reported that providing principles led users to better operate the system only when the principles clearly related to the interface and to how the tasks were completed. This shows that principles have to clearly link components of how the system works to
what the users have to do when completing tasks; otherwise, learners are unlikely to make the effort to apply knowledge provided in the principles to the task. Therefore, it might be the case that principles aid performance to the extent that they help people infer procedural information. The challenge for theorists and instructional designers is how to determine a priori that a particular set of principles will aid procedural inferring.

**Examples**

Examples seem to be effective instructions for initial performance, most likely because they provide a concrete instance of how the task is carried out (Catrambone, 1995b; Reder et al., 1986). Examples have, however, generally not been found to be as helpful for transfer. Even if learners should be able to infer rules and generalities in a domain by being exposed to examples, it turns out they often do not. Most likely this is because learners prefer not to expend the cognitive effort needed to make such inferences, instead relying on less effortful analogical mapping of example steps to task steps. Research on learning from examples has however indicated that with experience and practice learners stop using analogical mapping, start developing procedures, and with enough exposure end up flexibly applying relevant prior instances to solve tasks (Anderson & Fincham, 1994; Anderson, Fincham, & Douglass, 1997; Logan, 1988). This suggests that learners do try to generalize rules from examples with practice and, with enough exposure to different examples in the domain, become adept at applying the appropriate example to the task at hand. Therefore, having to complete tasks in a domain multiple times seems to encourage learners to invest the effort required to move beyond analogical processing and to use more effortful cognitive strategies for learning from examples. Further research is needed to investigate how exactly this trade-off between amount of practice and change in strategy is structured.

Two lines of research have revealed that besides experience with multiple examples, how learners process examples determines the learning that takes place. Research on self-explanations and fading has shown that inducing learner engagement is a key factor in learning and transfer.

**Self-explanations.** The self-explanation account of learning from examples focused on how successful learners used examples while learning. Chi, Bassok, Lewis, Reimann, and Glaser (1989) asked participants to study worked-out examples of problems while thinking aloud and then analyzed the verbal protocols of the good and poor students (defined post hoc) for comparison. They found that the good students generated more explanations while studying examples, and these self-explanations involved contemplations and inferences about principles governing the task as well as the relationships among goals, conditions, actions, and consequences. These results were later replicated by Pirolli and Recker (1994) and Renkl (1997) in different domains.

It is interesting that more than half of the participants in Renkl’s (1997) study were categorized as unsuccessful learners. Renkl pointed out that this result supports prior conclusions that without support learners typically fail to use strategies leading to effective learning. These learners are sometimes referred to as passive learners in contrast to more active learners who use effective self-explanation strategies (Atkinson & Renkl, 2007; Chi, 2009). Renkl’s results again indicate that learners often do not engage in the more cognitively effortful strategies necessary to induce generalities from the examples they use.

Even though quality of self-explanation can be considered a characteristic of the learner, Chi and colleagues found that learning increased when learners were asked to generate self-explanations compared to when they were asked to merely read the instructions twice (Chi et al., 1994). This suggests that instructions might be used to induce learners to employ active learning strategies, and this has been the focus of research on worked examples.

Worked examples have been extensively studied in terms of how they can be structured to enhance learning and transfer. The effectiveness of examples often depends on the processing or self-explanation the learner engages in when studying the example (Atkinson et al., 2000; Atkinson & Renkl, 2007; Chi et al., 1989, 1994). It becomes important to determine how examples can be structured so that learners use better strategies (such as self-explanations) to infer rules from the examples. Two methods successfully
enhance transfer of learning based on examples: fading and subgoal emphasis.

**Fading worked examples.** The use of faded examples that are incomplete and require completion on the part of the learners encourages learners to use effective strategies when learning from examples (Atkinson & Renkl, 2007). With this method, learners are initially presented with a fully worked out example, but successive examples are increasingly incomplete, until they are identical to a practice problem. As parts of the worked example are omitted, learners are required to actively process them and work out what needs to be done. This method has consistently been found to lead to better learning and transfer compared to methods in which learners refer to fully worked examples while working on a practice problem (Atkinson et al., 2003; Atkinson & Renkl, 2007; Renkl & Atkinson, 2003; Renkl, Atkinson, Maier, & Staley, 2002).

Fading systematically varies the amount of information the learner studies. Gradually decreasing the instructional support should help learners transition smoothly from relying on instructional materials to independent problem solving (Renkl et al., 2002). Renkl and colleagues (2002) reported that fading helped bridge the gap between analogical processing and problem solving and resulted in better transfer. They concluded that examples are useful initially because they allow the learner to use analogical processing and seem to be preferred by novices. However, with practice the learner should move from analogical processing to more active problem solving, especially if transfer of learning is the goal. Renkl et al. also found that fading was more effective when it started from the last step (backward fading) than when the first step was omitted first (forward fading).

Fading can also decrease cognitive load and thereby enhance other strategies. For example, cognitive load theory has been used to explain when self-explanation can be used by learners (Atkinson et al., 2003; Atkinson & Renkl, 2007; Renkl & Atkinson, 2003; Renkl et al., 2002). When the learning situation imposes too much cognitive load on the learner, fewer cognitive resources are available for generating self-explanations. Initially, when learners are trying to gain understanding of the domain and tasks, cognitive load is very high and learners have little spare capacity to engage in self-explanations. Fading helps make the transition from studying worked-out examples to practicing the task a gradual one. This reduces the cognitive load and frees up resources to engage in self-explanations or other learning enhancing strategies.

However, as indicated by earlier research, learners often do not spontaneously engage in such strategies. Atkinson et al. (2003) compared the method of fading to the method of providing more examples and practice problems. In addition, they provided half the participants with self-explanation prompts. The results showed clear benefits of fading for transfer; the participants in the fading condition performed better on the transfer tasks compared to the participants who used fully worked examples while solving practice tasks. Providing self-explanation prompts also benefitted transfer. Both fading and self-explanation prompts can benefit learning and transfer from examples.

**Emphasizing subgoals.** Another approach to increasing transfer of learning from examples is by emphasizing subgoals. Subgoals in this context are features of the task structure, and tasks within a domain typically share sets of subgoals. For example, in programming, the subgoals of defining variables or constructing iteration loops can be used in many different tasks. According to the subgoal learning model, emphasizing subgoals can help transfer of learning because learners are led to focus on these recurrent aspects of tasks within the domain rather than memorizing strings of steps with little meaning (Catrambone, 1998). Learners tend to try to memorize a whole procedure for completing tasks that poses difficulties when new tasks require some change to that procedure (Reed et al., 1985). When subgoals are emphasized, the learner can apply a flexible combination of subgoaled procedures to the new task instead of trying to apply a particular task procedure wholesale to the novel task (Catrambone, 1995a, 1998).

The subgoal model is based on the assumption that if learners realize that a subset of steps in a procedure forms a group, they will try to understand why this is so and be more likely to engage in self-explanation to define the subgoal. Catrambone (1995a, 1996, 1998) provided
evidence to support the subgoal model in a series of experiments in which participants studied probability and algebra concepts using worked examples. Grouping subgoals with either labels or visual separation in examples produced superior transfer of learning compared with control groups that were not provided with highlighted subgoals. Talk-aloud protocols also supported the hypothesis that subgoal learning is effective because of self-explanation (Catrambone, 1996, 1998). Learning subgoals therefore seems to encourage learners to use self-explanations and provide them with a more flexible strategy for task completion than approaching the procedure as a whole.

Summary of Instructions for Learning and Transfer

Procedural instructions can successfully be constructed to influence learning and transfer. Generally, providing incomplete and general information enhances learning and transfer. Incomplete procedural instructions induce learners to actively engage in the task, deduce rules governing the task, and explore the constraints of the task environment. Learners are unlikely to use these strategies when all details are provided. This is consistent with Schmidt and Bjork’s (1992) statement that initial performance is not necessarily indicative of the learning that takes place and that introducing some difficulty during performance might enhance learning. However, the research on goal specificity and exploration indicates that open-ended exploration poses difficult challenges for learners who are often unable to take advantage of the learning opportunity, set meaningful goals, and engage in fruitful learning behaviors. The implication is that the structure of the instructional materials can induce learners to expend the cognitive effort needed for effective learning but that they are unlikely to do so spontaneously.

Requiring the learners to actively engage in problem solving during the learning episode by providing them with less information is more conducive to learning than telling them exactly what to do or providing little or no support (as in open-ended exploration). The latter may decrease the learners’ impetus to engage in cognitively effortful processes required for learning.

Providing users with principles in instructions can be beneficial, especially for transfer. However, mixed results suggest that unidentified factors contribute to the effectiveness of principles. These mixed results might be the result of methodological issues concerning how the instructions are created and used and the specificity of the instructions. For instance, adding principles to specific procedural instructions seems to be less helpful than adding them to general procedural instructions.

The effect of providing principles is most often attributed to helping learners form a better mental model that directs performance. Including principles seems to increase understanding and knowledge of the system. However, evidence also shows that learners do not necessarily use this knowledge to direct their performance, possibly because doing so is cognitively effortful, especially when it is not obvious how the principles relate to the actions in the system.

When people use analogical reasoning to learn from examples they often do not engage in more effortful cognitive strategies that would help them infer the rules governing the examples or discover the generalities in the domain. However, with increased practice learners seem more inclined to use more effortful methods such as inferring and proceduralizing rules from examples or memorizing instances for direct application (Anderson et al., 1997; Anderson & Fincham, 1994; Logan, 1988). “Good” learners (as identified in a post hoc analysis based on problem solving performance) were more likely—relative to poor learners—to abandon analogical processing of examples in favor of a better learning strategy through the use of self-explanations (Chi et al., 1989). When using self-explanation the learner does not rely simply on analogical processing but tries to infer the rule governing the task. Encouraging learners to use self-explanations therefore results in a more robust strategy for learning and in better learning and transfer.

Fading also encourages learners to use more optimal cognitive strategies when using examples and leads to better transfer of learning. By fading a worked example, the example is gradually transformed into a practice problem, requiring learners to work out for themselves increasingly larger parts of the task (Atkinson &
Renkl, 2007). Fading results in better transfer performance, but it is not clear whether this is because learners use more efficient problem solving, self-explanations, or more optimal distribution of cognitive load.

Another method that results in better transfer of learning from examples is emphasizing subgoals of the task procedure (Catrambone, 1998). Common subgoals in a task domain can be identified and emphasized in training examples. The emphasis on subgoals seems to encourage learners to engage in self-explanations about the subgoals and lead to more flexible learning, whereby learners combine different subgoals to form procedures and solve novel tasks.

Generally, getting the learner to expend the cognitive effort needed for learning and transfer of learning is critical. Learners are unlikely to do so spontaneously, but instructions can be structured to help them do so effectively.

CONCLUSION

Our investigation of the factors that make instructions effective for different pedagogical goals has implications for the design of instructions for specific pedagogical goals. Table 1 provides a summary of the factors that help or hurt initial performance, and learning and transfer, and shows that instructions can be constructed to enhance both initial performance and learning and transfer.

Schmidt and Bjork (1992) and Schneider (1985) have pointed out that initial performance of a task is not a good indicator of learning, and factors that increase learning often increase difficulties during initial performance. This trade-off has important consequences for achieving usability and learnability of instructions.

First, as suggested by Schmidt and Bjork (1992), it is necessary to clearly define the performance criteria so that the appropriate learning processes can be encouraged. This trade-off means that the effectiveness of a particular instructional methodology is contingent on the desired pedagogical goal. For instance, examples are preferable for fast and accurate initial performance, and people prefer them to procedural instructions. Therefore, it is important that instructional designers specify the desired pedagogical goal when creating instructions. For example, the creators of IKEA furniture assembly instructions are presumably more interested in efficient initial performance than learning, whereas those teaching programming are more likely to be interested in learning and transfer. Designers interested in good initial performance should use examples and should ensure that instructions and goal descriptions resemble the task in as much detail as possible. Conversely, designers more concerned with learning and transfer should design the instructions and goal descriptions more generally, add principles, and emphasize subgoals when using examples.

Second, it is necessary to identify the factors that affect initial performance, learning, and transfer to determine how instructions can be constructed to fulfill different pedagogical goals. One such factor is the amount of effort users are willing to exert when using instructions to learn procedural tasks. Findings suggest people tend to minimize effort needed to reach their goal. For example, Szlachcinski (1979) concluded that people complete tasks in a way that requires the least amount of effort. Redish (1998) suggested that people will turn to instructions only when they cannot figure out what to do; otherwise, they will rely on expectations, interfaces, and prior knowledge. In addition, people do not necessarily engage in the required reasoning to determine how to apply system knowledge to system operations. Rather, they adopt passive or superficial strategies when learning from examples (Atkinson et al., 2000; Atkinson & Renkl, 2007; Chi et al., 1994; Morris & Rouse, 1985). Because good learning and transfer require learners to engage in effortful cognitive activities, instructions should be designed to encourage the use of strategies that are optimal for the pedagogical goal in question, especially for learning and transfer. Providing learners with some abstraction or general description of what to do increases the chances that they will engage in the necessary cognitive processes.

Finally, there are two methods that can be used to achieve both efficient initial performance and good learning. The first method is fading, in which specific procedural instructions are gradually transformed (faded) into general procedural instructions or examples are progressively changed into practice tasks. Instructional
designers interested in both good initial performance as well as good learning and transfer should consider using fading. The second method is to employ two different types of instructions at the same time, such as general procedural instructions and examples. This method capitalizes on the different strengths of different types of instructions in relation to the identified pedagogical goals. However, combining different types of instructions might have trade-offs. For example, Catrambone (1995b) showed that adding principles or examples to procedural instructions can help initial performance and transfer, whereas Duff and Bamard (1990) showed that providing detailed procedural instructions resulted in the principles being ignored. This indicates that further research is needed to determine the conditions under which different types of instructions can be combined effectively.

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**KEY POINTS**

- People often resist using instructions for procedural tasks and prefer to use them only when they cannot figure out what to do.
- Learning from instructions requires cognitive effort and can be difficult, and learners tend to select the least effortful method for getting the task done.

### TABLE 1: Factors That Either Help or Hurt Initial Performance, and Learning and Transfer, as a Function of Instruction Type

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<td>Helps</td>
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<td>Procedural instructions</td>
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<td>Adding examples to general step descriptions</td>
<td>Specific goal provided</td>
</tr>
<tr>
<td>Principles</td>
<td>Adding principles to general step descriptions</td>
<td>Adding principles to general procedural instructions</td>
</tr>
<tr>
<td>Examples</td>
<td>More similarity to task (content and surface)</td>
<td>Less similarity to task</td>
</tr>
</tbody>
</table>
when using procedural tasks. Left to their own devices learners often choose methods for good initial performance (as they are less effortful) but not for effective learning and transfer.

- Initial performance is generally facilitated when instructions are more specific and resemble the task itself.
- Learning and transfer are facilitated by more general instructions and goal descriptions, in part because they force the learner to try to understand the system or domain and engage in effortful cognitive strategies conducive to learning.
- There is a trade-off between factors that affect initial performance, and transfer and learning, in instructions for procedural tasks. Factors that help initial performance lead to poorer learning and transfer, whereas factors that help learning and transfer make initial performance difficult.
- It is possible to achieve efficient initial performance and good learning and transfer at the same time. This can be done with the method of fading, or by combining two different types of instructions.

REFERENCES


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