

The Role of Knowledge and Experience in Expert Problem Solving

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Abstract

This study examined how instructional design (ID) experts used their prior knowledge and previous experiences to solve an ill-defined case-based ID problem. Seven experienced designers used a think-aloud procedure to articulate their problem-solving processes. Results showed that although the experts conceptualized the design problem in slightly different ways, they proposed similar strategies for addressing it. Experts' interpretations of the problem situation relied primarily on an amalgamation of knowledge and experience, which created a personal perspective that organized and guided their thinking. That is, rather than accessing a single specific prior experience, each expert extracted one or more relevant rules from his/her collected experiences that could be applied to the current situation. Implications for the education of novice instructional designers are discussed.

Regardless of discipline, one of the key differences between experts and novices is their ability to solve problems, defined as the process of confronting and resolving gaps between a given situation and a desired goal state (Gredler, 2004). A problem typically consists of three components: givens (elements, relationships, and conditions), a goal (desired outcome), and allowable operators (steps and procedures that clear the obstacles between the givens and the goal). Furthermore, depending on the explicitness of these three components, problems may present themselves as either well- or ill-defined (Gredler, 2004). According to Jonassen (2000), ill-defined problems are those that 1) possess multiple solutions, solution paths, or no solutions at all; and 2) possess multiple criteria for evaluating solutions, leading to uncertainty about which concepts, rules, and principles to apply in order to develop a viable solution. In general, instructional design problems are thought to be ill-defined, as both the problem and the potential solutions must be “found” by the designer (Rowland, 1993). Furthermore, even once the design is complete and the solution implemented, uncertainty still exists regarding the adequacy of the solution.

Experts in any field tend to be better problem solvers than novices. Faced with a problem situation, experts quickly form solutions that are more likely to be effective than solutions formed by novices. This characteristic of expertise has been documented in diverse domains: playing bridge (Charness, 1979), reading X-rays (Lesgold, Rubinson, Feltovich, Glaser, Klopfer, & Wang, 1988), solving physics problems (Chi, Feltovich, & Glaser, 1981), repairing electrical generators (Jacobson, 1988), driving a taxi (Chase, 1983), and revising instructional text (LeMaistre, 1998).

Experts are able to achieve this superior problem-solving performance, in large part, because they have at their disposals vast, well-organized stores of domain-specific knowledge, gained through extensive experience (Bruer, 1993; Chi & Glaser, 1988). However, by itself, this knowledge and experience may not be enough. In fact, experience may lead to a kind of “crystallized expertise” (Bereiter & Scardamalia, 1993), resulting in individuals who may not be particularly good problem solvers because they simply implement well-practiced procedures. In contrast, individuals with “fluid expertise” (Bereiter & Scardamalia, 1993) use their experiences to think through a problem in a way that is more dynamic and constructive. While the former would include the acquisition of automaticity after extensive practice in a

relatively stable and constant system, the latter would be characterized by flexibility that is responsive to changes in a dynamic world (Feltovich, Spiro, & Coulson, 1997).

Drawing on the expert-novice literature, Ertmer and Stepich (2005) outlined six dimensions that characterize the problem solving processes of expert instructional designers. Central among these dimensions is the expert's ability to "synthesize" a particular problem situation; that is, to formulate a clear, coherent representation in terms of one or two central issues. According to Gredler (2004), experts begin the problem solving process by identifying the key information in the problem and creating a mental map of the relationships. Then, to achieve greater understanding, experts often restructure the given material, mentally redefine and clarify the problem, and/or reformulate the functions of the givens.

As a central component of expert problem solving, the ability to synthesize is consistent with prior descriptions of expert / novice differences. For example, Larkin, McDermott, Simon, and Simon (1980) investigated expert and novice problem solving in physics and found that experts frequently engaged in "low detail reasoning" before working out all of the particulars of the problem. More specifically, when experts were given complex problems to solve, they frequently began by drawing a sketch of the central elements of the problem. This physical representation reduced the problem space, allowing the experts to identify relevant variables and test relevant qualitative hypotheses. Once these hypotheses were checked, the experts would fill in the details and solve the problem quantitatively.

Similar results have been shown within the field of instructional design. For example, Perez and Emery (1995) asked expert and novice instructional designers to design a computer simulation on diesel engine mechanics. They found that the experts were more likely to identify a central element of the problem (e.g., the characteristics of the target audience) and to return to this central element as they began to work out the details of the design. In another study involving the revision of instructional text, the expert instructional designer initially identified the lack of overall structure of the text as the primary problem and continually referred to the importance of structure throughout the revision process (LeMaistre, 1998). LeMaistre noted that the expert was explicit in the creation of the problem space and employed "strategies of constantly adjusting decisions and decomposing the problem into manageable

parts” (p. 31) so that related aspects of the problem could be addressed collectively rather than in an isolated fashion.

While it seems clear that experts engage in this kind of synthesizing, it is less clear how synthesizing is influenced by the experts’ vast stores of knowledge and experience. There are at least two competing views. While both views explain synthesizing as the result of a dynamic interaction between the problem situation and the individual’s knowledge and experience, each suggests a different axis for that interaction. One view is that synthesizing is essentially *principle-based*. In this view, experts define a problem in terms of abstract conceptual principles drawn from their stores of domain knowledge (Ertmer & Stepich, 2005). For example, Chi et al. (1981) asked experts and novices to outline solutions to physics problems. While novices typically defined the problem in terms of literal objects and terminology used in the problem statement, experts were more likely to identify a “second order feature,” referring to a feature that was not explicitly described in the problem statement, but that was derived from a small piece of given information and that activated a relevant schema in the experts’ existing knowledge. Glaser and Chi (cited in Gredler, 2004) noted that with experience, experts encode not only the procedures for solving relevant problems but also the conditions under which they are applied.

An alternative view is that synthesizing is essentially *case-based*. In this view, experts define a problem in terms of a similar situation drawn from prior experiences (i.e., a case). For example, Rowland (1992) found that instructional design experts typically associated a given situation with similar problems they had previously experienced and used those prior experiences to develop an initial picture of the current problem and how it might be solved. Similarly, Perez, Jacobson, and Emery (1995) observed that instructional design experts often reflected on past design problems and solutions and compared them with the problems at hand. Klein and Calderwood (1988) studied decision making among urban fire commanders, wild land incident commanders, and tank platoon commanders and found that these individuals based their decision making more on prior cases than abstract principles. Crossland (2004) borrowed the term “differential diagnosis” from the health sciences to describe the process of recalling prior experiences in the form of specific cases and using the information obtained from those cases to

assist with the new problem. This interpretation is supported further by research on case-based reasoning (Kolodner, 1997), which posits that experts have amassed rich libraries of case experiences that they apply, through a type of analogical reasoning, when solving new problems.

To elaborate, case-based reasoning is defined as “solving a new problem by remembering a previous similar situation and by reusing information and knowledge of that situation” (Aamodt & Plaza, 1996, p. 40). Theorists claim that human reasoning is case-based; that is, we all have different experiences that are stored in our memories and then reused when new problems trigger the recall of similar situations (Kolodner, 1993; Schank, 1999). Jonassen and Hernandez-Serrano (2002), after reviewing studies in multiple realistic contexts, proposed that “experts relied more heavily on cases based on past experience than on abstract principles when making decisions with a high degree of uncertainty” (p. 68). They argued that cases and stories work more effectively than abstract rules or principles in knowledge construction because they “require less cognitive effort than exposition” (p. 66). Moreover, stories or cases facilitate vicarious learning by providing a substitute for first-hand experience (Jonassen, 1999).

Although these two explanations of the synthesis process appear conflicting, they may not be mutually exclusive. For example, Genberg (1992) suggested that expertise might be viewed from two different lenses: 1) an information-processing lens and 2) an intuitive lens. While the former emphasizes the organization of knowledge and the progression of skill acquisition, the latter focuses on the relevance of past experiences in a particular context. Kolodner and Guzdial (1999), while strong advocates of CBR, stressed that abstraction is necessary for organizing, or indexing, cases within one’s library, as well as for efficient retrieval. In other words, experts seem to extract guidelines and principles from concrete experiences that they then apply to new problem solving situations.

Purpose

The purpose of this study was to determine *if* instructional design (ID) experts synthesized the issues presented in an ill-structured case-based problem (as described in the literature), and if so, *how* knowledge and experience were used during the synthesizing process. Based on the six dimensions of expert thinking described by Ertmer and Stepich (2005), we selected synthesizing, a critical characteristic

that distinguishes experts from novices, to further our understanding of how experts use their prior knowledge of rules and principles, and/or draw upon their previous experiences. It is expected that the results of this research will lead to a better understanding of how to prepare novices to solve the types of ill-structured problems they will encounter in practice.

Method

Overview

This study was designed to examine the processes that experienced instructional designers use when solving ill-defined instructional design problems. Data consisted of think-aloud protocols and interview data from seven participants. The think-aloud protocols captured experts' verbalizations during the case-based problem-solving process and the interviews gathered additional data about how experience and knowledge were used during the process.

Theoretical Framework

The researchers used grounded theory, a method of qualitative inquiry designed to generate an explanatory theory of a specific process or phenomenon (Glaser & Strauss, 1967; Strauss & Corbin, 1997). Grounded theory is an inductive approach in which theory is derived from the data through a process of asking questions and making comparisons. The primary objective is to expand upon an explanation of a phenomenon by identifying the key elements and the relationships among them within the specific context of the research study (Davidson, 2002). Thus, in this study, a grounded theory approach enabled us to develop a theoretical account of the general features of expert problem solving while simultaneously grounding the account in empirical data (Glaser & Strauss, 1967).

Role of Researchers

This study was designed and implemented by a research team consisting of six doctoral students (five female and one male) and one faculty member from the educational technology program area at a large mid-western university. A second faculty member, located at a large western university, acted as a consultant to the team during the design and implementation of the study. The students were comprised of four Americans, one Chinese, and one Turk. All but one student had previously completed an advanced

instructional design course, taught by the same educational technology faculty member, which utilized ill-defined case problems. The faculty member served as a team mentor. Each member of the team had completed Institutional Review Board training on the use of human research subjects.

Prior to the start of the study, a pilot was conducted with one participant, during which the entire research team observed and/or participated in implementing the data collection procedures. Subsequently, the research team divided into two subgroups with each group taking primary responsibility for conducting the research with three of the six remaining participants. As a team, students worked to define the research protocol, to modify specific data collection procedures that were either problematic or unclear during the pilot, and to clarify each person's role in the subgroups. The researchers carefully checked and monitored each other during the entire research process.

Participants

Seven expert instructional designers (four women and three men) were purposefully selected. Each participant had eight or more years of instructional design experience, in a variety of settings. Demographic data (e.g., years and types of experience; current positions and responsibilities) were collected via a short online survey. On average, participants had 20.5 years of instructional design experience, ranging from 8 to 32 years. Four participants were currently working in higher education, while three were employed in the business sector. All seven designers indicated that they regularly participated in all aspects of the instructional design process (analysis, design, development, implementation, evaluation). In addition, six of the seven participants indicated that they had previous experience with face-to-face, computer-based, online, self-instructional, and hybrid instructional delivery formats. Table 1 provides additional demographic data for each participant.

Insert Table 1

Data Collection

Following the completion of the demographic survey, participants met individually with one of the two research subgroups to participate in a think-aloud process in which they read and reflected on an ill-defined instructional design problem. The problem (Hooper & Doering, 2007) was presented via a 12

page, double-spaced, typed narrative and dealt with the topic of converting a face-to-face HIV/AIDS workshop to an online format—a topic for which none of the participants had previously developed instruction. Each data collection session lasted about two hours and included a warm-up exercise, the think-aloud procedure, and a retrospective interview. The warm-up exercise included a small problem that the participants used to practice the think-aloud approach (e.g., identify the number of windows in your house). Retrospective interviewing (Ericsson & Simon, 1980) occurred after the think-aloud as a way to help participants reflect on, and verbalize, their thought processes *during* the process, drawing from both long- and short-term memory (e.g., describe the method you used to determine the number of windows in your house). Following the think-aloud case analysis, each participant was interviewed, using a semi-structured format, to clarify comments made during the think aloud and to explicate how knowledge and experiences were used during the process. The interviews included such questions as, “What was the first thing you thought about as you read the case?” and “Why did you think of that first?” All sessions were videotaped and transcribed.

Data Analysis

Transcriptions were examined using a constant comparison method, adapted for use with case studies (Merriam, 1998), and with specific attention given to participants’ references to prior knowledge and experiences. Initially, we conducted individual microanalyses of the transcriptions, which included a detailed line-by-line analysis of each transcription. This initial coding process entailed analyzing the data without establishing preconceived ideas about what might be discovered and allowing categories to emerge in an iterative manner. Open and axial coding were integral parts of the analysis and resulted in an initial set of categories and sub-categories. [Open coding refers to the process of creating initial categories to represent the data; axial coding refers to the selection of a primary category and then relating other categories to it (Creswell, 2005).] After the individual analyses were completed, the research team engaged in a detailed discussion of all analyses, leading to further refinement of our categories.

Next, each researcher created a profile for one participant, which was then reviewed by a second researcher who either verified the patterns described or suggested modifications. After searching for

commonalities across the seven profiles, three categories were created that captured the emergent themes: 1) representation of the problem, 2) role of prior knowledge and experience, and 3) frame of reference. Finally, one researcher completed a third review of each protocol, checking for and verifying identified patterns, and adding additional evidence to support claims. These revised profiles were then submitted to the group for additional comment and final team verification.

Validity/Reliability

Reliability and validity of this study were established through the following: 1) the objectivity of the researchers, 2) use of a standard research protocol, which was developed by the researchers and applied to all participants, 3) use of a standard coding scheme to code and categorize the data, and 4) triangulation of data sources and among analysts. For example, data regarding the problem-solving process came from a demographic survey, think-aloud transcriptions, and retrospective interviews, as well as the handwritten notes made by the researchers. Seven different researchers reviewed the entire data set, providing researcher triangulation.

Throughout the study, weekly meetings of the researchers helped to ensure understanding of research questions, consistency of data collection and application of analysis codes, and interpretations of data, using the constant comparative method. Overall, the research process was goal-oriented, self-monitored, and continuously modified to improve the research quality.

Results and Discussion

Synthesizing the Issues in an Ill-Defined Problem

Ertmer and Stepich (2005) noted that the first major task of the problem-solving process involves “being able to articulate a clear and concise representation of the problem(s) in a particular situation” (p. 39). In this study, all seven participants articulated specific challenges related to converting a highly interactive face-to-face workshop to an online format (i.e., the problem presented in the case). Yet, participants focused on different aspects of that conversion (see Table 2). Problem representations included a focus on 1) the powerful / sensitive aspects (hot cognitions, intense experiences) of the

workshop (Jacob, Thad, Sammie), 2) the interactivity of the workshop (Simone, Jill), 3) facilitating attitudinal and behavioral change online (Sean), and 4) the length of the workshop (Marlene).

Insert Table 2

This variation in problem representation is similar to what Rowland (1992) observed among the ID experts in his study. Additionally, Rowland noted the rapidity with which the experts in his study developed preliminary ideas about what the problem was, as well as how it might be solved. This was also observed in the current study. For example, Jill had not even read the entire first paragraph of the case before stopping to point out a potential problem as well as a possible solution:

Right now at this point I'm thinking that something that is this interactive ... that'd be nice to put it online but you're going to lose so much of the quality of the workshop by making it online (potential problem), unless you worked at putting some sort of asynchronous discussion board together (potential solution).

In this study, all seven participants anticipated potential problems as they were reading the case. For some, this was apparent in the information they chose to highlight in the case (circling, underlining, jotting down notes); for others, this was relayed through explicit comments made about specific problems perceived. For example, as Jacob read the sentence, "Experiences were extremely powerful" he stopped and added "which is going to be wonderfully fun to try to do with the Internet." Similarly, when Marlene read the sentence, "The face-to-face ... workshop was presented to approximately 50-60 participants who traveled to a single location and met for approximately 16 hours over a two-day period," she noted, "That seems problematic to me, for something that's online."

Rowland (1993) noted in his study "expert designers explored, and appeared to consider within the scope of 'instructional design,' a variety of problem and solution possibilities" (p. 89). While the participants in this study also considered a wide variety of potential problems (e.g., interpersonal problems, securing online permissions, quality of the evaluation data), especially at the beginning of their think-alouds, not all of these problems emerged as being "key." Rather than stick to these initial ideas (as a novice might be inclined to do), our participants modified their thinking to accommodate new

information. This is particularly evident in Thad's protocol where he anticipated interpersonal problems between two stakeholders in the case, but then went back and reconsidered this notion in light of his own biases, consciously questioning if he were accurately representing the problem. According to Bereiter and Scardamalia (1993) experts are adept at assessing the "promisingness" of possible solutions. So, too, do they seem adept at assessing the promisingness of their problem representations. In general, participants' conceptualizations seemed to gain clarity as the think-alouds progressed.

Despite the fact that every participant articulated specific challenges related to converting the face-to-face workshop to an online format, not every participant synthesized these challenges into a clear concise statement of the overall problem, as suggested by the literature. While Jacob, for example, stated the problem in a very straightforward manner ("I see the problem as determining what are the essential characteristics to changing behavior?") three of the seven participants (Simone, Jill, and Marlene) simply pointed out a number of different elements that would be difficult to transfer to the online environment, without making a direct statement of this as the problem. This may have been due to a stylistic difference among participants or a variation in the way the researchers asked the participants to state the problem. Alternatively, it may suggest that "synthesizing" does not always result in a single concise statement of the problem. Instead, as Gredler (2004) suggested, experts may identify key information within a situation and use that information to create a mental map of the problem.

As another example, Sean never actually articulated what he believed to be the "real" problem in the case. Similar to the others, Sean described the "stated" goal as how to convert this face-to-face workshop to an online format. However, he continued to try to sort through other issues in the case that he thought were layered over the "presented issue" and that may or may not have been at the root of the presenting problem; for example, the "contentious relationship" (his words) between the designer and the e-learning specialist. This may have been due to the particular perspective Sean brought to the case, based on his background in clinical psychology. This perspective may have led him to focus as much, if not more so, on analyzing the interpersonal issues in the case as opposed to the specific instructional issues

presented. Alternately, this simply might have been due to the relatively short period of time he was able to devote to his analysis, not allowing him enough time to form a synthesizing statement of the problem.

Strategies for Addressing the Issues in an Ill-Defined Problem

While participants conceptualized the design challenges in slightly different ways, initial strategies for approaching the design issue were very similar (see Table 3). That is, six of the seven participants described the need to determine the specific characteristics of the current workshop that were essential to success. For example, Thad noted the need to identify and translate the strategies that were successful in the face-to-face workshop, while Jacob proposed determining the characteristics of the workshop that were essential to changing the behavior of the participants, describing these in terms of must-haves vs. nice-to-haves. Similarly, Marlene discussed the need to determine which workshop components provided “value added,” in order to determine which pieces could be safely eliminated.

Insert Table 3

While all of the participants noted specific challenges involved in effectively translating the workshop online, both Simone and Sammie questioned whether this conversion decision made sense. However, Sammie was the only one who decided that it should NOT be done due to the controversial nature of the topic, the potential discomfort the audience members may experience, and the inability of the instructor to handle the problems.

In summary, the participants in this study all articulated similar, but nuanced, conceptualizations of the design challenges in the case scenario. These differences were likely due to the various frames of reference (Rowland, 1992) they used to interpret the details of the case, described in more detail in the next section.

Use of Prior Knowledge and Experience During the Synthesizing Process

To answer our question related to *how* designers arrived at their syntheses of the issues in the case, we asked them to describe this process during the interviews. These interview comments were then analyzed to determine the extent to which the participants referenced knowledge gained from 1) textbooks, 2) a specific prior experience, or 3) a combination of many experiences.

Frames of reference. While all of the participants referred to specific prior experiences and six of seven referred to some specific piece of book knowledge (e.g., ADDIE model, Gagne’s types of learning, message design, etc.), their interpretations of the case details relied primarily on an amalgamation of knowledge and experience. For example, when asked if prior knowledge or experiences played a role in their abilities to solve the problem, all participants noted that it was a combination. Consider the following quotes drawn from their interviews:

- Jill: “I can’t say, ‘Oh this really reminds me of that,’ but ... all the little pieces remind me of something.”
- Thad: “There were a whole bunch of experiences.”
- Simone: “I’m thinking of my own experiences with taking online courses.”
- Sammie: “My instructional development background would lead me in that direction.”
- Jacob: “In my mind it all blends together.”
- Sean: “I have been in that situation many times.”
- Marlene: “I was drawing on past experiences.”

This amalgamation created a personal perspective or “frame of reference” (Rowland, 1992) that both organized and guided participants’ thinking about the problem situation. According to the Fontana Dictionary of Modern Thought (cited in Atherton, 2002), a frame of reference is defined as “the context, viewpoint, or set of presuppositions ... within which a person’s perception and thinking seem always to occur, and which constrains selectively the course and outcome of those activities.” In other words, each participant understood the case problem in terms of the personal experiences and perspectives s/he brought to the case as much as by the information provided by the case. Because each participant’s frame of reference was unique, his/her conceptualization of the problem was unique (see Table 4).

Insert Table 4

For example, Thad brought a “dissect and evaluate” frame of reference to the case. According to Thad, the primary challenge was to identify the pieces of the existing workshop (media, activities, presenters, etc.) that were effective and could be transferred to an online environment. The best way to do

this would be to “just evaluate the heck out of” the existing workshop materials to determine those that were most critical to the success of the workshop, or as Thad described it, “the magic of the face-to-face.” When asked to describe the link between his conceptualization of the case issues and his suggestion to dissect the current instructional materials, Thad specifically noted that “it was the evaluation idea; evaluation in that I had to know what the [face-to-face workshop] was like.” He noted that this was related to his previous experiences as a private consultant evaluating “a whole bunch of training materials.” He elaborated on this: “[The client] would hand me these big folders and say, ‘This is the whatever program. Would you take a look at it?’ And so I would go through the Leader’s [Instructor’s] Guide and build in my mind how someone would be presenting this and the questions they would have and that type of stuff. I could see myself in that same type of role.” This quote illustrates how Thad’s previous experiences evaluating training materials provided a frame of reference that allowed him to analyze the problem posed by the case study.

In contrast, Sammie brought a “holistic communication” frame of reference to the case, indicating that both verbal and nonverbal channels of communication were needed for communication to be complete: “I have a background in communications and all of my teaching is done in very small groups, face-to-face, where I can watch the faces of my students at any point, and especially their non-verbal behavior, and make instant corrections in the instruction.” A key concern for Sammie was the “controversial” nature of the topic in this situation. She indicated that she would want to “have control in the room,” especially with a topic like HIV, so she could notice and respond to any discomfort among the participants. One result of this was her “gut reaction” to keep the workshop face-to-face and she didn’t waver from this stance throughout her analysis: “If it were some other topic, just a plain old run-of-the-mill topic, I can see putting it out on the Internet; that it might be successfully reconstructed to work. But not with this topic. I think you’re opening up too big a can of worms.” It appears as though Sammie based this decision on her previous experiences working with sensitive topics (she recalled a specific prior experience doing a comedy reading about a woman getting a breast exam), as well as her broader background in communications.

As one more example, Marlene, who had 22 years of experience in the business and industry sector, brought an “ID process model” frame of reference to the case. She seemed to refer to her own internal instructional design model that provided her with a step-by-step procedure for working through the problem. When asked, at the beginning of her interview, what was the first thing she thought of as she read the case, she responded, “I was thinking in terms of the ADDIE model.” To elaborate, she noted that her first consideration would be the target audience because that “provides focus.” Second, she would define the objectives. Third, she would develop at least a “high-level picture” of the evaluation – a test that would tell her when the learners had reached the objectives. Finally, she thought about the “tactics” that would be used to help the participants learn, including the methods and media that might be used (“See what the message design is on those slides.” “Look at whether they had advanced organizers and summaries.”). In general, Marlene believed that her decisions were based on both knowledge and experience: “I’ve been around for twenty-some years. ... Where did I learn that? I learned it in school. It’s been reinforced over and over again with every single project I’ve ever done.” Throughout her interview, Marlene referred to a variety of related projects: “I had a project once ... I worked for a company that ... I’m working on an awful project right now.” Marlene appears to bring each of these previous experiences to mind when it becomes most relevant to the current situation.

Rules of thumb. As suggested above, the participants in this study appeared to frame the current case situation in terms of their previous experiences and background knowledge. But rather than accessing a single specific prior experience, they extracted from their collected experiences one or more relevant rules, or rules of thumb, which could be applied to the current situation. These rules were not rules that could be found in an ID textbook, but were much more idiosyncratic and were drawn from the unique collection of previous experiences that each participant brought to the current situation (Klein & Calderwood, 1988; Kolodner & Guzdia, 1999). For example, Thad appeared to apply a rule that states that you need to know exactly what’s making current materials effective before you can decide what to translate to an online environment. This rule is captured in his comment: “You have to take it [the

workshop] apart and make sure that the type of thing isn't going on where you think it is effective, but yet it really wasn't teaching what they needed."

In contrast, Sammie used a set of rules to guide her decision-making that related to her background in communication. These rules helped her decide how to handle sensitive topics in a workshop environment: "If [the workshop involves] interaction and the subject is controversial, the delivery should be face-to-face." For Sammie, the decision to keep the workshop face-to-face appears to be based on what she views as a critical rule of thumb. Similarly, a related rule, or corollary, was captured when she stated, "If it's a run-of-the-mill topic, then it could be successfully converted to the Internet." Table 4 captures a few of the rules that participants applied in their analyses of this case.

While each participant expressed more than one rule, in general, the majority of these rules seemed to be rooted in knowledge gained from a variety of previous personal experiences. However, a few rules can be seen as being based in general "book" knowledge gained from previous courses or textbooks. For example, both Thad and Sean described the importance of matching the type of learning desired (e.g., attitudes or verbal information) with the type of strategies used. These guidelines can be linked to Gagne's conditions of learning, something we tend to learn in early instructional design courses. As another example, both Simone and Marlene specifically refer to using the ADDIE model as a general guideline to assure that they've "covered all the bases."

Implications for the Education of Designers

The results of this study have important implications for the education of instructional designers. First, the results support findings from previous research (LeMaistre, 1998; Perez & Emery, 1995) that suggest that ID experts synthesize the issues in an ill-structured problem as a first step in the problem-solving process. It is possible that, with practice and support, novices also can learn to do this effectively. This idea is supported by findings from Dufresne, Gerace, Hardiman, and Mestre (1992) who taught students to solve physics problems using a computer-based "Hierarchical Analysis Tool" (HAT) that prompted them to analyze the problem in more expert-like ways. In subsequent problem-solving exercises, students who received the HAT instruction were noted to use the expert-like strategy more

often than students who received other types of instruction. That is, by using a hierarchical analysis structure that integrated concepts, principles, and procedures, novices were able to increase their focus on the deep structure of the problem rather than on surface details. A similar approach may be used with ID novices who could be given “analysis templates” that compel them to consider “big picture” (as opposed to surface) issues when analyzing ill-defined problems.

Using a slightly different approach, van Merriënboer, Jelsma, and Paas (1992) suggested that the ability to solve unfamiliar problems depended on a rich knowledge base, organized in schemata, and that one way to build these schemata was to expose novices to increasingly less-complete worked examples. So, rather than asking students to solve increasingly complex ID problems (i.e., a simple to complex instructional sequence), instructors would gradually require them to complete larger portions of incomplete problems (i.e., a complete to incomplete instructional sequence) until they could finally generate solutions on their own. Collins’ (1991) recommendations for cognitive apprenticeships takes this a step further by suggesting that novices *observe* experts as they solve problems so they can witness the false starts and dead-ends that are typical of real-world problem solving. Furthermore, by hearing experts’ reflections-in-action (Schon, 1993), novices can gain deeper understanding of the entire problem-solving process. So, for example, if students were to view videotapes of experts as they analyzed ill-structured case studies, they could not only *see* real-world examples of completed case analyses, but also *hear* how the experts arrived at their final solutions. Furthermore, students could compare their own ideas about the case with those of experts, providing rich fodder for meaningful reflection.

The experts in this study used personal frames of reference, based on accumulated sets of previous experiences, when conceptualizing the ID challenges embedded within an ill-defined problem. While it is unlikely that ID students will have amassed many personal experiences (related to ID practice) while still in school, there is some indication that students can benefit, vicariously, from the experiences of others (Jonassen, 1999; Lave & Wenger, 1991; Schon, 1993). Fortunately, there are a variety of ways to incorporate both direct and vicarious learning experiences into our graduate programs including the use of case studies; internship and practicum experiences; guest speakers; as well as consulting with, and

working for, real clients as part of a studio design approach. Each of these strategies provides opportunities for novices to hear and benefit from the experiences of more expert others.

Still, it may be important to help students index these experiences in ways that are readily retrievable (Kolodner, Owensby, & Guzdial, 2004). According to Jonassen and Hernandez-Serrano (2002), the ability to recall prior experiences depends on how those experiences are stored in memory. Aamodt and Plaza (1994) noted that effective case-based reasoning requires a “well thought out set of methods” (p. 41) for indexing cases/experiences so they can be readily integrated into existing knowledge and then easily retrieved when needed to solve similar problems. Since only a subset of one’s knowledge and/or experience will be relevant to any single problem, a practitioner needs to be able to select and retrieve only that which is relevant to a particular situation. Part of the job of the ID educator, then, becomes that of supporting novices as they observe, accumulate, and store (in memory) relevant experiences during their graduate programs. Providing appropriate learning experiences is not the whole answer; it is also important to help students *reflect* on those experiences in ways that enable them to readily recall and use those experiences during future problem solving situations. According to Bransford, Brown, and Cocking (2000), the knowledge of a novice needs to become “conditionalized;” that is, to include information about the context in which it is useful. Finding ways to help students index their experiences offers one means for accomplishing this.

For example, Haack and Mischke (2005) suggested helping students extract abstract rules from concrete experience by formulating the types of rules of thumbs that experts apply, thus reinforcing the connection between experience and knowledge. A public record could be kept of these rules (Kolodner et al., 2003) and students could revisit them as they gain more experience, with the expectation that they would be modified with new experiences and insights. This could help students create an expert-like indexing scheme to facilitate later recall, not based on textbook models, but on conditionalized knowledge gained through experience. Unfortunately, students are not yet able to abstract rules at the same level of sophistication as experts, although the use of scaffolding strategies might help alleviate this difficulty. For example, after analyzing and discussing an ID case study, students could be asked to consider where they

might “shelve” the case in their individual “case libraries.” This type of discussion could enable students to: 1) see how and why others might catalog a case, and 2) compare their cataloging ideas to those of an expert (the instructor). In effect, this approach could, over time, teach students how to index a case using a variety of different perspectives. Additionally, early classifications could be revisited periodically to determine if something could be reclassified, or perhaps cross-classified, once new meanings are abstracted. The ultimate goal is to help novices recognize and index meaningful *patterns* of information as it is the patterns that provide the triggering conditions for accessing relevant knowledge and experiences (Bransford et al., 2000).

Limitations and Suggestions for Future Research

In addition to the small number of participants, a primary limitation of this study relates to the use of think-aloud protocols for data collection. While this is a common approach used in expert-novice studies (LeMaistre, 1998; Perez & Emery, 1995; Rowland, 1992), some participants are better at engaging in the concurrent tasks of problem solving and thinking aloud than others. In this study, this may have been complicated further by the manner in which the design problem was presented to the participants, that is, as a text-based case study. Asking participants to think-aloud as they read the case out loud may have interfered with their normal problem solving processes. Furthermore, according to Lloyd, Lawson, and Sean (1995), protocol analysis itself may interfere with designing and thus not accurately represent the design thinking we are trying to analyze. Additional research is needed to determine the extent of the influence of a think-aloud procedure on design thinking, as well as to evaluate other means for capturing the thought processes of experts.

While this study focused primarily on experts’ approaches to analysis (problem-finding), it will be important also to look at experts’ approaches to designing solutions to the problems identified. While all of the participants in this study made some suggestions about how to solve the problems described in the case, this was not pursued in depth due to time constraints. Future research should examine how experts use their previous knowledge and experiences to design solutions to ill-structured problems, including the extent to which they apply personal rules of thumb as they did during the analysis process.

Conclusion

The results of this study suggest that experts synthesize the ill-defined issues in a case-based problem by drawing on their previous knowledge and personal experiences to quickly filter through the layers of the problem to determine the promisingness of the problem representation as well as the problem solution. Regardless of whether individual, multiple, or composites of previous experiences were recalled, these were used to create personal rules which were not gleaned from knowledge or experience alone, but from a combination of the two. Specifically, knowledge and experience facilitated the problem solving process by providing the individual with:

1. A personal perspective or frame of reference that guided the individual's thinking about the problem.
2. A set of idiosyncratic rules of thumb that helped the individual determine a course of action.

According to Dufresne et al. (1992), "It is the organization and use of knowledge, not the knowledge itself, that play the pivotal role in successful problem solving" (p. 330). This suggests the need to rethink the way we scaffold student problem solving activities in order to more effectively enable them to organize their domain knowledge in ways that facilitate more expert problem solving. Based on the results of this study, we suggest three specific strategies for the education of designers: 1) helping students recognize and synthesize the key issues in an ill-structured problem by either constraining their analysis efforts to be more expert-like or by engaging them in a series of increasingly less-complete design problems, 2) helping students accumulate a variety of ID experiences, either directly or vicariously, from which they can draw when faced with an unfamiliar design situation, and 3) enabling students to index these experiences in ways that facilitate efficient recall of relevant cases when solving future ID problems. It is our hope that the use of these strategies will lead to more skillful problem-solvers who are able to strategically apply their knowledge, whether from textbooks or vicarious experiences, to articulate clear conceptualizations of ill-structured ID problems and, ultimately, to generate powerful and effective solutions.

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Table 1
Participant Demographics

| Participant | Years of Experience | Current Employment (Years in current position) | Highest Degree | Professional Development | Current ID Tasks | Instructional Formats Used |
|-------------|---------------------|--|----------------|--|---|--|
| Sammie | 32 | Academic ID; Designer for a Center for Instructional Excellence (32 years) | Masters | NR | Planning Design Development Implementation Evaluation | Face-to-face |
| Simone | 24 | Industry (4.5 years) | Masters | ABD--All courses for doctorate in IST | Planning Design Development Evaluation | Face-to-face Computer-based Online Self-instructional Hybrid (online and face-to-face) |
| Thad | 22 | University Professor, Consulting (22 years) | Ph.D. | Additional training through workshops (mostly web development) | Planning Design Development Implementation Evaluation | Face-to-face; Computer-based; Online; Self-Instructional; Hybrid |
| Marlene | 22 | Industry (3 years) | Masters | Internal courses, Design and Development workshops (e.g., qualification, evaluation, test design); Software training | Planning Design Development Implementation Evaluation | Face-to-face Computer-based Online Self-instructional Hybrid (online and face-to-face) |
| Jacob | 21 | Academic ID Administration (5.5 years) | Masters | Regular attendee at conferences - Completed some course work (1992-1996) in Instructional Systems | NR | Computer-based Online Hybrid (online and face-to-face) |

Table 1 (con't)
Participant Demographics

| Participant | Years of Experience | Current Employment (Years in current position) | Highest Degree | Professional Development | Current ID Tasks | Instructional Formats Used |
|-------------|---------------------|--|----------------|---|---|--|
| Jill | 15 | Industry (4.5 years) | Masters | Additional training through Department of Training (D.O.T.) from the U.S. Army. | Planning Design Development Implementation Evaluation | Face-to-face; Computer-based; Online; Self-instructional |
| Sean | 8 | University Professor, Consulting (5.5 years) | Ph.D. | On the job | Planning Design Development Implementation Evaluation | Face-to-face Computer-based Online Self-instructional Hybrid (online and face-to-face) |

Table 2
Participants' Representations of the Issues in the Design Case Study

| Participant | Recognition/Identification of design challenges embedded in the problem scenario |
|-------------|--|
| Jacob | "If that's what they're getting at [trying to recreate powerful experiences online], their options are going to be very limited; it's going to be a challenge." |
| Thad | "That's probably where they are having the most difficulty ... is that transfer of some of these things here" (referring to hot cognitions, heightened self-analysis, counseling services, etc.) |
| Sammie | "The problem is whether you can translate the positive things that were in the F2F workshop into an Internet workshop. ... How are they going to handle these [hot cognitions] in an online environment?" |
| Simone | "If it is a workshop, it could very well be interactive. But if it is online, how could you get the same interactivity ... going?" |
| Jill | "Something that is this interactive ... that'd be nice to put it online but you're going to lose so much of the quality." |
| Sean | "As a designer, the challenge is to figure out the complex combination of learning outcomes they're after...it sounds like an attitudinal change first and [then] behavioral change. Very difficult to do online." |
| Marlene | "Because the problem is converting something that's 16 hours to something online, I really have to wrestle with that issue of how this can be shorter." |

Table 3
Participants' Initial Strategies for Addressing the Issue in the Design Case Study

| Participant | Process for converting a highly interactive F2F workshop into online format |
|--------------------|--|
| Jacob | What are the characteristics of the workshop that are essential? What are the must haves vs nice to haves? I view the problem as determining what are the essential [workshop] characteristics to changing behavior? |
| Thad | Some of this may not transfer but before you know, let's see what all the pieces are. ... You've got to go through the workshop and identify all the different strategies they use to teach this. |
| Sammie | I don't see this as a good Internet course because of the audience, because of the topic. |
| Simone | I want to hone in on what elements of the instruction itself—the format, the instruction, the affective aspect, the group interaction—What parts of this made it the most effective and can parts of it be duplicated? |
| Jill | [Gather people in a focus group] who have already experienced it ... What were the things that were really most effective? What really stuck with them? |
| Sean | I'm looking for possible ways to either blend it, or do other things that will use the media well but also make it more effective. |
| Marlene | If there are 10 modules, I'd want to look critically at ... were all those value-added modules? |

Table 4

Frames of Reference and Rules of Thumb Applied by Participants

| Participant | Frame of Reference | Sample experience-based rules applied during the problem-solving process |
|--------------------|---------------------------|--|
| Jacob | Consulting | <ul style="list-style-type: none"> • My initial gut is ... it's an interaction with a small group. It may not have the same effect when you're at home at your computer. • Completion doesn't mean learning • Converting [this] F2F workshop to online instruction requires paying particular attention to the characteristics of the instruction that are essential to changing the behavior of the participants. |
| Thad | Dissect and Evaluate | <ul style="list-style-type: none"> • You have to watch that with subject matter experts...and others who think you question their authority. • Need to see the types of media being used because media, when it comes to attitudinal learning, can have an impact. • You kind of have to take it apart and make sure that that type of thing isn't going on where they think it is effective but yet it really wasn't in teaching what they needed (it related more to the personality of the presenter). |
| Sammie | Holistic Communication | <ul style="list-style-type: none"> • If there is interaction and the subject is controversial, the delivery should be F2F. • If something is successful, and changing it might pose obstacles/problems, don't change it. |
| Simone | Classroom Teacher | <ul style="list-style-type: none"> • The more you know about the audience, the more you can ... tailor your class to that audience. • It is good practice to include learning checks because that is one way ... to see if people are getting it |
| Jill | Audience Sensitivity | <ul style="list-style-type: none"> • The length of time someone is going to be interested and involved is probably going to be an hour max • A leader-led class ... gets most of the content across and is pretty effective for getting everybody into the training. • When you start talking about health and HIV and different lifestyles, you tend to get people who are living more on the edge. |
| Sean | Clinical Psychology | <ul style="list-style-type: none"> • ... if I am asked to ... try to solve this problem, these questions... are too general for me to be able to think about solving the problem. • My academic training is ... not to assume anything. Not assume that you know the real problem. So when the problem is presented, I'm always wondering if that is the real problem. |
| Marlene | ID Process Model | <ul style="list-style-type: none"> • Online time must be shorter than face-to-face. • If I chose certain ones [tactics] that I thought would work, I'd have to make a business case to him [the boss] somehow. • If you don't know who that [my target audience] is, or if it hasn't been made clear, or it changes, then I know I'm in trouble because I'm not meeting the needs of the person that's learning. |