How Instructional Design Experts Use Knowledge and Experience to Solve Ill-Structured Problems

Peggy A. Ertmer, Donald A. Stepich, Cindy S. York, Ann Stickman, Xuemei (Lily) Wu, Stacey Zurek, and Yuksel Goktas

This study examined how instructional design (ID) experts used their prior knowledge and previous experiences to solve an ill-structured instructional design problem. Seven experienced designers used a think-aloud procedure to articulate their problem-solving processes while reading a case narrative. Results, presented in the form of four assertions, showed that experts (1) narrowed the problem space by identifying key design challenges, (2) used an amalgam of knowledge and experience to interpret the problem situation, (3) incorporated a mental model of the ID process in their problem analyses, and (4) came to similar conclusions about how to respond to the situation, despite differences in their initial conceptualizations. Implications for educating novice instructional designers are discussed.

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 et al., 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 disposal vast, well-organized stores of domain-specific knowledge, gained through extensive experience (Bruer, 1993; Glaser & Chi, 1988). Expertise comprises two major components: abstract knowledge and practical experiences (Bonner, 2007; Didierjean & Cauzinille-Marmeche, 1998; Laurillard, 2002). Although expert *knowledge* may arise from only one of these sources, both may be necessary to develop the kind of "fluid expertise" (Bereiter & Scardamalia, 1993) that allows individuals to adapt and apply their knowledge to a novel situation. According to Bereiter and Scardamalia, practical experience by itself may lead to a kind of "crystallized expertise" that results in individuals who are not particularly good problem solvers because they simply implement well-practiced procedures. Similarly, abstract knowledge that has not been contextualized through practice may lead to the kind of "inert

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knowledge" Whitehead (1929) described, that is, knowledge that can be expressed but not used. In contrast, individuals with *fluid expertise* use both abstract knowledge and practical experience to think through a problem in a way that is more dynamic and constructive. Crystallized expertise would include acquisition of automaticity after extensive practice in a relatively stable and constant system; fluid expertise 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, formulate a clear, coherent representation in terms of one or two central issues. This kind of synthesizing has been a recognized aspect of expert practice for a long time. For example, Larkin, McDermott, Simon, and Simon (1980) found that physics experts routinely generated a physical representation of the problem situation before attempting a computational solution. 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. Larkin (1979) referred to this process by several names: low detail reasoning, qualitative reasoning, and physical intuition. In the nursing field, Benner (1984) used the term *recognitional ability* to describe the capacity of expert nurses to discriminate relevant information from irrelevant and develop a context-dependent, holistic perceptual understanding of the patient situation. According to Benner, this stems from collected practical experiences that expert nurses use to continuously refine their abstract knowledge. In both cases, the authors suggested that experts begin the problem-solving process by developing a big-picture understanding of the problem situation that is based on a conceptualization of the underlying principles.

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 (for example, the characteristics of the target audience) and return to this central element as they began to work out the design details. Perez and Emery referred to this approach as a "breadth-first, top-down, progressive" design strategy. In another study involving revision of instructional text (LeMaistre, 1998), 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 noted that the expert was explicit in creating 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.

Although it seems clear that experts engage in the kind of synthesizing described here, it is less clear how this process is influenced by the experts' vast store of knowledge. Building on the idea that expert knowledge comprises both abstract knowledge and practical experience, one view is that synthesizing is based primarily on recall of abstract knowledge (that is, principles and concepts drawn from the domain). In this view, experts define a problem in terms of conceptual principles drawn from their store of domain knowledge (Ertmer & Stepich, 2005). For example, Chi et al. (1981) asked experts and novices to outline solutions to physics problems. 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 not explicitly described in the problem statement but derived from a small piece of given information that activated a relevant schema in the experts' existing knowledge. Glaser and Chi (1988) noted that, with experience, experts encoded not only the procedures for solving relevant problems but also the conditions under which they were applied.

An alternative view is that synthesizing is based primarily on recall of practical experiences (real events in which designers participated). In this view, experts define a problem in terms of a similar situation drawn from prior experiences (that is, a case). For example, Rowland (1992) found that instructional design experts typically associated a given situation with similar problems they had previously encountered 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 grounded their decision making more in 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 a rich library of case experiences that they apply, through a type of analogical reasoning, to 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, 1994, p. 40). Theorists claim that human reasoning is case based; that is, we all have our own experiences stored in our memories and then those are reused when new problems trigger recall of similar situations (Kolodner, 1993;

Schank, 1999). Jonassen and Hernandez-Serrano (2002), after reviewing studies in multiple 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 supplying a substitute for first-hand experience (Jonassen, 1999).

Although these two explanations of synthesizing may appear conflicting, they are not mutually exclusive. For example, Genberg (1992) suggested that expertise might be viewed from two lenses: an information-processing lens and an intuitive one. The former emphasizes organization of knowledge and progression of skill acquisition and the latter focuses on the relevance of past experiences in a particular context. Kolodner and Guzdial (1999), strong advocates of reasoning from cases, nevertheless 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. This idea is supported further by research by Didierjean and Cauzinille-Marmeche (1998), who demonstrated that individuals develop, and even use simultaneously, these two types of reasoning processes.

Purpose

The purpose of this study was to determine *if* instructional design (ID) experts synthesized the issues presented in an ill-structured problem scenario (as described in the literature), and if so, *how* abstract knowledge and practical experiences were used during the synthesizing process. From 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 draw on their previous experiences.

Method

Overview

This study was designed to examine the processes that experienced instructional designers use in solving ill-defined instructional design problems. Data consisted of a demographic survey, think-aloud protocols, and interviews with seven participants. The think-aloud protocols captured experts' verbalizations during the 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, 1998). 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 on 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 characteristics of expert problem solving while simultaneously grounding it in empirical data (Strauss & Corbin, 1998).

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Role of Researchers

This study was designed and implemented by a research team consisting of six doctoral students and one faculty member at a large midwestern university. A second faculty member, located at a large western university, acted as a consultant to the team during design and implementation of the study. All but one student had previously completed an advanced instructional design course, which used ill-defined case problems. Students had a range of previous ID experiences in both educational and business contexts.

Prior to the start of the study, a pilot was conducted with one participant, during which the entire research team observed 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, modify specific data collection procedures that were either problematic or unclear during the pilot, and clarify each person's role in the subgroups. The researchers carefully checked and monitored each other during the entire research process, reviewing transcriptions for accuracy and requiring clear evidence of initial interpretations. For example, specific claims were linked to supporting data (using a line-numbering system for each transcription), thus enabling team members to challenge or support initial interpretations and provide additional or counter evidence.

Participants

Seven expert instructional designers (four women and three men) were purposively selected. Each participant had eight or more years of instructional design experience, in a variety of settings. Demographic data (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 (with two of them

TABLE 1
Participant Demographics

Participant	Years of Experience	Current Employment (Years in Current Position)	Highest Degree	Professional Development
Jacob	21	Academic administration (5.5)	Master's	Regular attendee at conferences; completed some course work (1992–1996) in instructional systems
Jill	15	Industry (4.5)	Master's	Additional training through Department of Training from U.S. Army
Marlene	22	Industry (3)	Master's	Internal courses, design and development workshops (e.g., qualification, evaluation, test design); software training
Sammie	32	Academic ID; designer for a center for instructional excellence (32)	Master's	No response
Sean	8	University professor, consulting (5.5)	PhD	On the job
Simone	24	Industry (4.5)	Master's	All courses for doctorate in IST[a]
Thad	22	University professor and consulting (22)	PhD	Additional training through workshops (mostly Web development)

[a]Instructional Systems Technology.

holding a Ph.D. degree), 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 they had previous experience with face-to-face, computer-based, online, self-instructional, and hybrid instructional delivery formats. Table 1 shows additional demographic data for each participant.

Data Collection

Following 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 through a 12-page, double-spaced, typed narrative dealing 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, as indicated by our survey results. Each data collection session lasted about two hours and included (1) a warm-up exercise, (2) the think-aloud procedure, and (3) a retrospective interview. The warm-up exercise included a small problem that the participants used to practice the think-aloud approach (for example, identify the number of windows in your house). For the think-aloud process, participants were instructed to "read aloud the case problem and to think aloud as you work on the problem, telling us everything you are thinking from the time we give you the problem, until finished." During the process, the researchers sat slightly behind each participant, so as not to engage him or her in conversation. Although nonverbals (such as a nod of the head or "Hmm-mmm") were used to encourage participants to continue talking, interruptions were minimized, being used only to prompt participants to resume talking aloud after a relatively long pause ("What are you thinking?" "Please continue"). Retrospective interviewing (Ericsson & Simon, 1993) occurred immediately after the think-aloud as a way to help participants reflect on, and verbalize, their thought processes *during* the think-aloud, drawing from both long-term and short-term memory (for instance, "Describe the process you used to think about the case"). In addition, interviews included questions to clarify comments participants made during the process and to explicate how knowledge and experiences were used. The interviews included questions such as "What was the first thing you thought about as you read the case?" "What made you think of that?" or "Where did you learn that?" All sessions were videotaped and transcribed.

Data Analysis

Transcriptions were examined using a constant comparison method (Strauss & Corbin, 1998), with specific attention given to participants' references to prior knowledge and experiences. Initially, each researcher conducted an analysis of a single transcription, looking for evidence that related to our two research questions but without establishing preconceived ideas about what might be discovered. This resulted in a set of tentative profiles that captured each participant's response to the case situation. Following this, two researchers applied a modified open-coding process using an electronic copy of each transcription, inserting comments and highlighting quotes that seemed particularly relevant to our questions. However, rather than create a set of categories and subcategories as is typical in open coding (Creswell, 2003), we created a set of themes that reflected each participant's responses. Themes for each participant were shared and discussed between the two researchers as they were developed. During these conversations, no attempts were made to come to consensus, but merely to note the similarities among the themes and seek clarification and additional evidence if the interpretations were unique or unusual.

After creating themes for each participant, the researchers then looked for similarities across participants as the first step in creating a set of assertions that could be applied to the majority, if not all, of our participants. If a theme was not evident among at least four participants, it was not used in the final set of assertions. For example, after noting that three of our participants engaged, simultaneously, in the processes of problem finding and problem solving, we earmarked this as a theme and anticipated that this might emerge as a finding of our study. However, none of the other four participants did this to any noticeable degree. We found this interesting (and would like to examine this difference further), but we judged that we did not have sufficient evidence to present this as an overall finding. Similarly, if one researcher noted a theme that the other did not, this was not incorporated into our final set of assertions if the theme could not be verified (with supporting quotes or evidence) for at least four participants.

Finally, after the assertions were developed, they were presented to the rest of the research team (with evidence) for additional comment and final team verification. The team then worked together to find relevant supporting or contradictory evidence from the literature.

Validity and Reliability

Lincoln and Guba (1985) recommended that qualitative results be evaluated using the standard of "trustworthiness," as established by credibility and confirmability. In this study, *credibility* was gained though triangulation of multiple data sources, including a demographic survey, think-aloud protocol, and retrospective interview. The use of multiple researchers led to *confirmability* of the data. Throughout the study, weekly meetings of the researchers helped to ensure understanding of our research questions, consistency of data collection, and interpretation of data. Data analysis involved individual and collaborative efforts to develop and verify the emergent themes and overall assertions. A line-numbering system was used to identify specific data supporting each finding, thus creating a traceable link between evidence and assertions. Finally, participants verified our interpretations, immediately during the interviews and later through their responses to specific e-mail queries.

Results and Discussion

In this study, we asked questions about how experts used their knowledge and experience to solve ill-structured problems presented through a case study narrative. We present our findings in the form of four assertions that were developed through our analysis and interpretation of the data. Excerpts from the participants' think-aloud and interview protocols are integrated with interpretive commentary to support each assertion. Subsequently, we discuss how each assertion is, or is not, supported by the literature.

Assertion 1: Narrowing the Problem Space

In identifying the key design challenges, experts narrowed the problem space. For some, this seemed to occur in place of, or prior to, making a synthesis statement. According to the literature, a 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" (Ertmer

& Stepich, 2005, p. 39). Referring to this as the ability to "synthesize" the issues in a problem situation, the authors noted that this is a key characteristic of expert instructional designers.

In this study, synthesizing typically took the form of highlighting. That is, all seven participants articulated specific design challenges related to converting a highly interactive face-to-face workshop to an online format (that is, the problem presented in the case). Specific aspects of the case situation were highlighted because they were seen as either particularly central to the effectiveness of the workshop or particularly difficult to translate to an online environment. 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." Additional challenges highlighted by the participants included, among others: the importance of interactions among the workshop participants; learning by doing; resolving access issues; facilitating and maintaining behavior change advocated by the workshop leaders; and "smoothing out" interpersonal relationships among the designers in the case (described in more detail in Assertion 4).

Though every participant highlighted specific challenges related to converting the face-to-face workshop to an online format, not everyone synthesized these challenges into a clear concise statement, as hypothesized earlier. 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"), but others simply pointed out a number of elements that would be difficult to transfer to the online environment without making a direct statement about how these elements contributed to, or constituted, the core problem. For example, as Jill engaged in the think-aloud process, she stopped periodically to comment on new challenges as they were introduced in the case narrative. These challenges related to a variety of issues: putting an interactive workshop online, moderating discussions, providing appropriate counseling services, securing online permissions, resolving access issues, and limiting the amount of time required. Jill noted that she usually begins the design process by "looking for some sort of initial analysis, starting with some kind of objectives," but because these were not immediately available she described her approach as just "kind of reacting to things as we went through." This lack of a synthesis statement, then, may have been due to a stylistic difference among participants or to variation in how the researchers asked the participants to state the problem (Jill was never specifically asked, "What is 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.

In almost all instances in which synthesizing occurred, highlighting preceded it. Most often, the synthesis statement captured one or two key design challenges that the participants had highlighted during the think-aloud process. For example, after highlighting a number of problem elements, Simone stated:

> If that data is [sic] actually true and correct, I'd want to hone in on what elements of instruction itself—the format, the instruction, the affective aspect of it, group interaction *[all problem elements noted earlier]*—all of that and say, "What part of this made it the most successful?" and "Can this be duplicated?"

As another example, after mentioning a number of potential problem elements, Thad synthesized the issues with this statement:

> Soon you're going to have some kind of table [in which] you compare what they've done in the past, and if it worked then, are you going to be able to transfer that over into the online environment and help them to solve some problems they are having in the transfer? That's probably where they are having their most difficulty in creating this thing, is that transfer of some of these things.

The literature suggests that experts tend to translate ill-defined or unfamiliar problems into well-defined or more familiar problems as a way to narrow the problem space and search for a solution (Glaser & Chi, 1988; LeMaistre, 1998; Perez et al., 1995). According to Rowland (1992), expert designers approach new problem situations using existing "frames of reference," built from their previous knowledge and experiences. Frames of reference, then, may be one way in which experts make this translation from an ill-defined problem to a more defined one. Similar to what Rowland (1992) and Perez and Niederman (1992) found, each participant in this study understood the case problem in terms of the personal experiences and perspectives she or he brought to the case as much as by the information provided by the case narrative. For example, from her 22 years of experience as a designer in business and industry, Marlene brought a "training" frame of reference to the problem: "What is the problem? Will training address it? Who are we dealing with?" She elaborated on her specific perspective:

> I look at it from a training perspective and then I add all of the human baggage that goes with it, or that is going on there. I go to "what is the target audience?" and get a clear definition of what that is. And then [I get] a clear definition of what the training issues are by defining the objectives.

Sean, who had a background in counseling psychology, used a "consulting" perspective: "The problem is *more* about the interaction of the cultural differences between the organizations as much as it's about a lack of specificity of the goals." As he explained further:

> This is a very typical problem … it's a challenge for consultants who work with the military, for example. And I was sort of using that as one of my frames of reference. I have experience in that. I do my research with consultants as well and … there is always tension between research design and product design.

Frames of reference may be one way in which experts make this translation from an ill-defined problem to a more defined one.

In contrast, Sammie used her communication background to frame the problem in terms of the type of topic that needed to be addressed and the kind of conversation that needed to occur:

> With such a . . . touchy topic, I would want to have control in the room so if something happened I would be there to handle it. . . . I have a background in communications and all of my teaching is done in very small groups where I can watch the faces of my students and especially their nonverbal behavior and make instant corrections in the instruction.

As a final example, Jacob, who was in charge of instructional computing on a large university campus, used an "administrative" perspective to consider whether the real problem could be addressed in an online environment: "I pull from components of projects and they are kind of reorganized into other types of situations. I'm primarily an administrator, so my categories right now are project timelines, budgets, legal, those types of things."

In summary, participants in this study all identified multiple design challenges in the case scenario, with these challenges later being combined, by five of the seven participants, into articulation of a synthesis statement during the interview process. As suggested by Schön (1983), the first step in the problem-solving process is problem finding or problem setting: "The designer must make sense of an uncertain situation that initially makes no sense" (p. 74). As part of this process, expert designers identify the constraints, or problem elements, of the given situation. Goel and Pirolli (1992) suggested that during this process expert designers may explicitly try to change the problem situation so it more closely matches their personal expertise and knowledge. Although we didn't observe our participants use their frames of reference to actually *transform* the case information, they employed them to *filter* through the details, facilitating a focus on those case details that were judged most critical.

Assertion 2: Amalgamating Knowledge and Experience

When analyzing ill-structured problems presented via a case narrative, instructional design experts used an amalgam of knowledge and experience. Even though all of our participants referred to specific prior experiences and six of seven referred to some specific piece of abstract, academic knowledge (such as the ADDIE model, Gagne's types of learning, message design), their interpretations of the case details relied primarily on a blend of knowledge and experience. When asked specifically how they knew to use a particular strategy or consider particular issues, our participants typically referred to previous experiences. For example, Marlene responded, ""How do I know that? I know that just from my experiences working in this company," while Simone reflected, "I'm thinking of my own experiences with taking online courses." Sean captured the general feeling of all of our participants when he stated, "I have been in that situation many times."

In general, recollection of *specific* ID experiences or *specific* ID principles was rare. Furthermore, if participants recalled specific experiences, they didn't really use the information from those experiences to narrow the problem space or solve the problem (at least not obviously). If they recalled specific book knowledge, it was usually embedded within their recall of experiences. More typically, the participants recalled a "mix" or "blend" of experiences that were relevant to the current problem. Consider these quotes from three participants:

- "I can't say, 'Oh this really reminds me of this,' but there is … all the little pieces remind me of something." (Jill)
- "I'm thinking it was background experiences, but there isn't one specific one." (Thad)
- "I have a blend in my head that is from many different experiences. … In my mind, it just all blends together. … I pull from components of projects, and they are kind of recategorized into other types of situations." (Jacob)

Rather than accessing a single specific prior experience (a case), participants extracted from their collected experiences one or more relevant rules, which they applied to the current situation. These rules were not ones that could be found in an ID textbook but were much more idiosyncratic and drawn from the unique collection of previous experiences that each participant brought to the current situation (Klein & Calderwood, 1988; Kolodner & Guzdial, 1999). According to Davenport and Prusak (2000), rules of thumb are "guides to action" that have developed over time through extensive experience and observation (p. 10). Schank (cited in Davenport & Prusak) referred to these internalized responses as "scripts," which, like play scripts or computer programming codes, act as an efficient guide to a complex situation, offering a plausible route through a maze of alternative solutions.

As an example of how our participants applied rules of thumb during their analyses of the case narrative, Thad suggested that before you can decide what to translate to an online environment you need to know exactly what's making the current materials effective. 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." As another example, 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 appeared to be based on what she viewed 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." Additional rules of thumbs are illustrated by these examples:

Experts in this study used an amalgam of knowledge and experience to analyze the problem situation presented in the case narrative.

- "The length of time someone is going to be interested and involved is probably going to be an hour max. . . . [Therefore] short lessons that are self-contained may be appropriate." (Jill)
- "[The designer] is really big on learning by doing. That confirms my thinking that we need to give a lot of scenarios and have people respond to those scenarios." (Marlene)
- "I have been in that environment many times and it's a cultural clash. So my immediate reaction was to think in terms of the relationships that have to happen to make that project work." (Sean)

In summary, experts in this study used an amalgam of knowledge and experience to analyze the problem situation presented in the case narrative. Similar to what Davenport and Prusak (2000) described as a "fluid mix of framed experience" (p. 5), our participants appeared to access domain-specific knowledge, which was built *of* experience. As noted by Kolodner (1988, 1997), expert problem solvers tend to access their case memories multiple times during a problem-solving episode, allowing them to recall several cases (previous experiences) rather than just one, to be used during the process. Results from this study support this contention.

Assertion 3: Accessing a Mental Model of the ID Process

When recalling previous ID knowledge and experiences to solve an ill-structured problem, ID experts accessed a mental model of the instructional design process to guide their thinking. According to the literature, experts have a large store of organized domain-specific knowledge (Bransford, Brown, & Cocking, 2000; Bruer, 1993; Glaser & Chi, 1988), organized as schemas or deep knowledge structures (Bedard &

Chi, 1992; Brophy, Hodge, & Bransford, 2004). Johnson (1988) suggested that expert knowledge is organized schematically as a mental model of the relevant system. Experts use this mental model, then, to create a large-scale, qualitative representation of the current problem (Larkin et al., 1980) as a first step in solving the problem.

In this study, all seven of our participants made statements suggesting that they approached the case with some kind of instructional design process model in mind. The models varied, but everyone had one. Two types of model accounted for six of the seven experts in this study. For example, three of the participants used an "audience first" model:

- "The first thing I like to do is write down what the target audience is." (Marlene)
- "You need to know what the audience is and the more you know about the audience the better you can design something." (Sammie)
- "OK, so I'm honing in on the target audience because any time you design instruction you are designing it for a particular audience and it is helpful to know who that audience is and as much information as possible about that audience." (Simone)

Three of the remaining four participants used an "outcomes first" model. This shows up, specifically, in comments about what is missing in the case:

- "A lot of the objectives are not clear to me. So, I'd really want to nail it down first of all." (Jill)
- "What are the objectives here? . . . These are goals, they're not objectives—they're way too broad." (Jacob)
- "As a designer, the challenge here is figuring out the complex combination of learning outcomes that they are after. … Thinking about a solution is way too far down the road because we don't know what the goal is." (Sean)

Finally, one participant used a "domains of learning first" model. A critical step in Thad's process was to "classify the type of learning that is occurring." In contrast to other experts, Thad did *not* refer to objectives or goals. Instead, he referred to the type of learning, specifically questioning whether the focus of the workshop was on verbal information or attitudes and noting that "we've got to go at it a little different" depending on the type of learning involved. This idea of domain-specific instructional strategies is a central principle in Gagne's instructional design model, which suggests that Thad's mental model was based on Gagne's theory.

In general, our participants used these mental models to guide their thinking about the case. Typically, they did not follow their models on a one-to-one basis like a recipe. Instead, they used their models more broadly and heuristically. The nature of the think-aloud task may have limited their uses of the models to the beginning stages of the analysis task, but our participants appeared to apply them in two explicit ways: (1)

to structure their search for information, as illustrated by Marlene and Simone respectively ("I needed to look for information to fit into a model like the ADDIE model"; "The ADDIE model is just sort of a nice little acronym that reminds me, 'Have you covered all of these bases?' It may not be in that order necessarily in reality"); and (2) to focus their attention on initial information considered critical to the instructional design process. This is not necessarily the first step in a particular textbook model, but rather the element of the ID process that the experts saw as critical at the start of the process. The following are examples:

- Sammie ("audience first") focused first on the needs of the target audience.
- Jacob ("objectives first") distinguished between objectives and goals and wanted to know what the objectives were. It's worth noting that objectives are not the first consideration in the Dick and Carey model (the textbook model that Jacob mentioned), which supports the idea that the mental models were individual heuristics rather than textbook-based recipes.
- Thad ("domains of learning first") based his thoughts about selecting the instructional media on the type of learning involved.

The fact that our designers all accessed a mental model of the ID process is not surprising, because it is supported by the literature. Recent research by Campbell, Schwier, and Kenny (2006) suggested that designers reference conventional ID processes in their conversations about design, although their practice varies significantly according to context. Perez and Neiderman (1992) also reported the experts in their study used a design process that reflected a systems approach yet varied in how they implemented the process. The authors argued that these differences were related to the frames of reference the experts used in making their design decisions. Again, this may explain why our participants used the models they did; that is, an "audience first" model was more compatible with a communications frame of reference, while an "outcomes first" model was more compatible with an administrator's frame of reference. After participating in a large number of relevant projects, our experts found the mental models of the ID process enabling them to reason not from textbook principles or models but rather from "first principles" (Merrill, 2002; Reigeluth, 1997; Winn, 1997). This is similar to what other researchers have described: Experts tend to look past the surface details in a problem to focus on the underlying principles or big ideas embedded in the situation (Bransford et al., 2000; Glaser & Chi, 1988; Larkin et al., 1980).

Mental models are one characteristic that has been used to distinguish between expert and novice designers. In general, novice designers have access primarily to textbook models, which do not necessarily apply to novel problem situations (Atherton, 2002; Reimann & Schult, 1996). In contrast, from their many years of experience in a variety of contexts, experts are able to recognize patterns or principles of practice and generate solutions based on those that have worked in similar situations (Hardre, Ge, & Thomas, 2006; Kirschner, Sweller, & Clark, 2006).

Assertion 4: Arriving at Similar Conclusions on How to Respond

The experts came to the same, or a very similar, conclusion about how to respond to the situation. Polya (cited in Wilson, 1997) stated that once we've figured out how to *see* a problem in a certain way, the solution becomes obvious. Given that the frames of reference used by our participants all incorporated some variation of an ID process model (Assertion 3), this may explain why (and how) the experts in our study all came to see the design problem similarly. As captured by Assertion 1, all seven participants articulated explicit design challenges related to converting the face-to-face workshop to an online format.

Specifically, as illustrated by Table 2, the participants mainly focused on four related issues: the affective nature of the workshop, use of diverse instructional strategies, achieving the goal of behavior change, and the interactive nature of the workshop.

All seven designers highlighted the difficulty in re-creating the affective nature of the workshop in an online environment. For example, Simone commented:

> There are some things that cannot be [translated online]. If it is [just] information and that changes behavior, then yes, there are ways to get at that. But if it's this closeness and a support group . . . if it's some other element, there are some things that just cannot be duplicated online.

Similarly, Jacob noted, "The empathy—yeah, that's going to be a challenge. … Their options are going to be very limited." In fact, due to the affective nature of the topic and the methods used in the face-to-face environment (hot cognitions, sexually explicit media, and so on), several designers expressed a healthy skepticism toward making this conversion. Simone and Sammie, in particular, challenged the decision to translate the workshop. Simone said:

> The first question I would ask is, Does this really lend itself to e-learning? I am not sure. You know, you will have to convince me. Why are they even doing this? What is the overriding advantage over what they've got, which is already successful?

This led Simone to the conclusion that "Maybe it shouldn't be an online course at all." Sammie echoed Simone's concerns and quickly came to the conclusion that this conversion should *not* be made:

> If the previous workshop has been successful, I would not go with the Internet. … It would open all sorts of cans of worms. With such a … touchy topic, I would want to have control in the room. … I would stick with what's been working.

TABLE 2
Design Challenges Identified by Participants

Identified Design Challenges	Jacob	Jill	Marlene	Sammie	Sean	Simone	Thad
The affective nature of the workshop (e.g., powerful experiences, intense engagement)	x	x	x	x	x	x	x
Converting the instructional strategies that were effective in the face-to-face workshop to an online format	x		x	x		x	x
Achieving, measuring, and maintaining behavior change	x		x		x	x	x
The interactive nature of the workshop	x	x	x			x	
The length of the workshop	x	x	x				
The interactions between the designers involved				x	x		x
Ethical and legal issues	x		x				

In addition to outlining the challenges of translating affective content and methods to an online environment, five of the seven designers identified specific challenges related to implementing the diverse range of strategies that had been effective in the face-to-face environment, noting, for instance, "We'll have to think about ways for doing that" (Marlene). Simone commented specifically on the learning-by-doing approach favored in the face-to-face workshop, stating, "As an educational approach this is great, but how you do that online . . . that's something to think about." Five designers also identified challenges related to the goal of the workshop, that is, to create a change in behavior. For Jacob in particular, this was the focal point of the case: "[For] how long does that behavior change, and for which people . . . that's what this group has to deal with."

Identifying these key design challenges shaped how our participants envisioned *addressing* those challenges. Although participants conceptualized the design challenges slightly differently, initial strategies for addressing the design issues were very similar. 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; 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 as opposed to nice-to-haves. Similarly, Marlene discussed the need to determine which workshop components provided "value added," to determine which pieces could be safely eliminated.

The results of this study suggest that expert designers, despite some variation in their conceptualizations of the issues in the problem situation, still reach similar conclusions about how to address those issues. This finding is similar to that of Spector and Koszalka (2004), who found that experts conceptualize complex problems in recognizably similar ways. As pointed out by Driscoll and Carliner (2005), this may relate to the nature of the problem-finding process in that early problem identification subsequently limits the number of solution paths that can be considered. It is conceivable that by initially highlighting similar elements, our designers had, in effect, constrained the number of possible solution paths. However, this finding contrasts with what Rowland (1992) reported in his study, in which the experts were described as demonstrating a "significant amount of variation" (p. 81) in terms of both their problem representations and their proposed solutions. Rowland attributed this result to the frames of reference used by his participants. No two designers in our study appeared to use the same frame of reference in analyzing the problem, but they all incorporated key elements of the design process within those frames—a similarity that was not described by Rowland. Perhaps the "significant" variation in initial problem representation left more solution paths open for Rowland's participants to explore. Finally, we must also consider the simple explanation that the case narrative used in this study was not as complex as the problem that Rowland's experts encountered, thus allowing our experts to more readily represent and address the core issues in similar ways. As another point of contrast, the specific problem presented to the experts in this study required only that they *translate* existing instruction to a new format, rather than *design* something new from scratch. Additional research is needed to help clarify these seemingly conflicting results.

Implications for the Education of Designers

The results of this study have implications for educating instructional designers. First, the results support findings from previous research (LeMaistre, 1998; Perez & Emery, 1995) suggesting that ID experts construct a clear understanding of the issues in an ill-structured problem as the first step in the problem-solving process. Although two of our experts did not specifically articulate a synthesis statement, they all narrowed the problem space by identifying key problem elements in the case narrative. 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 expertlike ways. In subsequent problem-solving exercises, students who received the HAT instruction were observed using the expertlike 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 guidelines that compel them to consider big-picture (as opposed to surface) issues in analyzing ill-structured problems. Preliminary results from a study by Ertmer et al. (in progress) suggest that use of guidelines or scaffolds that remind novices, among other things, to (1) focus on the big picture, (2) consider the core issues (those most central to understanding the case), and (3) consider the critical issues (those most likely to lead to a successful resolution) helped them analyze an ill-structured case scenario in more expertlike ways than novices who were not given these guidelines. Additional research is needed to verify these preliminary results.

The experts in this study appeared to use personal frames of reference, based on accumulated sets of previous experiences, in conceptualizing the ID challenges embedded within a problem scenario. It is unlikely that ID students have amassed many personal experiences (related to ID practice) while still in school, but there is some indication that students can benefit vicariously from the experiences of others (Jonassen, 1999; Schön, 1993). Fortunately, there are a variety of ways to incorporate both direct and vicarious learning experiences into our graduate programs, among them 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. This is in line with Collins's recommendations (1991) for designing cognitive apprenticeships, which suggest 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 (Schön, 1993), novices may 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 would not only *see* real-world examples of completed analyses but also *hear* how the experts arrived at their final solutions. Furthermore, students could compare their ideas about the case with those of experts, which supplies rich fodder for meaningful reflection. Each strategy could provide opportunities for novices to hear and benefit from the experiences of others who are more expert than they are.

Still, it may be important to help students index these experiences in a way that is 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 and experiences so they can be readily integrated into existing knowledge and then easily retrieved when needed to solve similar problems. Because only a subset of one's knowledge and experience is relevant to any single problem, a practitioner needs to be able to select and retrieve only what is relevant. Part of the job of the ID educator, then, is to support novices as they observe, accumulate, and store (in memory) relevant experiences during their graduate program.

Offering appropriate learning experiences may be *part* of the answer. At the same time, it is important to help students *reflect* on those experiences so as to enable them to readily recall and use those experiences during future problem-solving situations and thus, over time, develop their own mental models of the ID process. For example, case study discussions can focus students' attention on specific problem elements and design challenges in the case, as well as possible solutions and their implications. Following this, Didierjean and Cauzinille-Marmeche (1998) recommended that we help students represent the knowledge gained at multiple levels of abstraction. At the lowest level, this would entail simply storing or indexing "unabstracted" knowledge in the form of specific case details (context, stakeholders, events). At the next level, case details would be represented in the form of themes or concepts underlying the specifics (communication issues, project management decisions). Further abstraction might result in formation of a principle, or rule of thumb, that links the concepts or themes through causal, correlational, or chronological relationships (for example, "If the subject is controversial, the delivery should be face-to-face; if it's a run-of-the-mill topic, it could be converted to the Internet"). As students' case knowledge becomes more abstract, it would have the potential to be more generalizable. However, it also would lose the local and specific nuances that enable it to address novelties, ambiguities, and exceptions to generality (Didierjean & Cauzinille-Marmeche, 1998; Reimann & Schult, 1996). Ideally, students would integrate their knowledge across all levels of abstraction to enable the most effective reasoning and recall. As students' mental models become more sophisticated through each subsequent experience, it is expected they will over time increase their ability to identify the underlying structure of the problem situation and thus reason from first principles (Reigeluth, 1997).

Limitations and Suggestions for Future Research

In addition to the small number of participants, a primary limitation of this study relates to use of think-aloud protocols for data collection. This is a common approach used in expert-novice studies (LeMaistre, 1998; Perez & Emery, 1995; Rowland, 1992), but 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 design problem having been presented to the participants as a text-based case narrative. 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 first to determine the extent of the influence of a think-aloud procedure on design thinking and second to evaluate other means for capturing the thought processes of experts.

To address the first issue, the "silent dog" method of protocol analysis, proposed by Hayes, White, and Bissett (1998), may enable us to determine whether a think-aloud approach has an impact on design thinking. Using this method, two groups of designers are asked to solve a similar design problem, one while thinking aloud and the other not. By comparing solutions across groups, it may be possible to determine the extent to which thinking aloud affects design thinking. To address the second issue (effective means for capturing experts' thought processes), it may be possible to videotape a team of designers as they discuss a novel case, capturing their conversations and thus their thinking as they analyze the situation. Another option might be to present the case situation on video rather than in print, perhaps enabling a different type of thought process from that captured by reading and thinking aloud. Finally, asking individuals to write a synopsis of a case situation (presented in video or print) might be able to capture important components of the problem-solving process, such as initial design decisions or elements deemed critical by the designer. Each method has advantages and limitations, but it also may be possible to combine approaches to adequately address critical shortcomings. This area appears ripe for additional research.

Although this study focused primarily on experts' approaches to analysis (problem finding), it is important also to look at experts' approaches to designing solutions to the problems identified. Although 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 owing 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 problem-finding process.

Conclusion

The results of this study suggest that experts tend to quickly filter through the layers of a problem situation to determine the key elements, by drawing on their previous knowledge and personal experiences, as a first step in conceptualizing the ill-defined issues in a case-based problem. Regardless of whether individual, multiple, or composite previous experiences were recalled, they were used to create personal rules that were not gleaned from knowledge or experience alone, but from a combination of the two. Specifically, knowledge and experience appeared to facilitate the problem-solving process by giving the individual (1) a personal perspective or frame of reference, incorporating a mental model of the ID process, that guided the individual's thinking about the problem; and (2) a set of idiosyncratic rules of thumb that helped the individual reflect on specific ways to address the complex issues in the case.

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 how we scaffold students' problem-solving activities in order to more effectively enable them to organize their domain knowledge so as to facilitate more expert problem solving. Based on the results of this study, we suggest three specific strategies for educating designers: (1) helping students conceptualize the key issues in an ill-structured problem by scaffolding their analysis efforts to be more expertlike; (2) helping students accumulate a variety of ID experiences, directly or vicariously, that they can draw on when faced with an unfamiliar design situation; and (3) enabling students to index these experiences in a way that facilitates efficient recall of relevant cases and principles when solving future ID problems. It is our hope that 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 generate powerful and effective solutions.

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PEGGY A. ERTMER

Peggy A. Ertmer is a professor of educational technology at Purdue University. Her interests are related to helping students become expert instructional designers, specifically through use of case- and problem-based learning methods. *Mailing address*: Purdue University, Department of Curriculum and Instruction, 100 N. University Street, West Lafayette, IN 47907–2098. *Phone*: (765) 494–5675. *E-mail:* pertmer@purdue.edu

DONALD A. STEPICH

Donald A. Stepich is an associate professor in the Instructional and Performance Technology Department at Boise State University, where he teaches courses on instructional design, instructional strategies, and needs assessment. *Mailing address*: Department of Instructional and Performance Technology, Boise State University, 1910 University Drive ET 323, Boise, ID 83725–2070. *E-mail:* dstepich@boisestate.edu

CINDY S. YORK

Cindy S. York is a doctoral student in educational technology at Purdue University. Her interests focus on online learning, technology integration, and instructional design. *Mailing address:* Department of Curriculum and Instruction, Purdue University, 100 N. University Street, West Lafayette, IN 47907–2098. *E-mail:* cyork@purdue.edu

ANN STICKMAN

Ann Stickman, a teacher in her 28th year at Lyons Township High School (LaGrange, IL) and a doctoral student at Purdue University, researches technology integration, PBL, and online learning. *Mailing address:* Lyons Township High School, 100 South Brainard Avenue, LaGrange, IL 60525; or Department of Curriculum and Instruction, Purdue University, 100 North University Street, West Lafayette, IN 47907–2098. *E-mail:* estickma@purdue.edu

XUEMEI (LILY) WU

Xuemei (Lily) Wu is a doctoral student in the Educational Technology Program at Purdue University. She has had working experience in consulting and workplace training. Her interest is technology impact on learning and performance improvement. *Mailing address:* Department of Curriculum and Instruction, Purdue University, 100 N. University Street, West Lafayette, IN 47907–2098. *E-mail:* wu36@purdue.edu

STACEY ZUREK

Stacey Zurek is the coordinator of instructional technology and distance learning at Purdue University North Central. In addition, she teaches courses in instructional technology and health methodology in the Elementary Education Department at Purdue North Central. *Mailing address:* Purdue University North Central, 1401 S. U.S. 421, Westville, IN 46391. *E-mail:* szurek@pnc.edu

YUKSEL GOKTAS

Yuksel Goktas is an assistant professor of instructional technology at Ataturk University in Turkey. His research areas include technology integration, technology planning, instructional design, and problem-based learning. *Mailing address:* Department of Computer Education & Instructional Technology, Kazim Karabekir Faculty of Education, Ataturk University, 25240, Erzurum, Turkey. *E-mail:* yukselgoktas@atauni.edu.tr