Student Models of Instructional Design

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Mental models are one way that humans represent knowledge (Markman, 1999). Instructional design (ID) is a conceptual model for developing instruction and typically includes analysis, design, development, implementation, and evaluation (i.e., ADDIE model). ID, however, has been viewed differently by practicing teachers and instructional designers (Kennedy, 1994). In a graduate ID course students constructed their own ID models. This study analyzed student models for (a) what ADDIE components were included (by teacher, nonteacher), and (b) model structural characteristics (by teacher, nonteacher). Participants included 178 students in 12 deliveries of a master's level ID course (115 teachers, 63 nonteachers). Our conceptual ID model is presented, and the ID model task is described. Students most frequently represented design, followed by program evaluation, needs assessment, development, and implementation. In terms of structural characteristics, 76 models were characterized as metaphoric, 61 dynamic, and 35 sequential. Three interrelated conclusions and implications for ID learning are offered.

Keywords: mental model, instructional design, instructional design models

> Mental models are naturally evolving models . . . through interaction with a target system, people formulate mental models of that system. (Norman, 1983, p.7)

☐ People engaged in the study of a particular domain develop understandings that guide their interactions within that domain. In the field of instructional technology, instructional design (ID) is a central intellectual process that guides the design and development of successful learning environments (Nelson, Magliaro, & Sherman, 1987). Published ID models that depict this process guide teams of designers working on the design and development of techno-

logical products, while others are used to teach ID (Branch & Gustafson, 2002). How instructors represent the ID process influences how students come to understand this process and perhaps use or not use it. This conceptual representation is what Norman labeled as the conceptual model. "As teachers, it is our duty to develop conceptual models that will aid the learner to develop adequate and appropriate mental models" (1983, p. 14). An examination of how students understand the ID process through these conceptual models has not yet been articulated. If models are representations of how people understand a particular domain and the actions they would bring to the task, then it seems valuable to study student representations of ID. Instructors can use this information to understand the different structural characteristics and underlying social dimensions that characterize student models and help students design successful learning environments.

CONCEPTUAL FRAMEWORK

The research on mental models and ID models forms the foundation for our research.

Mental Models

What are mental models? For more than three decades, mental models research has sought to illuminate the ways humans understand the world (Gentner & Stevens, 1983; Mayer, 1989; Oliver & Hannafin, 2001). At the root of this research is the desire to find out how individuals think the world works. Carley and Palmquist (1992) defined *mental models* as internal representations that are best characterized as a personalized network or networks of concepts. The meanings for these concepts are imbedded in the relationships between concepts in the networks. Meanwhile, Rouse and Morris (1986) provide a functional definition. *Mental models* are the mechanisms by which humans describe the purpose and form of a system, explain its function and its current state, and predict what a system might do.

The structural nature of mental models, their components and relationships, can be represented by maps (Jonassen & Henning, 1999). These maps are multimodal and may include metaphoric images that help the individual to connect a complex phenomenon with a familiar system. Mental model maps are also multidimensional and contain structural, declarative, procedural, and executive knowledge. Mental models can also be represented as images or metaphors that enable the individual to connect the complex phenomenon with an image or system that is familiar.

Influencing and underlying the structural representation of mental models

is a social dimension consisting of an individual's cultural heritage, prior experiences, and ongoing social interactions with people, tools, and artifacts (Rogoff, 1990; Salomon, 1993). Mental models are based on an individual's interaction with a system, and his or her interpretation or construction of how that system operates. Factors such as belief systems, observability, and predictive power are central properties to the development and use of a model. Mental models represent an individual's understanding of a complex phenomenon at any given time and are essential tools in enabling that individual to adapt to the world.

To summarize, three general features are worth noting about mental models:

- First, a mental model is a human construct used to explain how humans make sense of the world. Models approximate reality, and they may help us to understand the intricacies of a complex system as the mind. In essence, humans are model builders.

- Second, mental models continually change, depending on our individual needs to cope, understand, and act. These context-specific constructions were described by Johnson-Laird (1983) as working models. To see how mental models are viewed by different fields one can consult several texts, including Johnson-Laird (1983), Gentner and Stevens (1983), and Rogers, Rutherford, and Bibby (1992).

- Third, mental models of concepts, rules, and human activity can be represented by networks, maps, even visual images.

How to teach with mental models. Mental models, because they are an individual's construction tied to personal experience and years of confirmation (Vosniadou, 1994), are resistant to change. Humans modify mental models as they encounter and confront complex and novel situations (Johnson-Laird, 1990). Conceptual change most likely occurs when the individual receives assistance and support in understanding the disconnect between long-held models and evolving representations (Brown, Collins, & Duguid, 1989; Vygotsky, 1978).

Johnson-Laird (1989) listed sources for students to construct mental models:

- From what they know about the world.

- From what they observe of the world.

- From outside explanations.

Seel (2003) linked each source with a teaching strategy. The first source, existing knowledge, suggests an inductive approach using self-organized discovery and exploratory learning. This would require high learner motivation

and metacognitive skills. The second source for students, observations, can be supported through inquiry, such as guided discovery.

The third source, explanations, is the most common teaching strategy and uses teaching behaviors or explanation. Conceptual models provide a typical strategy to help students learn a concept, task, or process. Conceptual models are frequently used in mathematics and science (see Hodgson, 1995; Mayer, 1989, respectively). Mayer, for example, reviewed 20 studies on how conceptual models helped students' understanding of scientific explanations. He defined a *conceptual model* as consisting of words and/or diagrams that depict system objects and actions, and the relationships between these. His review showed that models help lower-aptitude learners think systematically about scientific topics. Conceptual models provide strategies for model-based teaching. In turn these tools assist students to develop their own mental models of the conceptual model. Presenting the conceptual model at the beginning of instruction supports student construction of a mental model that helps them to learn. Given the nature of the task or process to be learned, these mental models can vary greatly. In terms of accountability for student learning, this third approach strongly connects conceptual foundations of content areas with what is to be learned.

Seel (2003) studied how a cognitive apprenticeship strategy incorporated into a multimedia environment helped students develop a mental model in order to acquire domain-specific knowledge (i.e., economics). His research using causal diagrams discovered that students exhibited varying degrees of similarity of their mental models to the conceptual models and demonstrated that students did not always adopt a presented conceptual model. Furthermore, students' mental models were dependent on the specific demands of the moment; in this case, mastering an academic task (see Doyle, 1983). Another conclusion from Seel was that "an effective design of successful learning environments presupposes the provision of cognitive tools which facilitate and support an individual model-building and revision for problem solving" (p. 78).

How to study mental models. Norman's (1983) extensive work on people's interaction with technology has revealed a number of important caveats about human representation of complex processes. In essence, human mental models tend to be incomplete, unstable, unscientific, parsimonious, and even superstitious. How then does one study mental models?

Rouse and Morris (1986) and Sasse (1992) summarized several approaches. Experimental methods provide evidence for the effect of independent variables on mental model characteristics (Kessel & Wickens, 1982). However, these studies can easily be confounded from the influence of other aspects of human information processing on mental models, such as perception and

response execution. A second approach is empirical modeling in which human observations and subsequent actions can be mathematically recorded, and regression can be used to identify the input-output relationships. From these equations inferences can be made as to the mental models used by the subjects (Jagancinski & Miller, (1978).

A third approach is analytical modeling, in which human performance is compared to performance data. The goal is to minimize the differences between what humans do and what they should do based on an agreed-upon mental model. This approach assumes that the mental model used for training is indeed the actual mental model being used by the worker. Manual-supervisory control systems are frequently based on this approach.

A fourth approach to studying mental models is the use of verbal and written reports. The use of "think-alouds" records what people say about what they do as they perform the task (Ericsson & Simon, 1993; Gentner & Stevens, 1983). The basis for Strauss and Shilony's (1994) study of teachers' models of children's minds was based on how teachers speak about instruction. Limitations include user descriptions that will be incomplete (Norman, 1983) and may be distorted and biased based partly on the person's inability to verbalize how he or she is thinking as well as responding to the needs of the researcher or instructor. This approach, according to Rouse and Morris (1986), may be useful in generating research questions for subsequent study. Interviews and surveys are often used after the task has been completed to study individual judgments and decisions (Gould & White, 1974). Online protocols can be used to record what users do, but do not capture why they are doing it.

In summary, the choice of the task or process to be modeled may dictate the choice of inquiry approach. Each of the above options carries disadvantages. Although using multiple methods might address these weaknesses, the overall limiting issue is the difficulty in grasping the critical features of an individual model. However, this range of mental models can be pedagogically useful in helping both instructors and students understand a complex concept, task, or process.

ID Models

What are ID models? Conceptual models have been created for teachers, professional developers, and the military—all with the goal of making instructional development efficient and predictable in terms of success of the final product—learning (Anderson & Goodson, 1980; Edmonds, Branch, & Mukherjee, 1994). But some models are advertised as applicable to a range of contexts, students, and content (e. g., Gagné, Wager, Golas, & Keller, 2005). These models often have components that reflect contextual requirements (Tessmer, 1990).

Gustafson and Branch (1997) have observed that "the number of models published far exceeds the number of unique environments" (p. 78). They developed a taxonomy that attempted to classify the plethora of models into the conceptual focus or purpose of the instruction that needs to be developed. Is the ID model being used to design classroom instruction, a particular product, or a long-term organizational and systemic approach to training or instruction?

ID models have been depicted in a range of visual representations. Perhaps the most frequently seen is a linear row of boxes that depicts ID as a step-by-step, invariant procedure, a strategy used to teach ID novices (Dick, Carey, & Carey, 2005). Other models represent the ID process with circles, curved intersecting lines—or no lines at all—trying to illustrate a more dynamic, interactive approach to the design of instruction (Morrison, Ross, & Kemp, 2004), but the question for students in these dynamic models remains Where do I start?

How to teach with ID models. ID is a field of study in which experts create models for understanding the ID process, and then use those models as tools to guide instruction in ID or the use of the actual ID process itself. The ID process is often represented by distinct components, typified by the so-called ADDIE model (analysis, design, development, implementation, and evaluation; Gustafson & Branch, 1997). Although different ID models may be presented, one version is typically used to introduce students to the different phases of ID and provides the conceptual model for instruction. The purpose of the conceptual model, whatever its choice, is to help students learn the value of a systematic process for developing instruction. One of the values of the systematic approach is identifying what is to be learned, exploring teaching options, assessing learning, and evaluating the overall instruction and student learning. The value of ID is to keep important issues of learning at the forefront of the development effort.

How to study student ID models. Embracing the idea that humans form mental models as a means to make sense of their world, what would student models of ID look like? How would students represent an approach for developing instruction? Analysis of student ID models not only affords instructors a concrete understanding of how students construe ID, but also provides them with the knowledge to create a more relevant and developmentally appropriate pedagogy. The purpose of this article is to document an exploratory study of a methodology analyzing how mental models represent student thinking about ID. The specific research questions are:

- What ADDIE components do students (teachers, nonteachers) include in their ID models?

- What is the structural nature (components, relationships between components) of students' ID models (teachers, nonteachers)?

METHODOLOGY

The researcher looking to analyze students' mental models faces the dilemma that "one or more persons [are] developing models of others' models of the external world" (Rouse & Morris, 1986, p 359). That portion of the external world at issue in this study is instructional development and the conceptual model we used to depict a systematic approach to instructional development. This reflexive problem requires acknowledging the bias inherent in externally developed conceptual models, frequently a pedagogical decision, as well as interpretive judgments of students' models. Although we had assessed students' ID models as a required task in the course, our intent with this research was to try out a means to categorize students' ID models, so as to understand how students viewed our conceptual model of ID.

Our research design employed content analysis (Spradley, 1980) to identify the components of the models (Question 1) and categorize the structural nature of student ID models (Question 2). In both questions we noted the different choices of components and structural categories, in terms of whether the students were teachers or nonteachers, because we had maintained records of students' teaching status.

Participants

Participants included 178 students who participated in a semester-long introductory master's course on ID. These students were enrolled in 1 of 12 deliveries of the course from 1994 to 2001. For all participants, this course experience was their first formal exposure to ID and ID models. The coauthors of this article were either solo instructors or coinstructors in the course. Table 1 records the semester, the instructor of record, the number of students with ID models available for analysis in each course delivery, and the numbers of students who were and were not teachers. Both authors cotaught the course across the first 6 deliveries. Subsequently, each instructor taught the course solo at different institutions. The solo teaching evolved somewhat for each instructor, but the student learning tasks and assessment were similar across all deliveries, a result of coteaching the course and communicating across the subsequent semesters.

Course Description and ID Model Task

The following description of the course and the ID model task remained constant across the course offerings. The conceptual model of ID used in the course consisted of the ADDIE components, introduced by two additional components, Learning Beliefs and Design Tools (see Figure 1), which set the

Table 1 ☐ Courses, instructors, ID models.

	Course	Instructor	Length	Models Available	Teachers	Non-Teachers
1.	Summer, 1994	A/B	5 week session, 9 hr/wk	15	9	6
2.	Fall, 1994	A/B	15 week semester, 3 hr/wk	19	12	7
3.	Fall, 1995	A/B	15 week semester, 3 hr/wk	12	5	7
4.	Fall, 1996	A/B	15 week semester, 3 hr/wk	20	10	10
5.	Fall, 1997	A/B	15 week semester, 3 hr/wk	6	6	0
6.	Spring, 1998	A/B	15 week semester, 3 hr/wk, off-campus	19	19	0
7.	Fall, 1998	B	15 week semester, 3 hr/wk	10	7	3
8.	Fall, 1999	A	15 week semester, 3 hr/wk, online	18	18	0
9.	Fall, 1999	B	15 week semester, 3 hr/wk	8	5	3
10.	Fall, 2000	B	15 week semester, 3 hr/wk	17	7	10
11.	Fall, 2001	B	15 week semester, 3 hr/wk	18	10	8
12.	Fall, 2001	A	15 week semester, 3 hr/wk	16	7	9
	Totals			178	115	63

A = first author; B = second author

context for teaching and learning ID (Shambaugh & Magliaro, 2001). Prior to the ADDIE instruction, students constructed a mission statement of their learning beliefs, which identified relevant learning principles. In addition, this ID component introduced students to several ID models, including Dick and Carey (1996), Gagné et al. (2005), the United States Air Force models (1975, 1999), Morrison et al. (2004), Gerlach and Ely (1980), layers of necessity (Wedman & Tessmer, 1990), and rapid prototyping (Tripp & Bichelmeyer, 1990). Students were then asked to define ID and construct their own preliminary ID model, borrowing from existing models as well as their own constructions. This required design activity (5% of the grade) served to help the students support their own understanding at that time, as well as examine how their colleagues in the class made sense of this complex process. Students were prompted to visualize their model of ID, including the components they believed necessary. Students were also prompted to write a narrative explaining the ID model components and the relationships between components.

Students were introduced to other ID components, including needs assessment, instructional sequence, assessment, instructional framework, prototype,

Figure 1 ☐ Conceptual model used in Instructional Design (ID) course.
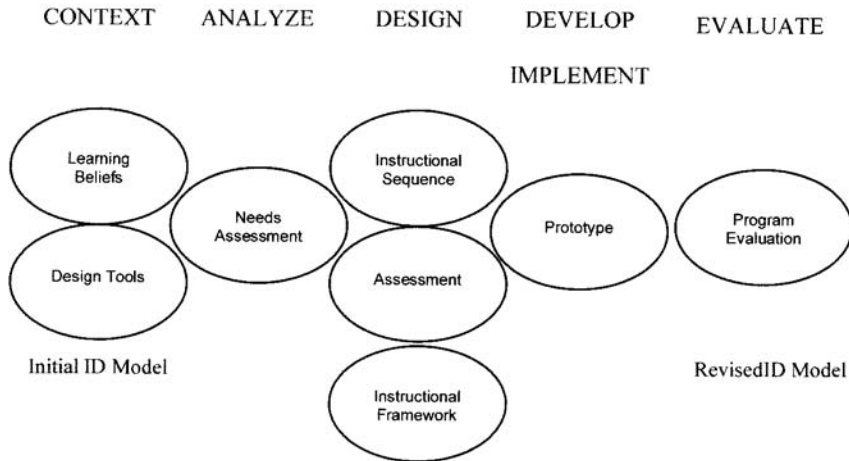
and program evaluation. Issues of instructional media and technology were addressed in each of these components. Throughout the course, students were asked to reflect on the various components of traditional ID models (e.g., Dick & Carey, 1996; Gagné, Briggs, & Wager, 1992), and how those models and their components fit the students' developing understanding of ID. The major task in the course required students to develop an ID project addressing an instructional problem of their choice. At the end of the course, students revisited their preliminary ID representation and either revised the model or constructed a new one based on their existing ID knowledge (worth another 5% of the course grade). The revised model required a visual representation and a paper that explained their ID components, the relationships between those components, and how their model worked. The evaluative criteria focused on the inclusion of the visual and narrative components, as well as a clear explanation of the model.

Data Sources and Analysis

Revised versions of students' ID models comprised the data for this study. The 178 models were collected from 12 deliveries of the course from 1994 to 2001. The ID model data consisted of a visual representation and a narrative explaining the model.

To answer research Question 1 (ADDIE components), a content analysis of student ID models involved recording in a table the descriptive labels attached to the visual components. These components were assigned one of the ADDIE

labels. Components not matching any of the ADDIE labels, but equivalent to Learning Beliefs and Design Tools components, were assigned to an Other position in the table. In some instances, student components matched an ADDIE component, such as Analysis. Judgments were made if a label was congruent to the nature of the ADDIE component. For example, a needs assessment label was assigned to the Analysis component. Issues involving teaching strategies, assessment, and sequencing were assigned to the Design category. Issues of instructional media and technology were assigned to the Development category if the visual component or explanation noted a media or technology development activity. Contextual issues were assigned to the Analysis category, as these issues were discussed in the Needs Assessment portion of the course. The ADDIE label assignment was recorded in a table location depending on whether the student was, had been, or was not a teacher. Frequency counts were tabulated for individual table cells.

To address research Question 2, the structural natures of the models were categorized, taking into account the relationships between the components. The category system evolved from several studies. In our initial study we analyzed model metaphors using the categories of sequence, holistic, process, and balance; we analyzed how students viewed themselves in the educational process using the categories of disseminating knowledge, meeting learner needs, addressing external expectations, and reacting (Magliaro & Shambaugh, 1999). In a subsequent study we analyzed ID models of students who were or had been teachers for their views of ID using the categories of process, sequence, holistic, and balance of concerns (Shambaugh & Magliaro, 2000). Subsequent to these studies we reexamined the literature on mental models and modeling in cognitive psychology, discussed our different ideas for organizing the data, and reached consensus on a new coding scheme. Three categories of ID models were chosen: (a) conceptual-sequential, (b) conceptual-dynamic, and (c) metaphoric. Both sequential and dynamic models were seen as representing our conceptual model of ID, whereas metaphoric models represented a personal activity. Conceptual-sequential models were defined as having a linear, step-by-step process linked by arrows; conceptual-dynamic models as having interactive components; and metaphoric models as having an overriding object, situation, or activities that explained the ID process.

Because more interpretation was needed to assigning a model category than identifying ADDIE components, we reviewed all of the models independently. Both the visual and narrative components were integral in providing information for this analysis. We reached 97% interrater reliability on model-category identification (172 out of 178). The differences in coding were because some models could be characterized by more than one category based on our respective interpretations of the written narratives; basically, we differed on

the category we each thought deserved primacy. Only those models for which agreement was reached are included in the final structural analysis.

RESULTS

ADDIE Components

An analysis of the ADDIE components included in each of the students' ID models was conducted to determine a general sense of what they identified as the critical components of ID. Table 2 reports the frequency with which the ADDIE components of the ID process appeared in student models. The Design component (264 items) consisted of multiple phases of activity, as represented in our conceptual model. Within Design, we included instructional sequence, assessment, instructional framework, and instructional media-technology. We included breakouts of these Design components in Table 2. In terms of frequency, assessment was the highest represented Design activity, followed by instructional framework, instructional media-technology, and instructional sequence. The other ADDIE components, which were addressed in the course, were typically identified by a single item, meaning that each model included one instance of that component. For example, 105 of the 172 models included instances of Analysis, 12 identified Development, 21 identified Implementation, and 120 identified Evaluation (i.e., Program Evaluation). The Other category accounted for 49 instances (Learning Beliefs = 31 instances, Design Tools = 18).

Structural Categories

Of those ID models with coding agreement (172/178), the frequencies within each category are: sequential ($n = 35$), dynamic ($n = 61$), metaphoric ($n = 76$). Table 3 records frequency counts across the 12 courses, and Table 4 summarizes the frequency of student models for teachers and nonteachers.

Conceptual-sequential models. The 35 ID models (19.7%) grouped in this category were nearly equal across teachers (16) and nonteachers (20). These models included conceptual model categories that were linked by arrows and/or lines in an ordered sequence. Similar to Gustafson and Branch's (1997) characterization of a "rectilinear row of boxes," these models depicted a clear order of operations. Some of the models classified in this group featured branching and/or operations that were to be considered simultaneously (c.f., Dick, Carey, & Carey, 2005) (see Figure 2). Another feature of models included in this category was an inherent hierarchy of activity. That is, the student organized the

Table 2A ☐ ADDIE* model components.

Component	C1-15	C2-19	C3-12	C4-20	C5-6	C6-19
Analysis	11	10	4	14	4	3
Design	31	22	13	37	13	28
Assessment	11	8	4	14	5	14
Instructional Framework	8	6	5	10	4	6
Instructional Media-Technology	5	6	3	5	3	4
Sequence	7	2	1	8	1	4
Development	2	3		2	1	12
Implementation	6	2		3	1	21
Evaluation	12	12	4	13	4	12
Other	3	4	6	11	1	1
Beliefs/theory	3	2	2	8	1	1
Design Tools		2	4	3		

Table continues, p. 93, as Table 2B.

* Analysis, Design, Development, Implementation, Evaluation

Table 3A ☐ Structural categories.

Component	C1-15	C2-19	C3-12	C4-20	C5-6	C6-19
Year	S94	F94	F95	F96	F97	S98
Instructor A/B	A/B	A/B	A/B	A/B	A/B	A/B
Teachers	9	12	5	10	6	19
Nonteachers	6	7	7	10	0	0
Category						
Sequential	3	3	3	2	0	0
Dynamic	6	6	6	8	4	2
Metaphorical	5	10	3	10	2	17
Nonagreement	1	0	0	0	0	0

Table continues, p. 93, as Table 3B.

steps visually so the intent was clear that certain steps were more important and, consequently, required more attention, time, and effort than others.

The words students used in the explanatory paper helped us to classify models into this category. Words such as *systematic, orderly, input, output,* and *linear* were characteristic of the descriptors used in the narratives of these mod-

Table 2B ☐ ADDIE* model components, *continued.*

Component	C7-10	C8-18	C9-8	C10-17	C11-18	C12-16	N=178
Analysis	6	14	4	9	13	13	105
Design	13	23	8	20	29	27	264
Assessment	5	10	3	6	9	7	106
Instructional Framework	5	6	3	6	10	9	78
Instructional Media-Technology	3	5	2	6	5	8	55
Sequence		2		2	5	3	35
Development	1		1		2	12	
Implementation		6		1	1	1	21
Evaluation	5	15	4	11	15	13	120
Other	5	5	3	3	2	5	49
Beliefs/theory	1	3	3	1	2	4	31
Design Tools	4	2		2	0	1	18

* Analysis, Design, Development, Implementation, Evaluation

Table 3B ☐ Structural categories, *continued.*

Component	C7-10	C8-18	C9-8	C10-17	C11-18	C12-16	N=178
Year	S98	F98	F99	F99	F00	F01	
Instructor B	A	B	B	B	A		
Teachers	7	18	5	7	10	7	115
Nonteachers	3	0	3	10	8	9	63
Category							
Sequential	3	2	1	4	7	7	35
Dynamic	4	3	3	8	5	6	61
Metaphorical	3	12	3	2	6	3	76
Nonagreement	0	1	1	3			6

els. Reinforced with the graphic representation, the narratives for these models indicated that the ID process had a clear beginning and a clear ending point. Although the students indicated that each stage of the process influenced and informed the next stage, the individual components were, for the most part, stand-alone units of activity.

Conceptual-dynamic models. The 61 models (35.5%) in this category included

Figure 2　☐　Conceptual-sequential model: simultaneous operations.
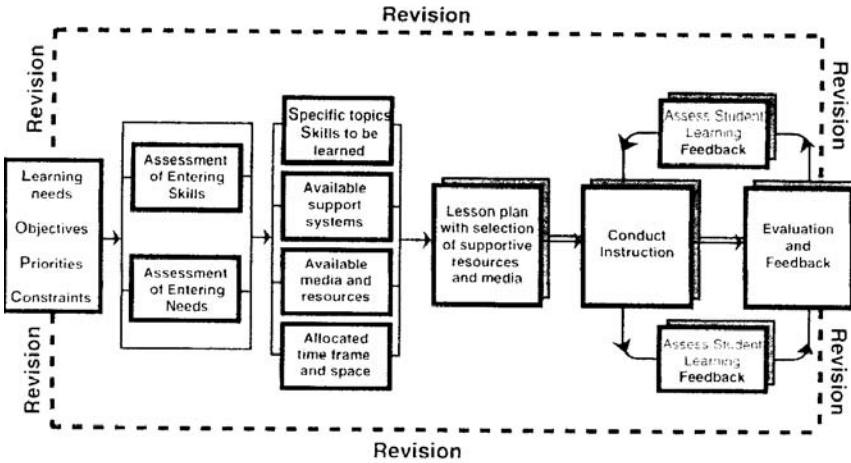
38 for teachers and 22 for nonteachers. Models in this category depicted the ID process with the various components organized into some abstract shape or set of shapes that was clearly interactive, with the ID process itself seen as a recursive intellectual activity (see Figure 3). Similar to the Kemp, Morrison, and Ross (1996) model, many of these models fit Gustafson and Branch's (1997) notion of a curvilinear composition that characterizes the way that ID is typically practiced. The students still tended to use arrows to depict the relationships between the model components, but often those arrows were bidirectional. Solid lines and dotted lines indicated primary and secondary connections and priorities between components. Moreover, the student depictions of these models tended to have components visually overlapping to illustrate the intimate connections between the design considerations.

The words used to describe the conceptual-dynamic models were key indicators for analysis. Typical words used included cycle, interaction, flexibility, creative, loop back, and recursive. The students spoke of "revisiting" many of the components at various points in the process to make necessary revisions based on new data or decisions. Overall, these students depicted the process holistically and fluidly,

Table 4　☐　Structural categories summary.

Category	Teachers	Non-teachers
Conceptual-Sequential	16	20
Conceptual-Dynamic	38	22
Metaphoric	58	18
Total	112	60

Figure 3 ☐ Conceptual-dynamic model: interactive.
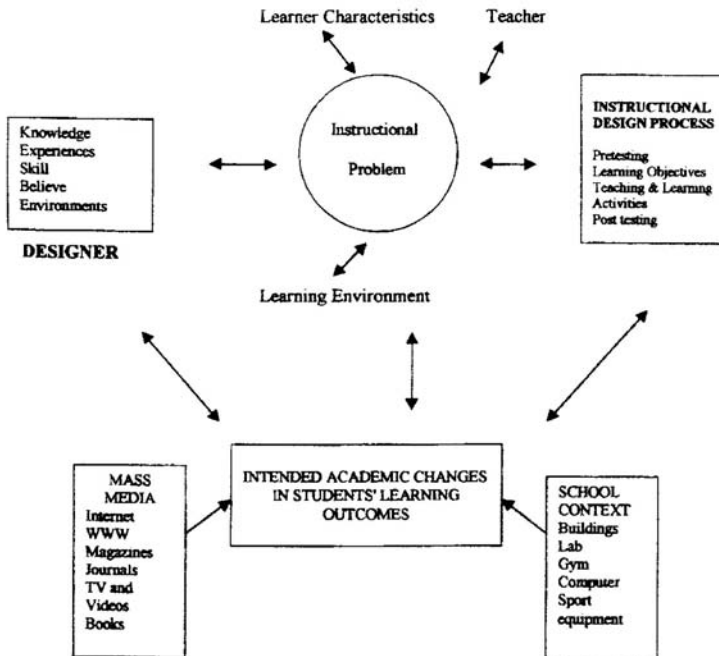
with no particular component taking precedence at all times. That is, these students, for the most part, considered the relative importance of each component to change based on the specific instruction to be designed.

Metaphoric models. The 76 metaphoric ID models (44.2%) included 58 from teachers and 18 from nonteachers. Students represented metaphors that were familiar to them. The metaphors provided concrete objects, situations, or activities with which the students could explain the ID process. The metaphors would characterize the ID process as essentially sequential or dynamic based on the nature of the metaphor. The majority of the metaphoric models were, however, dynamic. To illustrate concrete object examples, one student used a baseball diamond to arrange the various components in the order that a batter would run the bases after hitting the ball. Another student used a hamburger to illustrate that although you have separate components, the flavors from the various foods that you put on the hamburger blend together with each bite.

Metaphoric models more frequently appeared as situations or activities to illustrate the procedural nature of ID. One student likened the ID process to that of taking a sailing expedition (see Figure 4). The process was depicted as one in which there is constant checking of the wind, the water, and the

weather, as well as a constant balancing of weight dispersed around the boat. The weight is based on the cargo including the people (e.g., administrators, faculty, students) and resources. Another student used juggling as a metaphor, in which the designer in the juggler and the various ID considerations are the objects to be juggled. The student positioned the juggler on a balancing board while trying to keep all of the components in the air. The balancing board shifts based on the ball or student; here, the student was trying to communicate the importance of being responsive to student needs when designing instruction.

Figure 4 □   Metaphoric model: activity.

The words used to describe the metaphors were unique to each metaphor. Of particular note here is the extent to which the students explored all of the nuances of the metaphor and how its various features fit their understanding of ID. The narratives varied in elaboration from a very superficial set of connections between the metaphor and the ID process to very detailed explanations. Although no systematic analysis of why these descriptions varied was conducted, anecdotal evidence indicated variations were due to the degree to which the individual truly engaged in the task in a creative and playful manner, and the degree to which the individual was familiar with the metaphor (e.g., an experienced chef using a cooking metaphor).

DISCUSSION

ADDIE Components

Design was the most frequently included ADDIE component identified in students' ID models, but this was not surprising considering that the Design component comprises multiple activities represented by our conceptual

model. Program Evaluation (120 instances) and Analysis (105 instances) did not balance in terms of frequency over the 12 courses, although these two ADDIE components are addressed in the course as complementary activities. A needs assessment is considered to be absolutely essential in providing a database upon which to make design decisions (Burton & Merrill, 1991). And, given the fact that almost a quarter of the course time and focus was on how to actually conduct a needs assessment, we, as the course instructors, found this to be surprising. One explanation may be due to the serial position effect (Glanzer & Cunitz, 1966); program evaluation was the last major topic in the ID course, whereas needs assessment was studied earlier in the course sequence.

The Development component received the fewest instances (12) in students' ID models. This was probably because we did not have a distinct sequence of instruction for development issues, although this topic was addressed in instructional media-technology decisions. The Implementation component (21 instances) was labeled as Prototype in our conceptual model, and students experienced this ID component by developing the details of one instructional piece (e.g., class, lesson, tutorial) of their ID project.

Structural Categories

The highest ranking category of models was metaphoric (76 models, 44.2%). One limitation of this study is that the nature of the models may be attributed to existing exemplars in the ID literature that were discussed in class, as well as a class discussion on the use of metaphors as tools to represent knowledge (e.g., John-Steiner, 1997). However, the apparent preference for using metaphors may be because the participants were newcomers to ID. Using a concrete representation for a complex intellectual process may have been the most accessible thinking tool available to these students (Jonassen & Henning, 1999). Teachers (58 models), in particular, adopted the use of metaphors to represent ID, as compared to nonteachers (18). Metaphors helped teachers to embody the human activity they viewed as ID (Salomon, 1993).

Of particular interest, both theoretically and pedagogically, is the number of models that were dynamic (61 models), requiring complex manipulation of activity and parallel processing of design considerations. Only 35 models represent clearly defined, sequential processing—a predictable strategy for a satisfactory solution (Newell & Simon, 1972). The concern arises that, although the students are superficially representing the process as dynamic process, they may not really understand the complexities of the dynamic, and they might not end up with a satisfactory solution if they followed their own model. The personal ID models were generated at the end of the course, after the students had constructed a project with the guidance of the instructors. So,

the students never really had to use their own model in a design project, but merely had to review what they initially designed. We had determined that using their initial ID model was too difficult in their first ID course. As Oliver and Hannafin (2001) recently found, although novices could model at the macrolevel, their microlevel representations were partial and incomplete. Another explanation is that, although these individuals were novices in terms of the formal study of ID, many of them did have informal design experiences or had taught in either K–12, college, or corporate settings.

Given these concerns and cautions, it appears that the students clearly represent what they understand about the ID process in very different ways. Although some models were similar, no two models were exactly alike. For example, some students submitted models that looked similar to either the Dick and Carey (1996) model or the United States Air Force model (1975). A number of models were variations on the Kemp et al. (1996) model. In terms of metaphors, there were horticultural-growing themes: 5 trees, 4 flowers, and a couple of gardens. There were travel themes: highways, solar systems, journeys, train rides, space shuttle missions, and a pizza delivery. There were human development themes: pregnancies, and child growth into adulthood. Across all models that were similar, there were clear differences in the order of processes, the directional flow of arrows, and the context-related components unique to individual situations.

One particular note was the clear difficulty that at least two students had with creating a graphic representation. Both of these students were teachers of English and language arts, and their preference was to write the narrative only. Although one finally acquiesced, and used a play to depict the process, the other submitted only the narrative portion of the assignment.

In addition to the basic structural nature of models, other dimensions of difference related to the learning environment were revealed. These differences were not mutually exclusive or simplistic; variations in models were influenced by an interaction of factors (c.f., Norman, 1983). For example, some models, especially those constructed by teachers, revealed tensions among components, common in naturally occurring environments (e.g., state and local education agencies, available resources and instructor competence, availability of technology and complexity of curriculum). This particular observation directs us in future research to compare the nature of personal models to the specific context in which the novices applied ID, another limitation of the study. As noted earlier, although the participants in this study may have been newcomers to the formal study of ID, they may also have had experiences and knowledge that could be transferred to the ID field. A systematic analysis of contextual differences could be beneficial in future analysis of these models.

Finally, model components also differed in terms of the primacy of the

goals of the learners, instructors, and/or institution. That is, some models clearly represented the design of the instruction on the needs of the learner, while others fronted the needs of the administration, faculty, and staff. Other dimensions of difference included the amount of risk versus certainty built into the process, the influence of designer-instructor beliefs, and the inclusion of such features as caring, coparticipation of teacher-students, and creativity. These differences again may be attributed to the students' familiarity and experiences with their settings and, more specifically, how students developed models in response to our request. Students' models "are not fixed structures of the mind, but are rather constructed when needed to master a learning situation with its specific demands" (Seel, 2003, p. 77).

CONCLUSIONS AND IMPLICATIONS

The limitations to this study included the nature of teaching over time: namely, the iterative revision of design decisions over time based on continual evaluation and improvement. Thus, what is being studied is constantly changing; however, the course framework and ID model task remained constant over the analysis period. In addition, the ID field has evolved over time, and new versions of ID models have been revised, or new ones published. The student characteristics and numbers vary across the course deliveries. Identifying the student models as originating with either teachers or nonteachers was based on the availability of this information for each course. The analysis procedures were subjective in terms of model categories, although these were developed across several years of study. Our interpretations of the meaning of the relationships between components were individual. This limitation was addressed by using dual coding of the models and looking for disagreement, as well as reading student narratives to gain insight into the model. These student explanations enhanced our interpretations of the model relationships and what the students intended for the models.

Three interrelated conclusions and related implications can be drawn at this point in our research on students' ID models.

● First, as asserted by the original work on mental models (e.g., Gentner & Stevens, 1983), it is critical to understand how learners represent complex processes and their understanding of the target system (Norman, 1983), based on an instructor's conceptual model or what Merrill (2002) referred to as a metamental model. Our findings confirm Seel's (2003) findings that learners do not always use the models given to them, but construct mental models that meet specific needs. Conceptual models are themselves interactive based on more complex conceptual systems (Lesh & Doerr, 2000). Consequently,

according to Seel, "models cannot simply be handed to students in a meaning-ful form. This is the basis for the claim that models must be constructed" (p. 81). By asking our students how they understood the ID process, we have not only a better understanding of the complexity of learning ID, but also informa-tion to use in course improvement. For example, we may compare how pub-lished ID models represent relationships of components (i.e., what do the arrows mean?) with how students identify relationships of these components and others that they deem important. Another option is to have students reflect on their initial ID models as they learn about each ID component in the course and to revise their models. A third option would have students actually use their initial models in the inductive learning and understanding of ID components. Thus, students' ID models provide a heuristic for ID learning, and that ID pedagogy might benefit from the "role that emergent models play in individual students' learning and in the collective . . . development of the classroom community" (Seel, 2003, p. 81).

● Second, the student models call into question the value of conceptual models in teaching complex processes in which one process cannot address differences in users and contextual issues. Earlier research on mental models alluded to this dilemma; it appears that designers need to think about the use of conceptual models. One idea is that ID models represent a blend of two dif-ferent types of mental models as delineated by Markman (1999). (a) Mental models for reasoning identify specific components for the purpose of solving a problem. In contrast, (b) mental models of physical systems use components to represent objects, quantities, and processes. In our ID course students are constructing mental models partly of the instructor's conceptual model, but also of their decisions on what comprises this conceptual model. If the task were revised so that students were required to design using their model, then they would attend to constructing a mental model for reasoning, specifically, addressing an instructional problem. Pedagogically, implementing this third option would require careful assessment of what students submitted across the ID process in terms of their initial ID model. Currently, we ask students to reflect at each stage of the ID process as to the veracity of their preliminary ver-sion. The principal assessment tools we use across their ID project develop-ment are how their mission statement shows up in their design decisions and how these design decisions support their project goals, which were developed from a needs assessment.

Markman (1999) cited Keane, Byrne and Gentner (1997) on the implications of these two types of mental models for working and long-term memory. Men-tal models of physical systems are knowledge intensive, and users must have extensive domain knowledge to develop a workable system in that domain. Students in the ID course do not have the knowledge and experience to do this,

despite possibly having a rich repertoire of educational experiences. Mental models for reasoning are context specific and draw on many instances of long-term memory to solve a novel problem. Here, too, students may be experiencing difficulties in trying to bring this knowledge to bear while, at the same time, learning a new conceptual approach to problem solving.

If students are to make use of the decades of research on ID, instructors may need to rethink how they use the hundreds of published models in their ID coursework in terms of the challenges faced by students with both types of mental models. They might keep in mind how they could assist students to evolve from developing a model *of* ID to a model *for* ID (Seel, 2003). Specifically, the Design component of the ADDIE model represents substantial ID activity and decision making; thus, deconstructing this component of the ADDIE model appears warranted.

● Third, the value of concrete representations such as metaphors cannot be underestimated. Conceptual models are often abstract graphics, with each component conveying a series of complex, sophisticated processes and products. For example, in the Dick et al. (2005) model, a simple box represents all that an expert considers related to instructional strategies. Details, such as task design, classroom management issues, participation structures, and so forth, are masked by the superficial consideration of what the teacher might be doing in the instructional delivery phase. Moreover, simple symbols such as arrows are used to denote decision processes that are extremely complex. Yet, to a newcomer to ID, the arrow is interpreted as information input without appreciation of the cognitive activity underlying the input process. Student models frequently tap metaphors as starting points in student understanding of the ID process. By using metaphors that are meaningful, the students are able to connect their new understandings with familiar concepts and processes—a key principle of learning (Ausubel, 1968). Adopting a pragmatic perspective that values engagement with the world, metaphors help instructors to see into the inner thought processes of new designers (Coyne, 1995). In this study, metaphors helped students to represent important educational issues and thus the task helped students think about these issues in new ways. For nearly half of the students who used metaphors, the ID models provided a glimpse of how these students viewed teaching (Magliaro & Shambaugh, 2003).

Future research on students' mental models for ID not only adds to the ID literature, but also to the general literature on mental models. Mayer (1989) synthesized a review of the research on models for understanding and offered guidelines for the development of models for improving student understanding of complex phenomenon. However, based on current ideas about learners and learning, it seems that the action for model construction should be in the

students' hands and minds, not the teachers' (e.g., Hannafin, Hannafin, Land, & Oliver, 1997). This pragmatic use of mental models by model builders, we believe, will add to the understanding of mental models as a construct. Our interest remains in using these representations to help students understand and use the ID process, the conceptual target system for mental models mentioned by Norman (1983) in the quote at the beginning of this article. The present study illustrates the promise of having students show what they know. Future research with improved methodology and a more systematic analysis of learner experiences and contextual issues will continue to build understandings that will help theorists and practitioners alike.   □

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