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ABSTRACT

The purpose of this paper is to review literature on analogical reasoning, to work out the implications of Polya's model of analogical problem solving, and to propose an alternative model of instructional design based on the use of analogical reasoning. Justification of the model is based on research on the nature of analogical thought and an examination of analogous design models from other fields. In particular, Thorndike's and Gagne's theories of transfer of cognitive skill are discussed, as well as levels of knowledge, cognitive processes, and memory. It is concluded that because there exists a class of instructional design problems that may be amenable to analogical problem solving, a model of such a design can be constructed. (9 references) (DB)

Instructional Systems Design by Analogy

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In his book, **Designing Instructional Systems**, Romiszowski cites Polya's approach to problem solving as a model for instructional design. According to Polya, there are four steps in problem solving: (1) understanding the problem, (2) devising a plan, (3) carrying out the plan, and (4) examining the solution. Under the second step, Polya specifically advises that the problem-solver search for related, or analogous, problems which have been solved before. Although Romiszowski mentions this as a possible instructional design methodology, he does not work it out in any detail. Romiszowski's model, like all standard ISD models, seems to assume that instructional designers start from scratch for each project. Existing solutions, to the extent that they are considered, are limited to alternative, non-training, solutions to performance problems.

The purpose of this paper is first to review literature on analogical reasoning, second to work out the implications of the Polya model of analogical problem solving, and then to propose an alternative model of instructional design based on the use of analogical reasoning. Justification of the model will be based upon research on the nature of analogical thought and an examination of analogous design models from other fields.

What is analogical problem solving? This question has two parts: What is analogical thinking and what is problem solving? The question of analogical thinking will be discussed first. The question of the nature of problem solving will be dealt with later.

What is analogical thinking? In some sense it is the transfer of cognitive skill from one domain to another. Singley and Anderson (1989) review the literature on transfer and offer a new theory of transfer based Anderson's ACT* theory of cognition. They point out that constructing a theory of transfer has been problematic since Thorndike put forth his theory of identical elements. Thorndike sought to disprove the general transfer theory of the formal disciplines. Thorndike's theory foundered on the problems of defining exactly what an *identical element* might be. Since any two situations may differ in arbitrarily many ways there was no way of determining what identical means.

Another issue of transfer theory is the distinction between lateral and vertical transfer. Lateral transfer was defined as the the kind of transfer which encompasses a set of situations at approximately the same level of complexity. Vertical transfer involves transfer between lower-level and higher-level skills. Vertical transfer is the basis of Gagné's learning hierarchies. As Singley and Anderson point out, "...Gagné's notion...while quite intuitive and almost certainly true at some level, has been lacking in empirical support" (p. 19). This is due to the lack of an objective method of task analysis and is related to Thorndike's problem of determining what an element is.

Singley and Anderson's answer to this problem is to apply ACT* to the problem of transfer. ACT* makes several clear assertions about cognition. The first is that there are two kinds of long-term memory: *declarative* and *procedural*. Declarative memory consists of strings, images and propositions. Procedural memory consists of productions. They claim that knowledge passes through declarative memory before it becomes procedural. The transition from declarative to procedural memory is called *knowledge compilation*. This process consists of two mechanisms: *composition* and *proceduralization*. To these two mechanisms they have added *structural analogy* as a third mechanism. Under this theory, single productions become the elements of cognitive skill—the elements Thorndike and Gagné needed to construct a coherent theory. Singley and Anderson have constructed a taxonomy of transfer types based on their theory. (see Figure 1)

		Target knowledge procedural	declarative
Source knowledge	procedural	trained skill to transfer task	reading skill in learning
	declarative	application of old situation to solution of new problem	verbal learning and interference

Figure 1. Taxonomy of Transfer Types

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This 2 X 2 taxonomy generates four types of transfer: Procedural-to-Procedural, Procedural-to-Declarative , Declarative-to-Procedural, and Declarative-to-Declarative. It is Declarative-to-Procedural which is of most concern to us. Singley and Anderson assert that although this type of transfer allows flexibility and adaptation it is error-prone and often not spontaneous. They believe that weak methods (i.e., methods that do not take advantage of domain characteristics) such as analogy and means-ends analysis can combine for declarative-to-procedural transfer.

The issue of the nature of analogy is by no means exhausted by the above account as can be evidenced by Vosniadou and Ortony's recent (1989) book on the subject. According to this account, analogy is, at the very least, seeing similarities between things. There are kinds of similarity. One approach is to make a distinction between surface and deep similarity. Another approach is to distinguish global or holistic similarity from dimensional similarity. Yet another distinction could between object attributes and relations.

Vosniadou and Ortony also discuss analogical reasoning. Such reasoning involves the transfer of relational information from a domain that already exists in memory (called the base domain) to the domain to be explained (the target domain). This involves three process: Gaining access to an appropriate analog, mapping some part of the information associated with that analog onto the target domain, and last, dealing with the side effects in terms of the production of more general rules and representations.

Vosniadou and Ortony assert that there are two types of analogies: between-domain (metaphorical) and within domain (literal). Access in the case of literal analogies is straightforward they claim and it is primarily this type of analogy we are concerned with in this paper.

Problem-Solving and Polya's Method

Problems may classified in terms of their ends and means. Well-defined problems are problems that have well-defined ends and means. To the extent that ends and means cannot be well-defined problems become more complex. Although problems may differ in their complexity, from relatively well-formed to extremely ill-formed, Polya's method is fundamentally math-based and intended to be applied to a well-defined domain. Math consists of defined terms and a finite set of legal operators. Math problems are typically well-defined. Thus for Polya's method to be applicable to other domains it requires a well-defined problem space. In instructional design terms this translates into a situation which is well-understood. The various factors which impinge on an instructional situation must be familiar and replicable. Now it goes without saying that many, if not most, problems are not well-defined. Simon (1981) has pointed out that there is no clear line between well-defined problems and ill-defined problems. However, Rittel and Webber (1973) have gone one step further and asserted than many planning problem are worse than ill-defined, they are **wicked**. Wicked problems have ten characteristics, but the most salient are that they have no definitive formulation and they have no stopping rule. It seems apparent that many ISD problems are at least ill-defined, if not wicked, and therefore are not good candidates for design-by-analogy in Polya's sense. It is precisely because of this ill-definedness that heuristic methods such as the systems approach are used in ISD. To be applicable to ISD, Polya's method requires a well-defined problem space (in Simon's sense). Since many projects are complex, ill-structured, and have a hermeneutic dimension, we would expect that analogical design methods would be useful only for the subset of ISD project situations which have a simple, well-defined structure (see Figure 2). I believe there is a class of ISD problems which is at least well-defined enough that a Polya-type analogic approach would be more efficient than the standard means-ends heuristic.

Size / Complexity	Simple	Complex
Small	Analogy	Rapid Prototyping
Medium	Analogy/Closed Systems Approach	Rapid Prototyping/Open Systems Approach
Large	Closed Systems Approach	Open Systems Approach

Figure 2. Design Methodology by Project/Problem Characteristics

The terms in Figure 2 are undefined and I leave it to the reader to assign a meaning to simple, complex, large or small. Intuitively, it seems that only those problems classified as small and simple are likely candidates for analogical design. Larger, more complex problem situations may not themselves be amenable to analogical problem solving, but such problems may consist of components which are much more well-defined than the whole. Componential design-by-analogy, the borrowing of partial solutions to a larger problem, may be considered a kind of analogical problem solving. It is essentially a hybrid method, combining a macro systems approach with an analogical approach at the micro level (see Figure 2). The breaking down of problems into manageable parts, is essentially Descartes' second rule in his **Discourse on Method** (1637/1980). Interestingly, Descartes claims he derived his method by analogy from the methods of geometricians. The breaking down of problems into smaller, more manageable problems assumes, of course, that the components do not interact in any problematic way—a large assumption. Given that the assumption holds, a complex problem may be approached as a series of simple, manageable problems. What is a manageable problem? Essentially, it must be a problem that has been solved already or can be solved by analogy.

To give a fairly unambiguous example, if the problem is to teach Russian vocabulary, and we already have (or know of) a successful computer-based program in German vocabulary, then the application of the same or a similar computer program to the Russian vocabulary problem is a case of analogical problem solving or design-by-analogy. Needless to say, the analogy does not solve all our problems; indeed, it may not solve our problem at all, because the computer program may not accept the Cyrillic alphabet, but the strategy of design-by-analogy is still valid as a general heuristic. No heuristic guarantees a solution. Situations differ in many minor details; if they did not, no problem solving would be required. Minor details may always render a potential analogical solution impractical.

A Model of Design-byAnalogy

Given that there exists a class of instructional design problems which may be amenable to analogical problem solving, a model of such design can be constructed. A skeletal model of design-by-analogy is offered in Figure 3.

1.	**determine needs**
2.	**search for analogous situation**
2.1.	**establish search criteria**
2.2.	**determine likely target areas**
3.	**find existing instructional materials**
3.1.	**present selection rationale**
3.2.	**justify selection**
4.	**determine differences**
4.1.	**establish necessary modifications**
4.2.	**justify modifications**
5.	**make modifications**
6.	**test materials**
7.	**make modifications**
8.	**install**

Figure 3. A model of analogical ISD.

Design-by-analogy has not been much discussed in the ISD literature, but military applications of the fundamental principles of analogical design have been reported in Klein (1987) and Brackett (1979). Bruns and Potts (1987) described a design-by-analogy model for software design. Figure 3 is based upon an Air Force procedure called *comparability analysis* as reported in Klein (1987). Klein showed how engineers routinely use analogical reasoning to make specific deductions about emerging systems. Klein further argued that decision making is *typically* analogical because of both psychological and informational constraints in real world situations. Klein treats analogical reasoning as a fundamental form of reasoning and recommends it as a way of dealing with ill-defined problems also. I have advocated it as a means of dealing only with relatively well-defined problems, but the question of whether it can be applied to ill-defined problems is empirical and should not be ruled out *a priori*.

As Klein (1987) points out, the strength of analogical reasoning is that it allows rapid inferences and it can do so even when experts are unable to articulate all the factors leading to a conclusion. Given the inefficiency of traditional ISD methods any quick methodology is worth trying. The application of Polya's method to ISD is an example of analogical thinking itself. It asserts that some subset of ISD problems are well-defined enough that analogical solutions may be applied without the rigorous and time-consuming techniques of the systems approach. Needless to say, the application of analogical thinking to ISD problems requires a distinct set of skills and knowledge, not the least of which is the ability to recognize similarities where those similarities may be useful.

References

Brackett, J. W. (1979). TRAIDEX: A proposed system to minimize training duplication. In H. F. O'Neill, Jr. (Ed.), **Issues in instructional systems development** (pp. 101-131). New York: Academic Press.

Bruns, G., & Potts, C. (1987). **Requirements by analogy (STP-258-87).** Austin, TX: MCC Software Technology Program.

Descartes, R. (1980). **Discourse on method** (D. A. Cross Trans.). Indianapolis, IN: Hackett Publishing. (Original work published in 1637)

Klein, G. A. (1987). Applications of analogical reasoning. **Metaphor and Symbolic Activity, 2,** 201-218.

Rittel, H. W. J., & Webber, M. M. (1973). Dilemmas in a general theory of planning. **Policy Sciences, 4,** 155-169.

Romiszowski, A. J. (1981). **Designing instructional systems.** New York: Nichols Publishing.

Simon, H. A. (1984). The structure of ill-structured problems. In N. Cross (ed.) **Developments in design methodology.** New York: John Wiley & Sons.

Singley, M. K., & Anderson, J. R. (1989). **The transfer of cognitive skill.** Cambridge, MA: Harvard University.

Vosniadou, S. & Ortony, A. (1989). **Similarity and analogical reasoning.** Cambridge: Cambridge University.