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Analogical Reasoning in a Natural Working Group

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Abstract

This study analyzed how a working group used an analogy of "education as a pathway" as a tool for conceptual understanding and teamwork. The team's definition of the analogical structure remained consistent over the course of team work, but they applied the analogy to different targets. Ambiguities in the analogy contributed to its limited application as a tool in detailed analysis. Implications are noted with respect to how analogies are evaluated in team work, how the nature of a metaphor influences its applicability in analytical work, and how group process may affect analogy use in team work.

Introduction

This study explored how analogical reasoning was used by an interdisciplinary working group to understand a complex phenomenon and design an analysis. Analogical reasoning is the process through which learners use knowledge of one domain to address a similar problem in a new domain. The details of particular steps have been outlined in several different models (e.g., Gentner, 1983; Holyoak & Thagard, 1989), but the broad pattern of applying analogies involves the following steps: identifying an appropriate analogy, mapping components of the source domain to the target domain, and evaluating the mapping. Through this process, information about relationships in the source domain is applied to relationships in the target domain, allowing for new insight and understanding about the target.

Research has shown that analogies can enhance many areas of discourse and problem solving, including explanation (Gentner, 1983), theory formation (Nersessian, 1992), probability reasoning (Ross, 1984), argumentation (Schön, 1979), scientific insight (Langley & Jones, 1988), and problem solving in academic domains (Chi, et al., 1989). Studies in business and social science (e.g., Schön, 1979) indicate that the selection and use of an analogy can have a strong effect on people's understanding of a problem. Analogies affect cognitive processes by constraining the thinking that occurs. If an individual or group accepts the validity of an analogy, the objects and relationships in that analogy are active in participants' memories. For instance, viewing college education as a pathway might imply that the educational process has a starting point, an ending point, and a direction. People using the metaphor might not explicate these implications, yet the implications nevertheless might shape their views of college education. The analogy also may influence people's choice of problem solutions. From a problem solving perspective, the most helpful analogies highlight elements of the issue that are salient for solving the problem. Schön (1979) called metaphors that facilitate problem solution "*generative*" because they provide a new perspective or solution to a problem. The utility of an analogy may depend on the its structure, with highly systematic explanatory analogies (or scientific analogies) being useful in scientific model building and expressive analogies (metaphors) being more successful at prompting rich descriptions or idea generation (Gentner, 1982).

This study analyzed how one natural working group used an analogy between education and a pathway as a basis for building an analytical model. First, we identified how the team defined and applied this potentially ambiguous metaphor. Like many common analogies (e.g., an electricity/water analogy, Gentner & Gentner, 1983), both the target and source domains were familiar to participants. In addition, just as instructional analogies are provided to students by a teacher or textbook, the pathway analogy was supplied to the team by the team leader prior to the beginning of team work. As such, selection of the analogy (the first step in analogical reasoning) was not an issue for the team. However, unlike typical instructional analogies the pathway analogy's detailed structure was not explicitly presented to participants, so team members needed to generate and explain the structure on their own in order for it to be used in the team work. Our goal was to identify the characteristics of the analogy that facilitated or hindered the team's analogical reasoning.

Subject and Methods

Subject of Study

The subject of study was an interdisciplinary working group (Team A) within an institution that had an overall mission of developing strategies to improve education in science, math, engineering, and technology (SMET) at a national level. As part of its task, Team A intended to investigate questions about college SMET education by drawing an analogy between college education and a pathway. The goals for the pathway project included (1) characterizing and comparing student pathways in selected SMET and non-SMET majors, (2) identifying the impact that reformed courses had on students' paths, and (3) developing a model that could be used to analyze pathways in other situations.

At the time observation began, the team comprised 6 members (3 professors of various levels and disciplines, 2 graduate students, and 1 academic staff). By the end of the one-year observation period, one graduate student and the staff member had left the group, and a new graduate student had joined the team. Each team member missed at least one meeting.

Data Collection and Analysis

The data set analyzed here included videotape, audiotape, and observers' notes from 21 meetings and 16 interviews that spanned a one-year period. Observations began shortly after Team A began its work and ended with interviews conducted after the last meeting of the team. In the first phase of work (Meetings 1-10), Team A's primary pathway-related task was to begin an analysis of student course transcript data. These meetings included discussions of the team's approach to pathway analysis and reviews of initial data analyses. The end of this phase was signified by a lapse in team meetings and a shift of focus away from the course transcript analysis. During the second phase of research (Meetings 11-21) conversations focused on theoretical issues with little group discussion of the specific transcript analysis. The transcript analysis was eventually discontinued, and at the end of the period of observation the group stopped meeting as a team. Individual interviews were conducted periodically throughout this time period.

The qualitative analysis that follows is the product of an extensive inductive identification of ideas and patterns evident in conversational and interview data. First, relevant meeting segments (involving a reference to a pathway metaphor or related task) were targeted for detailed analysis as described in Chi (1997). An "open coding" (see Strauss & Corbin, 1990) was done on the reduced protocols to identify salient data categories. The resulting emergent coding categories included analogy components and characteristics, targets, evaluations, and applications.

Definitions of the Pathways Analogy

Our inductive analysis revealed that while the basic structure of the analogy did not shift significantly over the course of team meetings, the target of the analogy application changed.

Analogy Definition

Analogy source. Participants' explicit definitions of a pathway described a basic picture of a pathway as comprising movement between two points. For example, Protocol 1 presents excerpts of three participants' descriptions of pathways.

Protocol 1

- "the route that students take from starting college to when they get their major"
- "where they start and where they end"
- "a way to get from here to there, . . . the sequence of courses that are taken."

This generic view represented a path as a series of points along a single direction. In this definition, a pathway (the source domain) had three major components: starting/entry point, gateways or milestones, and end point. In addition, different types of pathways were characterized in different ways. For example, all paths were presumed to have a general direction, but the degree of flexibility or rigidity of the path varied, with "true paths" being rigid in nature while other types of paths were more flexible. Figure 1 illustrates conceptual representations of "true paths" versus other types of paths.

As shown in Figure 1, "true" paths require a sequential progression along a single route. This view of a pathway corresponded to the stereotypical view of some SMET disciplines (e.g., engineering) as strict, "unforgiving" pipelines. Other, more flexible, paths have multiple starting points, a chance for re-entry, and optional gateways that are not sequentially organized. Some majors (e.g., biology) might allow students to follow this type of less sequential path through school.

Analogy target domain. Conversations included references to two target domains: a target related to student course work, and a target related to non-course-related events. A

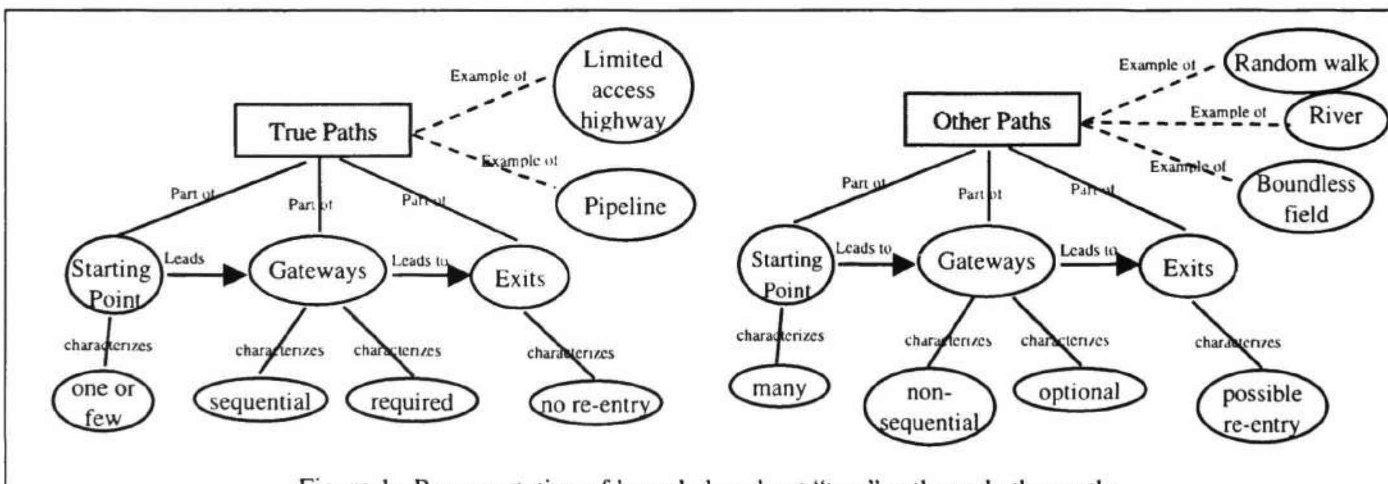

Figure 1: Representation of knowledge about "true" paths and other paths

mapping had a *course work target* if it connected pathway components (start, finish, milestones) to specific courses or educational milestones such as graduation. In this view a pathway was a progression from course to course, with courses and grades being the primary markers identifying parts of a path. In contrast, a mapping targeted a life path if it referred to non-course-related events such as entering school with a certain type of motivation, finding the correct advisors, or pursuing a career in a certain field.

In initial conversations (Meetings 1-11), all references to pathways implied course-related targets, and course-related references continued through Meeting 21. In Meetings 12, 15, and 16, team members extended the target of the pathway analogy to include "life paths." Although team members realized that the analogy could be applied to a life-related target, they recognized that they did not have access to data—such as social networks or student friendships—necessary to analyze a life path and thus did not see life targets as appropriate for their task.

This shift in target of the pathway analogy reflected an implicit evaluation of the metaphor. Participants were aware of the pathway analogy as a potential tool with limitations and benefits, and they viewed the original target as at least partially inadequate. It is interesting that they did not alter the structure of the metaphor (i.e., the components of a pathway) but merely shifted the target of analogical reasoning. This might indicate that they viewed the structure as correct but limited in its application.

Analogy target level of specificity. The target's level of specificity indicated whether the source domain was mapped to individual *pathways* (an individual student's experience) or to non-individual, *or* aggregate, *pathways*. A comment referred to an individual pathway *if it indicated that a pathway was unique to an individual or determined by an individual's choices.* An aggregate pathway was defined as a path-related reference that implied that the path was not based on experiences of a single individual. This included references to group pathways (common paths taken by a group of students) and *institutional pathways* (expected pathways defined by a major department or university).

Both levels of specificity were referred to throughout the team meetings and interviews. For example, in Meeting 1, 18 turns contained pathway references. Of these turns, 30% referred to individual paths and 11% implied aggregate pathways. Protocol 2 (from Meeting 1) illustrates references to aggregate and individual targets in the same conversation.

Protocol 2

DL: I wonder if we can characterize a hard science pathway versus a . . . biological science pathway.

//

DL: [The analyst] is looking at percentages. He's not tracking the person throughout.

HC: Right, it's not really path-oriented.

//

DL: If we could get him to . . . plot data sets per person, . . . we can see where the dropouts occur along the path.

DL's first statement implies the existence of group pathways ("hard science path" versus "biological science path") and thus uses an aggregate pathway target. The subsequent exchange, in contrast, explicitly indicates that a "path oriented" approach requires tracking individuals, thus specifying that the desired target is individual rather than aggregate.

While participants acknowledged in interviews that a "path" could refer to both individual and aggregate paths, this ambiguity was never explicitly addressed in team meetings. As will be discussed, this ambiguity was a source of communication difficulties.

Analogy Mappings

There was only one explicit mapping made between a component of a pathway and educational experience (i.e., a link between a particular course and the start of a path), but participants frequently linked characteristics of pathways and various educational experiences. For example, participants frequently described educational pathways as having different degrees of flexibility and rigidity, just as real paths differ in their ease of access.

This indicated that team members' analogical reasoning was based on specific paths rather than on representations of a generic pathway. As Figure 1 indicated, at a generic level all types of paths shared basic components (start, gateway, exit), while specific pathways had different characteristics (e.g., true paths were rigid and sequential while others were flexible). Most mappings, however, involved characteristics (which differed only for specific paths) rather than components (common to a generic pathway), indicating that specific paths (identified by specific characteristics) were the basis for analogical reasoning.

In addition, participants mentioned pathways when describing the goals of the group. For instance, Protocol 3 shows excerpts from two participants' interviews in which they comment on the team goals.

Protocol 3

DL: I think that [we are trying] to empirically show, . . . "Is it [science education] a true path?"

//

SY: We got a large data set of people in the different sciences and . . . [want to] see if we can plot out what their pathways look like. So that we can say that there are pathways, and these are variations across disciplines.

In both statements, the term *pathway* was used in referring to educational experiences, thus implying the validity of viewing education as a pathway. However, details of how education was a like a pathway were never discussed. This constituted a high-level mapping which linked the two domains but which did not provide any detailed description of how relationships within the domains were linked to each other.

Alternate Metaphors

In meetings and interviews participants used alternate metaphors—some closely resembling the pathway analogy—to clarify their view of how students traverse educational institutions. Examples of alternate metaphors included pipelines, rivers, expressways, footpaths, and trains. Some references constituted a simple mention of a metaphor, while others involved elaborate descriptions. For example, one participant described how school was like a turbulent channel of water constrained by steep embankments. Students caught in the stream were thrown about by institutional forces. In this view, educational reform represented a "softening of the banks" that would decrease the turbulence of the water and thus ease students' experiences. This illustrated how an alternative metaphor could vividly emphasize situational elements that were not highlighted with a simple pathway metaphor.

Although these alternate metaphors could be viewed as challenges to a pathway metaphor (i.e., that the pathway metaphor was inadequate in explaining a concept), team members indicated that they felt metaphors such as roads, rivers, and pipelines exemplified specific types of paths. This view is represented in Figure 1 through inclusion of alternative metaphors as examples of various paths.

Notwithstanding this definition of the term pathway as denoting a generic path, participants' use of the term pathway periodically was ambiguous. For example, one participant indicated that a "random walk" was not a "real path." Another indicated that a "true path" was similar to an inflexible pipeline. This dual connotation of the term pathway introduced ambiguity into the use of the metaphor. While the term was periodically used to imply a broad category encompassing several variants, it also occasionally had connotations of rigidity.

Uses of the Pathways Analogy

Two meetings (Meetings 1 and 16) stood out as examples of in-depth pathway-related discussions. These meetings included the highest percentage of turns containing explicit pathway-related propositions (with 7.7 and 9.5% of turns being path-related, compared to an average of 1.7%). In addition, both meetings contained pathway-related exchanges that were complex (e.g., multiple propositions about pathways raised in a single turn) and generative (e.g., participants building on each other's ideas). These two meetings illustrated the dual purpose of the pathway analogy in Team A's work.

In Meeting 1, the pathways metaphor was invoked as a planning tool, with the intent of designing the analysis to conform to designated characteristics of a pathway. In particular, participants indicated that they expected the analysis would be "path related" if it tracked individuals, as shown in Protocol 2. Subsequent meetings (at which data were reviewed but no planning took place) contained less frequent mentions of the analogy. When the metaphor was mentioned in these meetings, it was not discussed in-depth, and its characteristics or components were rarely invoked. This indicated that while the metaphor was useful in planning the analysis (and in providing a framework for designing the analysis), it was not invoked in detailed discussions of data. This reflected a limited application of the analogy in the analysis.

Meeting 16, in contrast, comprised a broad conceptual discussion in which the nature of the underlying metaphor was explored. In this meeting, the discussion focused on the nature of the metaphor itself, with little discussion of the transcript analysis. Meeting 16 illustrated how the analogy could prompt higher level conceptual discussions; this represented a use of the analogy as a framework for meaning-making rather than as a tool in detailed analysis.

Factors Influencing Analogy Use

While the pathway analogy was to be used as the basis for building a model of student educational experiences, specific analogical mappings were discussed infrequently. As a result, while high-level mappings between the approach to the work and the nature of a pathway (such as those found in discussions of planning activities) may have helped team members generate interesting ideas about education, they did not help participants in the detailed analysis of student transcript data. Based on the results discussed above, we believed that the lack of success of analogical reasoning was exacerbated by failure to build an explicit componential model of the base analogy and failure to clarify ambiguities in mappings between the base and target domains.

Lack of Discussion about Model Components

In order to determine how to identify student "paths" in transcripts, participants needed to determine what data corresponded to particular parts of a pathway. However, only one explicit mapping was identified in team meetings, indicating that the team as a whole did not discuss how mappings should be made. In addition, only in one meeting (at which no analysts were present) did a participant acknowledge the complexity of identifying how various courses corresponded to components of a pathway.

The lack of explication of specific mappings hindered team progress on the task by making it difficult for the analysts to know how to use the analogy as a basis for model building. Explicit discussions about possible components of pathways and mappings between the pathway model and student coursework likely would have facilitated the analysts' ability to proceed on the task.

It is possible that the lack of explicit discussion about the pathway model and its application resulted from participants' acceptance of the metaphor as a "common sense" idea that did not need further explanation. Because participants presumed a common understanding of the metaphor, further explication or discussion of the model components appeared unnecessary.

Ambiguous Mappings: Aggregate Goals Versus Individual Analyses

Application of the pathway analogy also was difficult because the research goals and the expected analytical approach comprised two different levels of analysis.

As mentioned above, the pathway analogy was mapped to targets at two levels of specificity: individual student pathways and aggregate pathways. The team's primary research questions involved analyzing aggregate pathways. For example, participants wanted to compare paths through various majors and to examine the impact that a major path's flexibility or rigidity had on retention of students from different backgrounds. As a result, the research questions mapped the base domain of a pathway onto an aggregate target comprising experiences of groups of students.

However, in planning the analysis most team members indicated that an "individually based" approach should be used. At early meetings group members criticized the initial analyst's reports for providing summary statistics (aggregates) instead of tracking individuals and thus not being "path oriented." These statements reflected mappings between a pathway and an individual-level target. Because these team members' expectations were based on a view of individual pathways, the initial analyst's work (which implied an aggregate target) did not meet their expectations. An in-depth analysis of this situation (see DuRussel & Derry, in preparation) indicated that the ambiguity contributed to a social conflict that hindered the team's effectiveness.

The issue of how to use individual transcripts to obtain conclusions about aggregate paths was never clarified by any group member. Similarly, while in final interviews participants recognized the existence of both individual- and aggregate-level targets, this issue was never discussed in team meetings. Possibly because of this lack of clarification, analysts expressed confusion about how to approach the detailed analysis. The individual/aggregate ambiguity in analogical mappings complicated the task and thus contributed to the lack of progress.

The fact that the individual/aggregate mismatch for the transcript analysis was problematic was underscored by the fact that a different task involving pathways did not seem to pose a problem for the team. As a related endeavor, one team member created flow charts of institutional pathways as defined in course catalogs. In this project, the research goal and the data were at a parallel aggregate level. Because the level of data (course catalog information) and the expected result (a map of the path reflected in the course catalog) were aligned, the application of the analogy was unambiguous and thus less complex. This, in combination with the fact that the data were clearer and more easily available, made this task easier than the transcript analysis task.

Participants' Evaluations of the Analogy

Team members' actions and comments indicated that they recognized the analogical mappings were not clearly defined. First, in meetings and interviews participants indicated that identifying how the "pathway" model should be applied was more complex than it initially seemed. Several participants (in particular the analysts) described the pathway idea as not very important or interesting.

In addition, participants' actions revealed their awareness of the limitations of the analogy in its current form. At Meeting 11 the team initiated a literature search of research that would take the pathway analogy "from metaphor to model" by identifying how the pathway analogy had been used in other lines of research. The literature review was not completed, so it is uncertain how such a product—one that provided more specific information about applying the analogy as an analytical tool—might have influenced a subsequent analysis.

Team members' negative reactions to the metaphor may have reflected the difficulty of using a simple abstract structure (such as a pathway) to analyze a complex data set. Although the metaphor provided a framework for participants to understand the general goal of their task, it was not specific enough to be an easily accessible analogical tool for a detailed analysis of student courses. There thus was a gap between the abstract metaphor and the specific analogy (including mappings) needed in the data analysis.

Alternatively, the lack of progress may have reflected a lack of metacognitive knowledge and reflection about the analogical reasoning process. Participants seemed to accept the appropriateness of the metaphor (including the existence of educational pathways) without discussing explicit mappings and their implications. This indicated that while participants acknowledged the analogy as a tool in their work, they did not know how to apply it successfully in a process of analogical reasoning.

In either case, however, participants' discussions and reactions to the metaphor indicated that even if team members did not explicate all the implications of the pathway metaphor, they were active users of the analogy, not passive recipients of it.

Conclusion

This case study illustrated how an analogy was used by a natural group to address a complex problem. The pathway metaphor had limited application as a basis for detailed analogical reasoning. This analysis raised several issues relevant to analogy use in group work, including the value of explicitly discussing the analogical reasoning process, the impact that domain clarity may have on an analogy's utility, and possible subtleties in analogical evaluation.

First, effective team use of the analogy relies on common understanding and application of the metaphor. However, participants may interpret the analogy differently and use it in different ways in their work. This may result in misunderstandings among team members, and may contribute to team products being created and evaluated based on different criteria. If a metaphor is commonly used in normal speech, then an assumption of common understanding may preclude explicit discussions about the assumptions and ambiguities in the metaphor. This lack of discussion might result in an inefficient or inconsistent application of the metaphor both in analogical tasks and in conceptualization. It also is possible that participants' familiarity with the term and the concept may blind them to the fact that it can be broken into components that could be compared separately as a part of an analogy.

Adequate communication also may enhance metacognitive monitoring of the reasoning process, which in turn would facilitate analogy application. If team members do not attend to the ways in which the analogy could be used—and to the implications of various mappings—then the analogical reasoning process may not result in a productive understanding of the target domain. Even if the analogy is implicitly evaluated (as was the case for Team A), the evaluation may not result in improved application of the analogy. A higher level of metacognitive awareness of the reasoning process is probably required to apply a complex analogy successfully in teamwork.

Second, ambiguities in the source and target domains appeare to influence participants' ability to generate analogical mappings. An analogy that requires far transfer across domains may not provide enough clues about how to apply the analogy in detailed work. Because this type of analogy involves a source and target of radically different domains, many details may need to be supplied by the group before generating mappings, making analogical reasoning complex. In order to avoid miscommunications among team members, it is important that team members clarify both the base and the intended target of the analogy and explicate the type of mappings that are to be made.

This case study also provided information about analogical evaluation in a natural group. While little explicit evaluation of the metaphor was evident in team conversation, participants' actions—including their expansion of the analogy target and their search for examples of its application in other fields—indicated subtle evaluation of the metaphor's utility. The use of alternate metaphors to extend and clarify the pathway metaphor also revealed that participants were constantly evaluating the validity of the pathway metaphor. However, these evaluations apparently did not improve the application of the analogy.

This analysis highlights that while analogy can be a useful tool in team work, the nature of the analogy and the skill of the group in analogical reasoning constrain its utility for certain functions. In this case, the pathway analogy was unsuccessful as an explanatory analogy (see Gentner, 1982) designed to facilitate detailed understanding of patterns in student educational data, but it was more successful as an expressive metaphor that highlighted interesting questions for study. The analogy's lack of success as an explanatory analogy likely was related to its status as a "common sense" idea. While instructional analogies may be selected either for their ease of application or their emphasis of particular aspects of the target domain (thus ensuring their success as explanatory devices), a "common sense" analogy is not necessarily as carefully selected. If the analogy's ambiguities and limitations are not identified and resolved by team members, the analogy application may be limited or misapplied, resulting in a lack of progress on the team task. Team managers and members need to be aware of these issues in order to facilitate the application of an analogy in teamwork.

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