Collaboration for Innovation through Knowledge Representation

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Abstract: Innovators use externalized knowledge representations when they consult blueprints, read spectrographs, or develop mathematical models. These representations may impact not only individuals' capacities for creative transformation or other mental work, but also project teams' collective understanding and coordination. For this study, 219 team members were surveyed concerning the knowledge representations they used, the social and organizational impacts of their representations, and further consequences for aspects of project performance. Representations were characterized in terms of abstractness-concreteness and simplicity-complexity, in line with theory developed for this research. Through path analysis of data, flows of causal influence were identified from representations to their benefits and then to further consequences. For example, greater simplicity of the knowledge representation promoted a shared language and other facets of common understanding among disparate team members, which, in turn, promoted higher value creation performance. Innovators are advised to consider social and organizational consequences of their chosen knowledge representations.

Keywords: Collaboration, knowledge representation, knowledge production, team processes, boundary objects

Introduction
Managing collaboration between participants with different disciplinary, organizational and cultural backgrounds is a key success factor in innovation (Cooper, 2001). Prior research has focused on the effectiveness of integrating diverse contributions, and has identified factors such as team composition and the creation of channels for communication (Ancona & Caldwell, 1992). By focusing on the role of external knowledge representations, we aim to extend the range of collaboration aspects that can be effectively managed and of the tools that managers can use for this purpose.
Knowledge is a key input and output of innovation projects. Previous research has emphasized innovators’ personal and tacit knowledge as a key to success and as an impediment to collaboration (Nonaka, 1994). Less attention has been given to “externalized” knowledge representations. Yet, any project uses a wide range of external representations, encompassing flowcharts, blueprints, equations, algorithms, item lists, tables, measurement and test data, function graphs, perceptual maps, incident reports, and digital images such as spectrograms. Even virtual and physical prototypes are representations that embed knowledge about the product form considered to be most efficient.

We aim to understand the role of external representations in team-level effort guidance, allocation and integration by answering the following question: What is the connection between features of externalized knowledge representations used in innovation projects and aspects of team collaboration that impact on innovation project success?

Social cognition research investigated similar questions with respect to mental representations. Thus, research on “team mental models,” defined as “members’ shared, organized understanding and mental representation of knowledge about key elements of the team’s relevant environment” (Mohammed, Ferzandi, & Hamilton, 2010: 879), indicates that teams are more effective when members develop a common understanding about their collaboration process. Organization theory also investigated the role of mental representations (Weick & Roberts, 1993), but also directly addressed the role external representations. For instance, research on “boundary objects” (Star & Griesemer, 1989) shows that external representations enable collaboration across departmental boundaries by helping create a shared vocabulary and meaning (Carlile, 2002). “Epistemic objects” research attempted to understand how the joint construction of external representations helps integrate contributions when team members work together (Ewenstein & Whyte, 2009).

But these literatures consider a limited range of representations, and overlook important team processes, such as guidance and manipulation. In this paper, we build on these theories to develop a theoretical framework that connects the form of external representations to the social benefits they bring to team processes, and to innovation project performance. Two dimensions (abstract-concrete and simple-complex) capture the properties of external representations and are used to position a broad array of representations. We also theorize four types of collaboration benefits that representations provide and suggest ways in which representation properties support these benefits and project performance.

Anticipated relations were tested using an original survey administered to 219 innovation project participants in a broad variety of industries. Results support our basic argument that external knowledge representations play an important role in team processes and that collaboration benefits mediate between representation properties and project performance. In particular, the study reveals the beneficial role of concrete and simple representations.

Theoretical Framework
The perceived world is a representation constructed by our cognitive abilities (Schopenhauer 1966). An external reality exists, and the representation is correlated with this reality. But “distortions” created in the process of representation construction prevent
us from knowing the true nature of this reality. Biology and cognitive science suggest that such distortions are adaptations that ensure our survival (Maturana & Varela 1980), among others, by selecting the qualities and magnitudes that enter the representation. Thus, we have a powerful ability to set apart objects from ground, or to perceive features and expressions of other people. More significantly, by automatically attributing meaning to the objects encountered in the world we can react quickly to dangers. A later adaptation is the ability to develop and operate with abstract categories, which enables planning future actions and increases our control over the world.

Studies of our “internal” representations also reveal the limits of our cognitive abilities, which may explain the widespread use of external representations. The latter overcome the limits by fixing aspects of the world on external supports. They enable us to perceive elements left out by our cognitive abilities, such as those that are too small, move too fast or change too slowly, and preserve important element in spite our memory limitations. They can also provide feedback about specific forms by letting us see these forms in the world. This is particularly beneficial in engineering and industrial design, which are representation construction activities that rely on nonverbal though, as external representations can be manipulated in more ways than mental ones (Fersguson 1978: 137).

These cognitive advantages are supplemented by social benefits. External representations support communication and joint work even when simultaneous presence is impossible. These social benefits are the focus of this paper. But before analyzing them in detail, we outline two properties of representations that play an equally important role in cognitive and social processes in innovation projects.

Properties of External Knowledge Representations

We assume that the impact of external representations depends on the relation between the aspects of the world that they fix or constrain, and the aspects that they leave free, unconstrained and open for manipulation by users. To identify what aspects have the highest impact when fixed or freed, we considered the most fundamental operations through which we construct the world (Kandel 2006). The first, is automatic pattern recognition (object from ground, familiarity) and attribution of properties or categories (such as friend and foe) (Rosch 1978). The second, is putting objects in relation, such as relative position in time and space, or mutual influence. These operations inspired the two properties that used to characterize representations: the abstract-concrete dimension and the simple-complex dimension.

The abstract-concrete dimension relates to our innate pattern recognition abilities and parallels an important distinction in the innovation literature (Bunge 1967, Kline 1987, Nightingale 1998). Abstract representations use symbols to denote a general class of objects, properties or relations and, in doing so, they fix the meaning of these elements. Yet, beyond the set constraints, they leave open a range of object forms to which they can apply. For example, a formula for heat diffusion operates with clear terms (heat flow, object dimensions, conductivity of materials etc.), but, by giving different values to variables, it can apply to different turbine forms. On the other hand, concrete representations freeze the form of an object, by reproducing it as closely as possible, for example by pixelizing the light reflected from the object. But, they leave open the interpretation given to the form. In spite of this freedom, two persons with similar backgrounds and expectations will interpret similarly the same concrete representation.
The simple-complex dimension is associated to our ability to relate objects in the world. On both ends of this dimension representations fix relations between elements but do so differently. In simple representations, relations are spatiotemporal, such as inclusion, order, “distance” or difference. Such representations often include objects as whole entities, referred to only by name or distinctive property. By relating a large number of objects, they offer more breadth for user exploration. For example, users can compare benefits across many objects, and identify those suitable for their needs. By contrast, complex representations fix relations of influence, such as physical impacts, action by fields and logical operations. They often unbundle objects and show their components and internal influences. By fixing influences, complex representations put stricter constraints on users’ exploration. However, users can follow more precisely the ramifications of their manipulations, which increases the exploration depth.

Figure 1 Distinctive properties of representations

Figure 1 sums up the properties of external representations. Figure 2 includes a list of representations used in innovation projects, arranged by levels of abstraction (most abstract at left) and complexity (most complex at the top). We hypothesize that these properties affect social and organizational benefits in innovation projects, which, in turn, influence project performance. To test this hypothesis, we first theorize the social benefits of external representations.
Figure 2 Types of representations used in innovation projects

Social Benefits of External Knowledge Representations

To understand these benefits it is useful to conceive innovation project teams or organizations as networks of participants with different interests, disciplinary backgrounds, and past experience. These participants are not passive implementers; prompted by their particular desires and dissimilar mental frames, they react to other participants’ decisions and want to influence the project, convince or impose their views on others. They carry out activities together but also separately, and coordinate, using ties established with other participants. Social benefits ensue when external representations intervene in these ties. Some would even argue that representations become, in turn, full participants in the network, exerting their own influence on other actors (Callon 1986; Latour 1991). Below we present four categories of social benefits.

Demonstrative Benefit

Demonstrative benefit increases the influence that some actors, usually those who produce the external representation, exert over other actors. Specifically the representation is used to alter or disguise the perceived characteristics of the first group of actors, in the same way a screen or a curtain may filter the image that the public gets of a performer. This benefit is related to the social psychological mechanism of trait and cause attribution (Fiske & Taylor, 1991). By the action of this mechanism, project participants attach a rather stable categorization to a certain actor. Subsequently, this frame will condition the attitudes and actions towards the given actor. The sociological literature on symbolic interactionism adds the suggestion that actors or groups act to create and maintain their image in social settings (Goffman 1958). Among their actions is creating and protecting the distinction between the stage, which others can see, and the backstage, where others are not allowed. Willingly or not, the projected image can be very different from the identity that actors attribute themselves (Gioia and Thomas 1996). In turn, this
identity, and the associated roles and initiatives, often result from a contrast with other actors’ images. Reciprocal categorization among innovation team members establishes a background structure of potential influence, a sort of pecking order with respect to status, influence, and roles that people play or would be able to play in the project (Weick 1979, Stryker 2007). Active manipulation of representations can alter this order, for example, by increasing the perceived competence, probity, diligence and reliability of the actors that produced them, and hence, augmenting their status, legitimacy, credibility, and, ultimately, potential influence on other actors.

The influence that representation properties have on the demonstrative benefit is mostly indirect, meaning that they do not follow from the use of the representation but result from inferences that other actors make about the creators of the representation. Hence, an abstract representation can convey a high level of competence, but can also lead to its authors being qualified as too academic and even esoteric. Similarly, a complex representation can convey a high level of cognitive abilities and of work ethic, because they require more effort to produce. But representations that are too complex may create confusion and generate a negative attitude towards those who have produced them, which can result in these persons being avoided. Because of their reliance on inferences, the extent of the benefit is contingent on the context and hence difficult to predict in advance.

**Directive Benefit**

Directive benefit refers to the more active and specific ability of an actor or a group to guide towards, or impose to other actors a certain course of action in the innovation project. A crucial form of the exercise of power consists in taking actions that structure other actors’ fields of action (Foucault 1982: 791). This is different from offering cash incentives, threatening, or even beating and imprisoning other actors, because this form is not directly related to actors’ resources or physical force, but is made possible by actors’ knowledge, by the opportunity it gives them to depict certain actions as possible, “reasonable” or “rational” (effective) or even inevitable. The mechanism underlying this benefit is captured by terms such as “frame” (Minsky 1975), or “script” (Barley 1986), which designate a set of concepts that defines the basic parameters of a situation. A frame points out, often implicitly, to a series of “default” consequences, including actions that participants must carry out in the given situation. Research in decision making, strategy and political communication suggests that by framing a situation, for example by presenting an event as an opportunity rather than a threat, actors can generate very different reactions (Tversky and Kahneman 1986).

External representations, including those referring to technical objects, can be used as a frame that defines the basic parameters of a situation. Although directive benefits depend on the content of the representation, and the substantive indications that it suggests to the actors, the properties of abstraction and complexity play a more direct role in this case. Concrete representations, even though they “free” the sense while “freezing” the form, have the most obvious consequences in a given cultural and action context. The popularity of physical prototypes and of test and measurement results probably reflects the fact that these representations clearly indicate, within a context of expectations, what action is called for, including what form to give an object (e.g. a product) and what are its chances of success. In contrast, the abstract representations freeze the sense but leave too much discretion regarding the form of the object, and hence, do not point towards a
particular action. A complex representation allows a more precise exploration of possible actions by varying parameters within the same class of forms. In contrast, a simple representation allows actors to compare benefits across forms and objects.

**Allocative Benefit**

This collaborative benefit enables actors to allot project tasks among themselves and to execute them separately. A typical innovation project requires the collaboration of groups based in different functional departments, for example marketing, engineering, and manufacturing. Likewise, in biotechnology innovation projects, a molecular biology group may collaborate with a chemistry group and an information technology group. The problem is that these groups live, in Schopenhauer’s terms, in different representations of the world, or “thought worlds” (Dougherty 1992). In addition to their distinct knowledge, members of these groups do not have the same perceptions about goals, resources, time and so on. The difficulties are made worse by the fact that, increasingly, distinct parts of an innovation project are executed by different organizations located on different continents. One way to ensure coordination of their activities is to minimize the interactions between groups, by letting them occur only through limited and precisely defined interfaces, which can span the different thought worlds. In terms of the “team mental models” literature, project participants would develop a “teamwork mental model,” meaning a shared understanding on what are the tasks, goals and deadlines of other subgroups, without understanding in detail what the nature of their problems and of their work. The extent to which a team shares the teamwork has been found to predict task performance (e.g., Rentsch and Klimoski 2001).

Sharing is facilitated by external representations, such as a form to be filled or a Work Breakdown Structure (WBS) graph, that constitute boundary objects (Star and Griesemer 1989). Such objects either provide participants a map of tasks with temporal or “spatial” limits, as in the case of the WBS. Alternatively, they can act as an interface between subgroups, as in the case of a form to be filled, by establishing a limited but mutually comprehensible language for cross-boundary interactions (Carlile 2002). Representations of technical objects, which are the focus of our research, can also be used to increase the extent of sharing. For example, a product architecture diagram would enable agreeing on the areas of responsibility for each subgroup would work, and on the kind of information each of them would provide to other subgroups. Likewise, a list of specifications could be used to agree on goals between different subgroups. These examples suggest that representations should be rather simple, enabling a “spatial” exploration of the most efficient boundaries. At most, representations of moderate complexity, such as flowcharts or block diagrams, would be used, when participants need to include all key elements within the same object. Too much complexity would preclude the understanding of representations across all relevant groups and would overemphasize the interactions between subtasks at the expense of their separable nature. One the abstract-concrete dimension, using abstract representations, with their fixed meaning, would appear to enable, at first sight, a more accurate coordination. However, such coordination is only possible if all groups attribute the same meaning to the symbols included in the representation. For highly abstract symbols, this would demand from all subgroups to share an extensive amount of prior background knowledge. Representations that are concrete or use symbols with mid-range abstraction that are widely shared in a culture would ensure that most of the required background knowledge is already shared in the
group. Hence, representations using a small set of rather concrete symbols would enable all subgroups to read a shared map, perhaps at the expense of some precision, and would create a rudimentary language for subsequent interactions across interfaces.

**Integrative Benefit**

Unlike the previous benefit, which stems from separating as much as possible the activities of different subgroups, and minimizing their knowledge of the activities of other subgroups, the integrative benefit stems from interpenetrating as much as possible the various activities and helping participants get a grasp of what others are doing. The “team mental models” literature suggests that this benefit is associated with a “taskwork mental model” (e.g. Cooke et al. 2001; Lim & Klein 2006), which includes knowledge about how others perform their tasks. Almost all studies examining both teamwork and taskwork models found that the taskwork mental model similarity within a team had stronger direct effects on performance than that of teamwork mental models (e.g., Cooke et al., 2001). Weick and Roberts (1993) propose a more nuanced mechanism, by suggesting that high reliability organization, such as aircraft carriers, can avoid accidents only by establishing a “collective mind,” meaning team members have a profound, almost reflexive, knowledge on other members’ tasks, so they understand in real time the reasons and nature of their actions and act accordingly on their side. A collective mind is based on more than sharing but on the interpenetration and flexible articulation of the respective knowledge areas. While innovation teams do not face the same sense of urgency as high reliability organizations, some are facing a very similar problem, namely collective action on objects whose components interact strongly. Therefore, rich task mental models and, even better, a collective mind, can provide significant benefits (Dougherty 2001).

**Methods**

**Survey Instrument**

We followed Schwab’s (1980) three-phased process of instrument development in each of the domains of interest. The investigators chose a Likert-type format (ratings of agreement-disagreement) for measurement of all variables. Therefore the first step was to develop statements that would characterize states or values of variables. For example, three statements were drafted which, if agreed with, would indicate that the primary knowledge representation for an innovation project was of an abstract nature. One such statement was “Captured the quantitative relations between a few essential properties of objects.”

Within this first phase, the instrument was pre-tested in two steps. In the first step, we asked four academics, all studying innovation projects, to provide a critique of our measures (Schriesheim & Hinkin 1990). Then we asked 15 innovation project practitioners to complete the questionnaire and send comments. Further refinement followed.

The second phase—psychometric evaluation—became possible after the major data collection. We used principal axis factor analysis with promax rotation in order to detect consistency among items intended to measure the same variable as well as distinctiveness between variables.
Thirdly, for each of the obtained factors a composite score for the corresponding variable was calculated by summing the survey items most associated with their common factor.

**Knowledge Representations**

The survey items concerning dimensional attributes of knowledge representations that we retained for further analysis appear in Table 1 along with their structure coefficients obtained in factor analysis. In addition to the items shown, for simplicity and concreteness, items designed to measure abstractness and complexity also were administered (e.g., "Attempted to capture in as much detail as possible the inner workings of an object" for complexity). The pattern of correlations among the four resulting scores required us to select just two scores, one for abstract-concrete and one for simple-complex. The alpha reliabilities of the scores for simplicity (.75) and complexity (.72) were highest and their correlation with one another was lowest (.25) thus maintaining fidelity with the theoretical scheme of Figure 1.

**Table 1.** Factor Structure of the Survey Measures of Dimensional Attributes of Knowledge Representations.

<table>
<thead>
<tr>
<th>Survey Item</th>
<th>Concrete</th>
<th>Simple</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conveyed as fully as possible the perceptions one would have when observing a real object or situation</td>
<td>0.51</td>
<td>-0.04</td>
</tr>
<tr>
<td>Recorded objects in a mirror-like way, with as much raw perceptual detail as possible</td>
<td>0.47</td>
<td>0.11</td>
</tr>
<tr>
<td>Described as abundantly as possible the appearance and behavior of concrete objects</td>
<td>0.93</td>
<td>-0.04</td>
</tr>
<tr>
<td>Arranged a diversity of objects by highlighting a few basic distinctions between them</td>
<td>0.02</td>
<td>0.52</td>
</tr>
<tr>
<td>Positioned relative to each other numerous objects designated by name or pictogram</td>
<td>-0.10</td>
<td>0.77</td>
</tr>
<tr>
<td>Captured simple relations, such as self-evident similarities, between several objects</td>
<td>0.08</td>
<td>0.81</td>
</tr>
</tbody>
</table>

Note. The four obtained principal axis factors with eigenvalues above 1.0 were rotated by promax. Items shown in bold were summed to produce a corresponding composite score.

**Social and Organizational Benefits of Knowledge Representations**

For 12 survey items concerning social and organizational benefits of knowledge representations, the rule of retaining as many factors as had eigenvalues above 1.0 yielded four factors. Allocative benefits (alpha = .82) accrued when the knowledge representation "Helped coordinate the activities of various groups that worked in parallel" in the words of one of this measure's 3 items. Integrative benefits (.90; 9 items) concerned common understandings, as when the representation "Helped build a common understanding of project activities among all participants." Demonstrative benefits (.84; 3
items) accrued to the developers of the knowledge representation: "Helped establish the authority of its creators inside the project organization." Directive benefits (.70; 3 items) entailed definite influence: "Was helpful in persuading other participants to adopt a course of action that later proved to be beneficial."

Aspects of Project Performance
The 12 survey items concerning aspects of project performance also yielded a 4-factor solution. The 4 items of the corresponding score for Overall and Technical performance (alpha = .76) included "Given the time and budget we had, we completed an outstanding sum of activities" and "The product achieved technical characteristics that were superior to our initial goals." Operational performance (.77, 3 items) included "Use, operation and maintenance costs for this product are much lower than expected." Value Creation (.75, 3 items) included "The users of the product are delighted with the value it provides to them." Budget performance (.68, 2 items) included "The funds used by this project were below the budget approved at the go-ahead date."

Survey Sampling Procedure
Members of innovation project teams were invited by email, sent by one of the investigators, to participate in a survey study of the impact of knowledge representations in project success. Some were contacted in connection with industry associations or professional associations. Others were identified from their having published a report involving a suitable project. To ensure heterogeneity of project types, three categories served approximately as sampling strata: science-related (e.g., biotechnology), computer-related, and manufacturing. Thus, for example, we sought industry association connection and publication outlets in each of these categories for our recruiting. Ultimately approximately 2800 email messages were sent to possibly valid (not returned) addresses.

Obtained Sample
The total number of survey responses received was 241. Twenty-two of these (i.e., less than 10%) were eliminated because they did not provide enough information about the knowledge representations that they used and/or about the other variables for this study, yielding a usable sample of 219.

Results

Path Analysis Approach
Data were analyzed to produce a path model by use of structural equation modeling (Arbuckle, 1997) with manifest variables. Figure 3 shows the resulting model.

The major theory-derived, a priori constraint for the modeling concerned the left-to-right ordering of the variables in the three domains of representations, benefits, and performance. Within that constraint, top-to-bottom ordering minimizes crossing of paths. The particular paths included are those that allow this model to represent simultaneously
the various associations among the measured variables. Indeed, Figure 3 is a knowledge representation.

![Figure 3](image)

**Figure 3** Path representation of associations among measured variables.

**Model Fit**

The effectiveness of the path model in representing the associations may be described globally by various indices of model fit. The following indices imply reasonably good fit (Byrne, 2001): NFI = .942; CFI = .976; RMSEA = .054; CMIN/DF = 1.625; Chi-squared = 32.50, df = 20, p = .038.

**Direct Effects**

The values shown with paths in Figure 3 are standardized path coefficients. Their levels of statistical significance are given by the symbols shown in the legend. Thus, for example, it may be seen that greater Simplicity of a knowledge representation is associated with significantly more allocative and integrative benefit. Allocative benefit, in turn, is associated with significantly higher Operational performance and Overall/Technical performance.

Concreteness is seen to have two associations with benefits that are of "marginal" statistical significance (p < .10 with Allocative and Directive benefits). The significant associations for Concreteness run directly to two aspects of performance, Overall/Technical and Value Creation. These latter associations point to favourable impacts on project performance that accrue from greater representation Concreteness, but not as a result of the social or organizational processes measured here in these two instances.
A further instance of a direct effect involves the negative relation between Simplicity and the Overall/Technical aspect of performance. This result—in the context of the others for Simplicity—indicates that Simplicity of the knowledge representation carries a trade-off. Simplicity promotes social and organizational processes which can be seen in the figure to promote project performance. However, by some process that is not identified in this study, Simplicity can be detrimental.

**Mediated, Indirect Effects**

The modeling method used here allows formal tests of whether the two features of knowledge representations ultimately impact on project performance as mediated by the social and organizational benefit variables. Table 2 shows the results of these tests.

All of the possible indirect paths from Simplicity to aspects of performance were seen to be statistically significant. This indicates, for example, that Simplicity impacts favourably on Operational Success partly because of Simplicity's impact on favourable allocation of project responsibilities.

The indirect effects of Concreteness were uniformly of marginal statistical significance.

**Table 2 Mediation Tests.**

<table>
<thead>
<tr>
<th>Representation Feature</th>
<th>Potential Mediator</th>
<th>Performance Aspect</th>
<th>Indirect Effect</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simplicity</td>
<td>Allocative</td>
<td>Operational Success</td>
<td>.037</td>
<td>.009</td>
</tr>
<tr>
<td>Simplicity</td>
<td>Allocative</td>
<td>Overall/Tech. Success</td>
<td>.025</td>
<td>.009</td>
</tr>
<tr>
<td>Simplicity</td>
<td>Integrative</td>
<td>Value Creation</td>
<td>.022</td>
<td>.010</td>
</tr>
<tr>
<td>Concreteness</td>
<td>Allocative</td>
<td>Operational Success</td>
<td>.020</td>
<td>.084</td>
</tr>
<tr>
<td>Concreteness</td>
<td>Allocative</td>
<td>Overall/Tech. Success</td>
<td>.013</td>
<td>.084</td>
</tr>
<tr>
<td>Concreteness</td>
<td>Directive</td>
<td>Budget</td>
<td>.009</td>
<td>.109</td>
</tr>
</tbody>
</table>

Note. Indirect effects are expressed as means of parameters estimated from 5000 bootstrap samples. Probability levels describe the proportion of survey samples that could be expected to yield, by chance, a parameter as high or higher than the indirect effect parameter shown.

**Discussion and Conclusions**

Overall the findings support our theoretical analysis, which holds that knowledge representations impact upon project team social and organizational processes (such as task allocation) and thereby, on project performance.

The apparently greater role here of Simplicity as opposed to Concreteness may be tied to the potential for project teams to have members with various backgrounds and expertise. The strongest association originating in knowledge representation involves Simplicity promoting Integrative benefit. As described in the Methods section this is the benefit of promoting common understanding. Simplicity can be expected to be helpful in this regard. Concreteness, on the other hand, does not necessarily mean comprehensibility, as when a knowledge representation is somewhat complex because of its concreteness.
But as noted, simplicity is not completely favourable toward performance. It should also be noted that there are likely to be many contingent variables such as team heterogeneity, geographic dispersion, and so forth that would moderate the associations seen in this study.

Based this study's findings, innovators may want to reconsider the kinds of knowledge representations that they use and how they use them with disparate groups involved in complex projects. Specifically, up to a point, innovators may want to keep it simple—and concrete.

References


