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The Social Context of Industrial Creativity:

R&D Planning Using Roadmaps

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Abstract

Attempts to enhance creative performance can backfire. This paper presents the results of an administrative experiment involving teams working on a complex task. The task, part of an exercise called technology roadmapping, is increasingly being used by large industrial firms as a technology planning and integration process. Two treatments are hypothesized to diminish the creative output of roadmapping teams: instruction in particular forecasting techniques and external evaluation of creativity. Existing theories of creativity and extrinsic motivation are extended and a new mechanism explaining creative influence is presented.

Individuals and organizations alike appreciate creativity. Not considered to be a very mysterious concept, most people have some working understanding of what it means to be creative -- even if they would trouble explicitly defining it. Given such an imperfect understanding, we still make conscious attempts to enhance creativity in organizations and sometimes unknowingly trample over it. This paper will suggest that the two sometimes happen simultaneously. This paper will connect our general knowledge about creativity to its specific role in organizational life. In particular, we focus on one part of the organization where creativity is required, the R&D organization. For the manager, the purpose here is to identify how certain administrative practices can influence the innovative capability and performance of the firm. For researchers, this study suggests how a general understanding of creativity plays out in at least one real world setting of some consequence.

The study takes advantage of a somewhat unusual opportunity to do experimental organizational research in a real organization (Thompson 1974). The organization referred to is one that is participating in a consortium based research program to advance the understanding and practice of technology management. A large high-tech organization, it has opened its doors to investigation and allowed us to manipulate the environment to study the impact of a new management process on creativity. Moving experiments like this from the lab to the field provides some important benefits. First, they retain the superior ability of experiments to improve one's confidence in the relationship between induced changes and their results. Also, observing a process in the complex environment of an organization may help the researcher to re-connect the findings with organizational practice. Science necessarily looks at things in a controlled environment, detached from their linkages to a complex, real world environment. The researcher, and ultimately the practitioner, must make that knowledge useful by relinking it to the world in which it will be used (Steiner 1995). The study provides both conceptual understanding of creativity and a rich set of data from which to develop useful recommendations.

Creativity – A Working Definition

Psychologists have argued for many years about the definition of creativity. Part of the discord stems from the fact that creativity is used to describe a variety of things. Studying the creative process, the creative person, or the creative product each present a different set of demands for a definition that can be operationalized in research (Amabile 1983). We acknowledge the debate, but do not wish to or need to take sides here. Instead we suggest that in the industrial setting, as in most practical situations, creativity is of little value in a process or person unless it manifests itself in an artifact or some behavior. If an acceptable definition of creative output is available then, the subject is made available for scientific study.

Defining creativity by identifying specific attributes of creative products would provide such a means for empirical study. However, Amabile (1983) suggests an operational definition of creativity that is useful for research purposes but lacks references to those attributes: "A product or response is creative to the extent that appropriate observers independently agree it is creative. Appropriate observers are those familiar with the domain in which the product was created or the response articulated" (359). At first glance this definition appears to be less than satisfying to just about everyone. For the interested observer, it does not specify anything about the aforementioned product attributes -- exactly what is it about a product that makes it creative? For the researcher, the subjective definition seems to encourage unreliable responses from judges of creativity by not using objective criteria. For the historian, the definition makes it possible for an assessment of creativity to change. An unchanging artifact can literally change its creative colors with the passage of time. Creativity has a historically bound social context (Csikszentmihalyi 1988).

Fortunately, those concerns can all be addressed while the definition provides its great advantages for experiments like the present study. First, it the definition does not depend upon training creativity judges, which could be problematic, but relies instead upon their native ability to recognize creativity when they see it. The criteria for judging creativity may not be consciously available to judges, and yet their independent judgments of creativity will still be reliable, at least when assessing objects (Amabile 1982, Barron 1965). Either imposing or extracting the criteria used for evaluating creativity would therefore be problematic, and ultimately undermine the reliability and validity of the study. For the frustrated observer who still wishes to know what makes a product creative, Bruner's (1962) definition of a creative product: one that is novel, appropriate, and valuable in its domain, provides the essence of it. That fact that those criteria are not made explicit and measured by the judges of creativity should not hold us back. Applying them would actually invite suspicion. A study about the impact of social factors on creativity, therefore, need not worry about defining the creative *individual* or articulating the creative *process*. Controlling for these factors, the effect of contextual (organizational) changes on the creative output of a person or group can be evaluated with this simple understanding of creativity.

Originality and creativity are intimately related, although not synonymous. Boden (1991) proposes a distinction between "psychologically creative" and "historically creative," the former representing an idea that is new to its originator whereas the latter is novel to the whole of history. Dasgupta (1996) refines this by distinguishing the community in which an artifact is created. If, for example, the disk drive industry believes that there exists no other thought in its public knowledge body like idea X, then X is judged historically creative for that community. She goes even further by judging the significance of that contribution and by calling a new idea historically "novel" and an idea that adds significantly to its knowledge body historically "original." These definitions derive from arguments similar to those of Csikszentmihalyi (1988) and Amabile (1995) that creativity is a socially and historically relative concept. For a product to be deemed creative, observers familiar with the domain must judge it so.

This presents two interesting implications. First, if a product is produced for which a similar and appropriate solution already exists, although unknown to its producers (person or organization), is it creative? From the perspective of a more knowledgeable observer, since the product is not historically novel (new to history) it is not creative, largely because it is not as valuable to society as the original product. There is always, therefore, the possibility that an artifact will have to be downgraded from one level of creativity to another as history provides a more knowledgeable perspective. Creative upgrades are possible as well. Simon (1996) has been most prominent in promoting the idea that computers can be creative, either independently or by assisting a person's creative work. Csikszentmihalyi's (1988) criticism of this notion focuses on the fact that a computer reproducing an idea does not have the same impact on its domain and time as the original idea. A computer that reproduces an original painting by Rembrandt has not done anything creative, despite the fact that the two canvases might be indistinguishable.

Dismissing Simon's claim this way ignores the possibility that the computer algorithm may produce this idea *first*. And it does happen that way. The fact that the social domain may not appreciate the idea would only temporarily keep the idea from being considered creative. This scenario is valid in the human realm as well, as Galileo learned.

Creativity and the Industrial Firm

Some argue that creative acts are definitive episodes that differentiate between successful innovation and less noteworthy efforts (Ford 1996). This gives creativity too much importance by implying that it is necessary for innovation. Innovation can, and often does, result from deductive searches for discontinuities, not creative acts (Drucker 1985, Utterback and Brown 1972). The relationship between creativity and innovation is not strong in a causal sense either. Creativity is not sufficient for successful innovation, in that many or most creative acts do not result in anything useful or viable commercially. The best that can be said is that creativity and innovation are closely related and that diminishing creative activity would have some negative impact on the innovative capacity of the firm. This justifies the effort of the companies participating in the present research to understand creativity.

Experimental studies of the social influences on creativity are rare. Much more creativity research has attempted to identify the personality differences between creative and noncreative individuals (Nicholls 1972). A more complete understanding of creativity, and one more relevant to users of such research, must consider the organization that receives, recognizes, accepts, and preserves the variations produced by individuals. As a practical consideration, the social factors may be only a small part of the variance in creative activity, but they may represent the largest share of the variance that an organization can do anything about. Studying creative situations to identify factors that contribute to creative outcomes is at least as important to organizations as identifying creative people, and it should be as well to researchers trying to understand all relevant components of creative performance.

When looking for creativity in the firm, at least the creativity associated with innovation, the organizational structure helps by tending to concentrate them. Creativity is tolerated, if not expected, in only a few functions or departments in the firm (March and Simon 1993). The inertial force in organizations is to routinize and standardize processes, reducing variation rather than creating change the way creativity does. Among those groups from which creative ideas are likely to be received, the research and development, engineering, and advertising functions often have the most direct charter. Even among these, the organization develops a hierarchy about the way creative ideas are received and accepted (Thomas 1994). A manufacturing process innovation may not get much consideration as a product innovation, not based on the idea itself, but because of the relative status of the originators. The social context of creativity, even if "irrational," is real.

What happens to the creative idea once it is conceived is a function of the organization and the originating individual's beliefs and perceptions of it. In organizations generally, creativity is facilitated and motivated by expectations drawn from how past ideas were received (Ford 1996). Studies within R&D organizations suggest a complex mechanism by which ideas are prosecuted by their originators and the surrounding organization. Originators may do several things with a new idea. They may talk about it with colleagues, try to sell it on the idea's merits, modify it, or keep it to themselves. If they shares all or part of the idea, their colleagues may offer advice or evaluation (Rubenstein 1989). Baker (1965) studied the ideation behavior of industrial R&D personnel to map the process and its discover the organizational influences. Researchers and technicians tend to screen ideas, prior to their formal submission, according to their perceptions of the idea's relevance. A relevant idea is defined as one perceived to solve an existing problem and is possible to investigate with a firm's current resources. To perform this self-screening, an engineer has to learn the organization's goals and objectives. This can be done through trial and error, although the preferred method (quickest, easiest, and safest) is to consult with colleagues who have already learned. The eventual commercial success of the innovation is dependent on a diffusion process external to the firm, and outside the scope of this paper. In short, creativity is a fragile process, easily disrupted by negative influences from the organization. The influence of roadmapping practices on creativity is the subject of this study.

Creativity and Roadmapping

This paper is more about creativity than about roadmapping, although some understanding of the latter will facilitate the discussion. The industrial setting and task used in the experiment are also central to understanding the hypotheses. What is a roadmap? In current practice, roadmapping can take several forms and have many different uses. For the present purpose, we use the original concept of technology roadmapping introduced at Motorola (Willyard and McClees 1987). A roadmap is a graphical depiction of a product's technologies extended over a certain planning horizon. A product with ten key technologies is roadmapped by grouping and listing the technologies down the page, and then indicating the planned/anticipated changes in each of those technologies across the page. See Figure 1 for an example. While it generally contains much more information (e.g., project funding, competitive data, technology source), the roadmap essentially shows what a product will look like in the future, at least in terms of its embedded technologies. For complex or technologically rich products, the roadmap is typically created by a group of people from research, engineering, and marketing functions in the firm -- and sometimes between firms.

Insert Figure 1 about here

Why do organizations roadmap? The ever increasing pressure on large and complex firms to operate efficiently and respond quickly to rapid market, competitive, and technology changes have combined to create new sets of problems for senior managers. Processes such as roadmapping highlight technology shifts and seek to promote strategic and organizational integration in the making of specific technology investment decisions. By focusing attention on the link between technology projects and larger organizational goals, roadmaps provide guidance to technical groups whose impact on the enterprise from their sometimes substantial activities is less than immediately obvious. Seeing a roadmap is significantly more informative and provides more guidance for employees' decision making than seeing a mission statement, especially for those in R&D roles. Technological forecasts assist the R&D planner by identifying reasonable goals for development programs and the likely levels of product performance from competitors. They can also be helpful in deciding when to abandon one technology in favor of another approach. How long will the current technological approach keep up with the overall technical or market requirements? These change points are shown on roadmaps for a given product. Combining these forecasts with assessments of market changes, the organization's capabilities, and corporate strategy results in a condensed reference to aid decision making. For senior managers without scientific or engineering backgrounds, who often are left out of the communication network on technical issues, the roadmapping tools have provided a forum for personal involvement in the firm's technology directions. Without a common structure, vocabulary and means of comparison, communication about technology has often remained limited and separated from discussions of strategy.

In generic terms, roadmapping acts as a sensemaking process and it serves to reduces equivocality. Sensemaking and roadmapping have both been said to resemble the process of cartography (Weick 1993, Pyke 1973). Weick's description of sensemaking is one of a problem solving process where people are not sure that there is one best solution (or map) or even what that solution would look like if they found it. Sensemakers in this situation make use of the available materials and information, looking for order in a domain without assurance that order exists. Without one *best* map for a given terrain there may exist many useful maps and many more uses to which the maps could be put. The task is not one of discovery (i.e., scientific analysis) to find a preexisting map. It is one of synthesis, to design a map that makes sense of the terrain, or technological future in this case.

Roadmapping is also an information processing tool used to reduce equivocality. Equivocality is basically uncertainty with the added distinction of having a messy, unclear field that is open to interpretation. Uncertainty is generally reduced by acquiring more information, whereas equivocality may actually increase when more data is considered. What managers in an organization do to deal with equivocality is to simply create an answer (Weick 1979), which in the present case is a roadmap. Roadmaps are the answer to the question: "how will the technical organization respond to the future," or perhaps more accurately, "what future will the organization create in order to meet its organizational goals?" The information used when generating that answer certainly contains uncertainty, and in several dimensions (Green 1995, Thompson 1981). There is uncertainty inherent in a new technology related to its feasibility and performance, as well as uncertainty for a given firm corresponding to its actual experience with that technology. The speed and cost of acquiring, developing, and integrating technology, the longevity and market acceptance of a technology, regulatory instability, and competitive changes all represent sources of uncertainty when developing a roadmap. What makes the situation equivocal is that simply assessing the varying levels of uncertainty does not always provide clarity and make evident a solution.

The technology plan, therefore, is one where interpretation and debate is required. It is not enough that it simply contain large amounts of information. The message must have the ability to change the understanding of people involved in the communication (Weick 1993). The message in this information processing mechanism requires a rich medium such as face to face communication or group meetings. In large, decentralized, often complex firms the opportunities for such communication events are limited and technological concerns are often not given highest priority, especially at the senior management level. The technology roadmap has been presented as a richer medium than was available before to such firms, providing for broader participation in the technology planning process (Cochrane, Temple, and Peterson 1996, Barker and Smith 1995). Rich media facilitate equivocality reduction by enabling managers to overcome different frames of reference and by providing the capacity to understand and process complex, subjective messages (Daft and Lengel 1986).

Hypotheses

H1: Training in specific roadmapping techniques diminishes creativity.

Providing roadmapping teams with a standard set of analysis tools and presentation formats is expected to discourage their creative performance. Why would a firm attempt to train the organization to perform a complex, creative, problem solving task using standard techniques and formats? An analogous situation existed in the realm of engineering design when computer-aided design (CAD) systems were introduced. CAD systems attempted to formalizing a creative process in the name of improving productivity and coordination, but in the process disturbed the social aspects of the creative process and often resulted in less creative work. Design is a social, visually oriented negotiation process involving design engineers, production employees, and the physical realities of the design problem. Henderson (1991) observed an organization that introduced CAD and inadvertently destroyed the traditional boundaries between design engineers the rest of the organization, where informal collaboration is integral to generating good designs. Drawings were generated faster and neater, and could be shared with other groups and re-used, but the content sometimes suffered. Engineers no longer stopped by and informally reviewed work in process by leaning over each other's drawing tables. There were no drawing tables. The very assumptions behind the integrated computer system excluded the activities that led to creative design. A fundamental misunderstanding of the social organization of design work, which, when built into inflexible computer programs and implemented in organizations, caused resistance, chaotic behavior, and poor results.

In a similar vein, roadmapping, in the interest of providing technology plans that are comparable with others across the organization, and providing them in a format and language that permits communication and debate among different, often non-technical, groups, influences the creative content of the plans. The way it does this is by implying that the technology planning process is more about analysis than synthesis -- more about science than engineering (Simon 1996). When work is perceived as analyzable, people tend to follow a computational, algorithmic procedure to solve problems (Perrow 1967). This algorithmic approach provided by the training affects the accessibility of alternative constructions by the roadmapping team. Without the training, many approaches to the roadmapping task may have been applied: scenario planning, s-curves, technological limits, etc. With the training, those approaches may be available in the long-term memory of team members, but will be relatively inaccessible during a roadmap session (Higgins and Chaires 1980).

The present study attempts to demonstrate the attenuating effect of the standard roadmapping techniques on creativity. A team that is asked to develop the roadmap for cordless phones, for example, might not consider a technology being developed for another purpose, say cellular phones. Even if they are vaguely aware of the antenna research being done by the cellular division, the roadmapping task uses analysis techniques that focus their attention on technologies closer to home. The future is an extension of the present. Without knowledge of the alternative technology, the forecasting techniques of roadmapping might discourage searching outside their present paradigm.

Whether effects like these linger with teams in future planning activities is another question altogether. Much of the research on small groups is done on a one-shot basis with groups newly formed for the purposes of research. This study is no different in this respect, and thus provides no information about the longer-term effect of the training on creativity. The impact may persist, become entrenched and increase, or diminish as individuals and groups exist and reconfigure over time.

H2: Evaluating a team on the creativity of its output diminishes creativity.

An innovation has to be appreciated by the organization for it to be pursued (Van de Ven 1986). As discussed earlier, an individual with a new idea prosecutes that idea by subjecting it in his mind to a simulation of the organization and evaluating the organization's reaction to the idea. It is presumed that a group performs the same evaluative function, although not necessarily in the same manner. The creativity evaluation in this experiment is not to be confused with the other dimensions of critical review that management and technical experts perform within any organization (and within the minds of the roadmappers). Rather, the evaluation introduces an incentive for producing the best roadmap along a new dimension -- optimized with a new objective function so to speak. The distinction here is critical. The “natural” evaluation is primarily a feasibility check against the (perceived) constraints: management policy, history, strategy, risk, potential return. In short, does the idea fit well enough to be appreciated by the organization? The latter reward mechanism, introduced to the treatment groups, imposes a new objective that may be beyond or even opposed to organizational fit. The impact of the former evaluation process is unavoidable and well chronicled in the literature. Individuals and groups within firms routinely reject technical ideas because they fail to see a fit, they suspect that the organization will reject them, or the interests of other groups or individuals will be threatened. The latter process, where creativity is asked for and rewarded, is new to the technology planning process as part of the roadmapping activity. The idea here is that creativity cannot be asked for directly from roadmapping teams, and from teams generally. A team cannot be given the directive to simply “be creative.”

Again, why would a firm give such a directive in the first place? They may do so, in part, because they suspect the first hypothesis to be true. Once the roadmapping process is in place and routinized, as it is in some firms, it begins to produce technology plans that look more and more alike. The future portrayed in them begins to look like a faster, smaller, cheaper, brighter extension of the present. Participants in firms who have spent a couple of years with the process have brought to our attention that they fear the process is encouraging linear thinking. Managers and roadmapping facilitators who catch wind of this and can react by encouraging the roadmapping teams to be more creative. “That’s what the company needs: creativity and innovation." It is not hard to imagine such a scenario when many firms today promote themselves in advertisements, annual reports, and recruiting materials as innovators. The work system reacts, however, in a way not anticipated by the well-intentioned managers. It becomes even less creative for reasons that follow.

Amabile (1983) lays out the arguments for the detrimental effects of extrinsic motivation on creativity, relying primarily on the theory that it decreases task motivation (Lepper and Greene 1978; Lepper, Greene, and Nisbett 1973). A large part of task motivation leading to creativity is supposed to hinge on innate or passionate interest in the task and an ability to cognitively minimize extrinsic constraints. The task becomes as an end in itself and not a means to some extrinsic goal. The mechanism being suggested by this paper, however, whereby evaluation sacrifices creativity, is quite different. Unlike the creative tasks generally chronicled by historians and creativity researchers, the roadmapping task is not one about which the participants are likely to be passionate, devoted to, or find richly rewarding. It is not a problem that would be described as "work and play" such as designing a new bridge, writing a program, or creating a network architecture. Roadmapping distracts most individuals from their real work. Although still a design task (Simon 1996) it is not like the typical design task where a real problem is solved with real constraints, real stakes, and real implications. It is just a planning problem, although creativity is often desirable in its solution. If not over-justification then, what is it about the creativity imperative imposed on the treatment groups that undermines creative team performance? First, another possible explanation by Amabile.

In order to explain the results of studies that show extrinsic constraints having a positive effect on creativity, Amabile claims that telling the subjects in those studies exactly what to do rendered their tasks "algorithmic." Her study to test the effects of evaluation on creativity involved subjects making paper collages (1979). Those students whose collages were rated higher on creative dimensions were the ones who were told of the evaluation and instructed that creativity meant novelty of idea, novelty of materials used, etc. The definition of algorithmic task is important to note: a task for which there is a clearly identified goal and readily identifiable path to solution. It follows that by telling someone how to be creative, they are no longer capable of being creative -- even if the outcome of the task is, indeed, novel and appropriate. Creativity is ruled out by definition.

The mechanism I am proposing instead, is one where the external reward distracts the team from other motivators in the problem solving process that yields truly creative products. It is not that the task has been rendered mechanical or algorithmic by explaining and rewarding for creativity (that factor is explained by Hypothesis 1), nor is it that the evaluation took the fun out of the task by shifting the motivation from intrinsic to extrinsic reward. What takes place is that evaluating a planning team on its creative output takes a complex design task and focuses the group on the wrong set of design parameters (see Hanson 1978 and Marples 1961 for relevant descriptions of this process).

The creativity evaluation suggests to the team that fit, feasibility, and value are less important dimensions of their task, and since these (likely) represent criteria for creativity, their output is likely to be deemed less creative by the judges. Put another way: The planning team assumes that creativity is equivalent to novelty, and they become fixated on satisfying a novelty objective over the other competing objectives in their design task. The judges, with the benefit of hindsight, are expected to balance novelty with the other creativity criteria. The directive to “be creative” is misunderstood by its receivers, actually making it a creativity supressor.

Experiment

To assess creative performance, a "real" roadmapping exercise was administered to several groups at a large technology oriented corporation. The choice of the creativity task used in this experiment was based on several factors. First, the task had to be one for which there was no solution easily identifiable by the participants. Even though such easily solvable tasks can result in products that are novel and appropriate, they nonetheless require no creative work, which is necessary for purposes of experimentation. The study therefore chose a roadmapping exercise that was similar in domain to that of the subjects, but outside of their specific expertise. The roadmapping task presented a problem with a wide variety of possible solutions and no clear paths to a preferred answer, except for the experimental groups who were trained in a technique that guided their solution process.

Company employees participated in the roadmapping exercise in groups of six, simulating the average number of active participants typically involved in these teams. The participants were drawn from a captive group of individuals who were scheduled for a regular in-house training seminar on roadmapping. Thirty-two groups were selected for the study that took place over four weeks, after which the roadmaps were evaluated by the judges. The roadmapping exercise was presented as a case study similar to the ones typically presented. The case was set in the information mass storage industry using the Quantum Technologies company (makers of hard disk drives). The case packet included historical information about a product, its architecture and technologies, technical performance characteristics, market data, company strategy and financial performance. Participants were also given reports from industry analysts concerning Quantum, its management, and its performance relative to the industry. Each team was given a full eight hour day to prepare the roadmaps.

Insert Figure 2 about here

Half of the teams (Treatment A - Technique) were randomly selected from the sample of 32 and were taught about roadmapping tools and techniques in advance of the case exercise. Their instruction emphasized a certain tool, experience curves, and a process for analyzing the situation and preparing a roadmap document. They were given templates for the analytical work and for presenting their roadmaps. The Non-Technique teams were not given this instruction in technique, process, and templates until after the case exercise, and for the company's training purposes, were later given a chance to revise their roadmaps after learning the techniques. Their task was to prepare "a high level product-technology plan that covered the next three to five years." As stated earlier, the Treatment A – Technique teams are expected to produce less creative roadmaps.

The experimental teams (Treatment B - Evaluation) were also randomly selected from the sample of 32 and told that their roadmaps would be evaluated by experts in the mass storage industry. In particular, they would be "graded on how creative the roadmaps were." They were not told that their roadmaps would be ranked against the other teams, knowing that that might encourage communication between teams within a training session and between sessions during the four-week period. The Non-Evaluation teams were told that the exercise was purely for education and practice, although their roadmaps would be presented later to the instructors and the larger training class. This expectation of outcome visibility was necessary to create enough

task motivation to create plans that were feasible and respectable within their peer community. Again the Treatment B – Evaluation teams are expected to produce less creative roadmaps. Creativity is a subjective judgment, not an inherent quality that can be measured independently. Further, it is domain dependent, and the judgment must be made by members of the field based on the novelty and value of a product (Ford 1996). Therefore, judges were chosen from companies who design and manufacture the disk drives that were the subject of the exercises. They were all engineering and marketing managers who were involved in their industry during the time period of the roadmap exercise. It was necessary to provide the study participants with data from four years prior to the experiment, in order for the judges to use historical context as a criterion for assessing creativity. Even though specific criteria were not explicitly presented to the judges, it was assumed that they might use appropriateness and value in their assessment.
It is reasonably assumed that creativity is a matter of degrees rather than a binary notion where a product either has or lacks creativity. Products can be more or less creative, and the experiment used an ordinal ranking of creativity where the outputs of each team were compared to each other. Although it would be desirable for the purposes of data analysis, there is no basis for using an interval scale in measuring creativity or that the subjective evaluation technique is compatible with such a scale.

The selection of sample participants from company training courses does a great deal to address potential problems related to sample selection. Although it is impossible to know for sure that the experimental and control groups were "equal" prior to the exercise, it can reasonably be assumed that they were, and that the random assignment of treatments would distribute any differences across the treatments. The limited sample size introduces some concern here, however. The participants' managers assigned them to their training, and thus a self-selection bias was avoided in the experiment. Assuming that the sample groups were representative of their company population, there may be some question about their similarity to the general population, or at least the population to which the conclusions are suggested apply. Because this target population is the set of individuals in industrial organizations, and not grade school children, medical illustrators, or MBA students, the assumption of representative samples is a fair one.

The experiment was somewhat reactive in the sense that the subjects were aware that they were being studied (or at least evaluated), and that their performance on the exercise was likely to be affected by this manipulation (Webb et al 1981). For Treatment B - Evaluation, this reactivity is not a problem, but precisely the point of the experiment. The principal validity question is whether the expectation of evaluation produces a comparable effect to such an evaluation in industrial practice.

As the training sessions occurred over a relatively short period and the creativity rankings were done in one session, there was no concern over creativity upgrading or downgrading as the experiment progressed. The most significant validity trouble comes from the nature of the setting in which the experiment took place. The training environment limited the deliberation over roadmap content to one day and the interaction was limited to six individuals per group. For this relatively complex task, unlike tasks used in many creativity studies, the imposed time constraint may have unpredictable effects on the creative content of the roadmaps.

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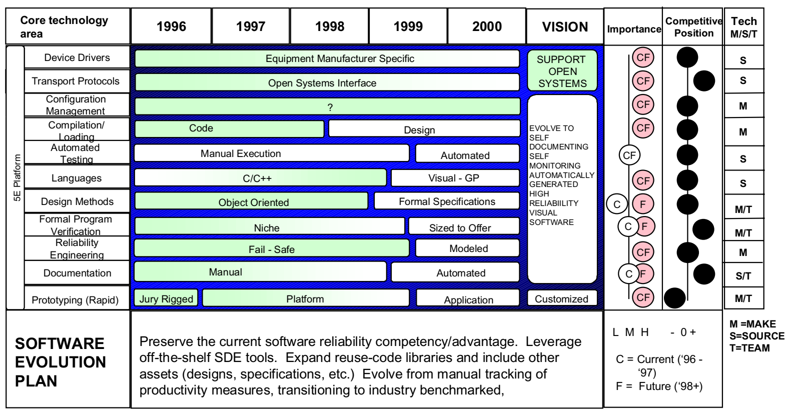
Figure 1. Technology Roadmap Example

Product Software Roadmap



Illustrative Data

Figure 2. Sequence of Experiment

Week 1 | Week 4 | Week 5

--Teams prepare roadmaps --
(using 1993 market
and technical data)

Judges
Evaluation
(1997 hindsight)