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Mutual Learning: Industry /Academia Collaboration for Improved Product Development

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In this research, with active collaboration with industry partners, an action-science approach was employed to develop and support (with tools and techniques) a normative model of the product concept decision process. This process—Concept Engineering—was then introduced into a number of product development teams in different companies. A comparative analysis of actual product concept development activities —with and without the use of Concept Engineering—was conducted. The comparative analysis led to a theory of the product concept decision process. This paper describes Concept Engineering, its evolution, preliminary evidence of its effectiveness, and some theoretical implications for product concept development.

1.0 Motivation

In the opening article of the first issue of Organization Science, an essay by the editors-in-chief cites a study (Miner 1984) of 32 established organizational science theories. This essay concluded that with the exception of theories of motivation, there is no relationship between usefulness and validity. The editors also state that "research on organizations has not typically focused on problems relevant to business and government organizations, and the real world of organizations has not drawn on the work undertaken by organizational scientists" (p.). Within the specific domain of product development, a similar disconnect exists between what the literature recommends and what actually happens in practice (Cooper and Klienschmidt 1986, Gupta and Wilemon 1990, Mahajan and Wind 1992).

The research effort reported in this paper is designed to bridge the gap between theory and practice with the development of an improved methodology and theory for bringing customer focus to the up-front product concept decision process. In the remainder of this paper we describe the path that we followed when carrying out this research. In Section 2.0, we describe the development of Concept Engineering as a case study for how mutual learning between industry and academia has improved the focus on substantive issues, leading to improved practice and theory. In Section 3.0, we recount the benefits and pitfalls which collaboration can bring can bring to the participants. In Section 4.0, we offer some concluding thoughts.

2.0 Concept Engineering Case Study

Mutual learning (Shiba et al. 1993), through collaborative research efforts by academics and practitioners, is designed to eliminate the disconnect between practice and theory. Mutual learning represents the active contribution by all participants—teachers and learners—toward the development of knowledge, understanding, and skill. A significant advantage of practitioner research partners is its ability to focus effort on substantive issues. "Practitioners often bring the pursuit of irrelevant or ill-conceived lines of inquiry to a rapid halt, correcting or refining the questions asked in ways that lead to sharper formulation and more productive research" (Whyte et al. 1991, p. 54). However, the perspective of company participants is strongly influenced by individual experiences and corporate culture. The researcher, on the other hand, if granted access to multiple corporate settings, can develop a broader comparative reference base and include the individual corporate experiences in a larger and more accessible context.

In this section we demonstrate the power of mutual learning. In Section 2.1, we describe the rapid evolution of Concept Engineering that resulted from the mutual learning process. In Section 2.2, we present evidence that Concept Engineering is a complete decision support process, a process subject to routine application and improvement. In Section 2.3, we provide preliminary evidence of improved product development practice resulting from this work, and in Section 2.4, we give evidence of improved theory.

2.1 Evolution of Concept Engineering Through Mutual Learning

Gary Burchill was the leading contributor in the development of Concept Engineering. Gary is now continuing service in the U.S. Navy and is based in Pennsylvania.

Concept Engineering had its genesis in the teachings of Dr. Shoji Shiba, a Japanese visiting professor at MIT, in the fall of 1990. Professor Shiba presented several Total Quality Management decision aides in the context of a quality deployment case study. The coupling of Shiba's work with Dr. Deming's concept of operational definitions (Deming 1986) led to the outline of a process for operationally defining customer requirements. This same process has been used by the lead author to design, patent, and license a product.[1] Shiba's initial effort at MIT blossomed into a two-year collaborative effort by MIT researchers and the representatives of several member companies of the Center for Quality Management (CQM)[2] to apply the Plan-Do-Check-Act cycle (Ishikawa 1985) to the development of the Concept Engineering process. For two years, representatives from MIT and four companies met to collectively discuss objectives and findings while independently pursuing particular assignments. In stretches, often lasting several months, the group met for as much as one full day per week. Interim periods were spent implementing and evaluating the results of previous decisions. During the evaluation periods, it was not unusual for members of one company to be present at the product development team meetings of other participating companies, observing the effects of proposed methodology improvements. This level of sharing allowed new insights into what worked and didn't work to be spread rapidly among participating companies. In this way, an innovation at one company would be applied at another company within days.

To better illustrate the results of the principle of mutual learning in action, we first describe the evolution of Concept Engineering between November, 1991 (Burchill et al. 1991) and September, 1992 (Burchill et al. 1992). In fall of 1991, Concept Engineering consisted of four stages and eight steps (see Figure 1). By the summer of 1992, subsequent to the use of the unrefined version of Concept Engineering by several product development teams in three companies, Concept Engineering as a methodology had evolved into 5 stages with 15 steps (see Figure 2).

Some of the apparent changes from 1991 to 1992 did not materially change the methodological steps, but instead these changes clarified conceptual understanding and improved project management. (For example, Step 3 in 1991 evolved into Steps 3 and 4 in 1992.) However, initial product development teams using Concept

Operationally Defining customer Requirements

Figure 1

Engineering, although excited about the depth of their understanding of customers' requirements, were frustrated with the lack of process for translating this knowledge into product concepts. Thus, based on our analysis of product development team requirements and process weeknesses, additional stages and steps regarding product concept generation and selection were added by 1992. Our solution to this problem tapped into the research of Professors Ulrich and Eppinger at MIT's Sloan School of Management (Ulrich and Eppinger 1991). (The results of this research did not become available to the general public until 1994 [Ulrich and Eppinger 1994].)

Not only were improvements in Concept Engineering developed in the overall completeness for assisting the product concept decision process, but improvements were also made within the detailed methodological steps associated with each stage. For example, the first step in 1991, "Explore the Market," called for identifying market trends/sources of innovation, identifying investigative partners, and selecting the data collection method. There was guidance in

[1] The saltwater flyfishing stripping basket, which has been patented and licensed, has been reviewed in The New York Times and was widely acclaimed in the flyfishing trade press in 1992 and 1993.
[2] The Center for Quality Management is a not-for-profit consortium of over thirty companies that are committed to the development and diffusion of Total Quality Management.

Concept Engineering

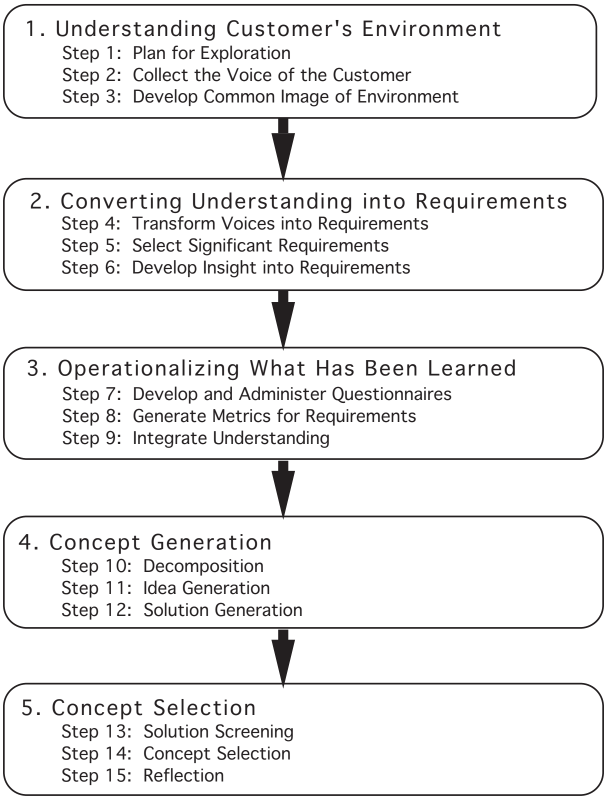


Figure 2

1991, but no decision aides were provided to assist the development team in completing this step. By 1992, the new first step, "Plan for Exploration," called for defining the scope of the project, selecting an exploration method, planning for the execution of Concept Engineering, planning for data collection, and developing the interview guide. Additionally, the Customer Selection Matrix was developed by 1992 as a decision aid to assist in planning for data collection, and a Gantt Chart (developed from the actual experiences of product development teams) was provided to show expected step completion time and opportunities for parallel processing. In both the 1991 and 1992 efforts, problems were identified and prioritized by the practitioners on the Concept Engineering research team or in one of the observed product development groups. The solutions to these problems were in some instances developed by the companies, such as the Customer Visitation Matrix, whereas other solutions stemmed from the research (often not formally published at the time) by members of the MIT community. (See, for example, Clausing and Pugh 1990, Griffin and Hauser 1991 and 1992, Ulrich and Eppinger 1991).

2.2 Concept Engineering as a Complete Decision Support Processes

Collaboration between the research participants and their application of the Plan-Do-Check-Act Cycle led to the development of Concept Engineering as a complete product concept decision support process (Burchill 1993a,b).[3] The conceptual model and supporting decision aids for developing product concepts provided the entire development team with a road map of the product concept decision process from start to finish. The process alternates between the level of thought (reflection/theory) and the level of experience (empirical data) (Kawakita 1991) in a way that allows participants to understand what is important to the customer, why it is important, how it will be measured, and how it will be addressed in the product concept.

Mintzberg and colleagues, in their classic field study of 25 strategic (unstructured) decision processes (Mintzberg et al. 1976) concluded that the decision process has three phases: identification, development, and selection. In the context of the product concept decision process, Mintzberg et al. empirically redefined the problem solving process: requirement identification, idea development, and concept selection. This framework can be used to illustrate how Concept Engineering is a complete Decision Support Process.[4] The table on the following page also outlines the relationships that are described in subsequent paragraphs.

Mintzberg et al. observed that the identification phase consists of both recognition and diagnosis activities. They defined diagnosis as "the tapping of existing channels and the opening of new ones to clarify and define the issues" (p. 254). Concept Engineering provides conceptual and methodological guidance for clarifying and defining the issues. Stages 1 and 2 deal explicitly with exploring the market and converting the knowledge gained in the exploration into a well-defined and focused set of customer require-

[3] Although "Decison Support System" has generally been applied to problem-solving assistance systems using computers (Elam et.al. 1986), there is evidence that pencil-and-paper delivery systems are just as effective as computerized versions (Cat-Baril and Huber 1987). Therefore, we use the term "Decision Support Process" (DSP) to refer to a problem-solving system without requiring the inclusion of computers. We define a complete DSP as one that supports the decision-maker in all phases of the problem-solving process.

[4] This argument could also have been made with alternative descriptions of the problem-solving process; see, for example, Sainfort et al. 1990, MacKay et al. 1992.

Decision Phase	C.E. Step	Decision Aid
Identification	1	Customer Selection Matrix
- recognition	2	Interview Guidelines
- diagnosis	3	Image KJ
	4	Transformation Process & Guidelines
	5	Multi-stage Picking-up Method
	6	Requirement KJ
Development	7	Self-stated Importance Assessment
- search		Kano's Analysis
- design	10	Multiple Design Decomposition's
	11	Idea Generation Process
	12	Solution Concept Generation
Selection	13	Screening Matrix
- screen	14	Selection Matrix
- evaluation-choice		Self-documenting Audit Trail
- authorization		

ments. Specifically, in Stage 1, "Understanding the Customer's Environment," a Customer Selection Matrix is developed to identify exploration arenas. This matrix explicitly includes past, present, and prospective customers. Next, "Interview Guidelines" are developed to assist the focus of the exploration efforts. Stage 2, "Converting Understanding into Customer Requirements," provides clear guidance in the forms of "Translation Guidelines" and "Transformation Worksheets" for converting the Voice of the Customer information gathered in Stage 1 into unambiguous and nonrestrictive Customer Requirements Statements. The vital few requirement statements are identified using the Multi Pick-up Method and structured using the KJ diagram (Kawakita 1991, Shiba et al. 1991a).

The Development Phase observed by Mintzberg et al. consists of both search and design routines. These routines indicate four different kinds of search behavior: memory, passive, trap, and active. In Stage 3 ("Operationally Defining Requirements for Downstream Development"), the requirements developed and selected in Stage 2 are actively validated with potential customers through the use of Self-Stated Importance questionnaires and Kano questionnaires. The "Idea Generation" step in Stage 4 ("Concept Generation") could conceivably incorporate all four types of search activities. The Mintzberg study identified design activities that resulted in either custom-made or modified solutions. The concluding step of Stage 4 is the generation of custom-made solutions that address the set of customer requirements. It is possible that constraints imposed upon the design team could limit idea generation—and thus solution generation—to existing solutions, which would result in "modification" design activities.

The Mintzberg study identified three routines in the Selection Phase: screen, evaluation-choice, and authorization. The first step in Stage 5 ("Concept Selection") is S"olution Screening." In this step a Screening Matrix is employed to reduce the number of alternatives to a smaller number of more feasible alternatives. Additionally, each proposed solution is evaluated against the customer requirements relative to a preselected datum. In "Solution Selection," the second step of Stage 5, a more analytical comparative process is introduced, if necessary, to further assist the development team in identifying the dominant concepts. "Authorization," the final routine observed by Mintzberg et al. in the Selection Phase, is not specifically addressed in

Concept Engineering. However, each step of Concept Engineering is self-documenting; some development teams have used their Concept Engineering working documents in their project proposal presentations before management authorization committees.

The three routines that support the three central phases of the decision process observed by Mintzberg et al. are decision control, decision communication, and politics. The decision control routine consist of two basic activities: planning and switching. Decision planning consists of "a rough schedule for solution, a development strategy, and an estimate of the resources" (p. 261). The CE process is described with a flow chart outlining a coordinated set of conceptual steps. Furthermore, in the introduction to the Concept Engineering Manual (Burchill et al. 1992), a Gantt Chart displaying the various activities and estimated completion times is provided to assist in project planning. Switching "directs the decision maker's attention to the next step, to choosing the appropriate routine, such as diagnosis or search . . ." (p. 261). With respect to switching, the Concept Engineering manual also provides checklists at the end of each step to assist in determining if a minimum set of observable conditions has been met before moving to the next set of activities.

The decision communication routines observed by Mintzberg et al. include exploration, investigation, and dissemination. Exploration is described as a general or passive search for information. The investigative routine involves a focused search and research for special-purpose information. Dissemination involves the communication of information about the progress out outcome of the decision process for the purpose of ensuring eventual acceptance. Concept Engineering is geared towards investigative information searches in that objectives and recommended information-processing approaches are clearly established for each step of the process. Concept Engineering facilitates dissemination by having clearly defined switching points and criteria as well as the self-documenting tools mentioned previously.

According to Mintzberg et al., political activities "reflect the influence of individuals who seek to satisfy their personal and institutional needs by the decisions made in an organization" (p. 262). This is consistent with Salancik and Pfeffer's (1974) view that power is used in organizations to influence decisions concerning the allocation of resources; the more scarce the resource, the less objective the criteria and the more power used to obtain it. Additionally, Salancik and Pfeffer state that when there is a disagreement about the priorities and consequences of possible actions, decisions can not be rationalized. Hickson et al. (1971) propose that "preventive routinization" reduces or removes uncertainty, thus reducing opportunity for the use of power. Concept Engineering, which assists all stages and supporting routines of the decision process, removes uncertainties, clarifies priorities, and makes plain the relationships between potential actions and objectives. This in turn increases the likelihood for rational decision-making, reducing the opportunity for political activities. Ultimately, improved decision-making will improve the practice of product development.

2.3 Preliminary Evidence of Improved Practice

While it is too early to determine with statistical conclusion validity (Cook and Campbell 1979) the effectiveness of Concept Engineering, preliminary results have been encouraging. In one company division, the project team that used Concept Engineering in developing a product concept found that the concept development stage took nearly twice as long as their traditional project performance (see Team 1A in Figure 3, next page). However, in comparison to other recent projects from this division, the total development time of the Concept Engineering project was slightly more than half of the expected total project development time.

Another noticeable advantage to Concept Engineering is the absence of frequent design redirection. For this team, the project prior to the CE project had 11 engineering change notices (after Concept Approval), significantly impacting the total product development time. In the CE project, however, there was only one engineering change notice—and all concerned believed the change to be optional. (See Figure 4, next page.)

The program manager's explanation for this difference between projects was, "This process allows us all to see the data and gain buy-in. Someone that has buy-in understands the program, understands the requirements, understands the how and why, and can explain to other people horizontally or vertically. They have ownership. They don't want to let other people down. Every single day that passion enabled us to come in and fight the good fight, to do the things that needed to be done." An assessment to determine the level of common understanding of customer requirements is shown in Figure 5, next page.

Although clearly not statistically significant,

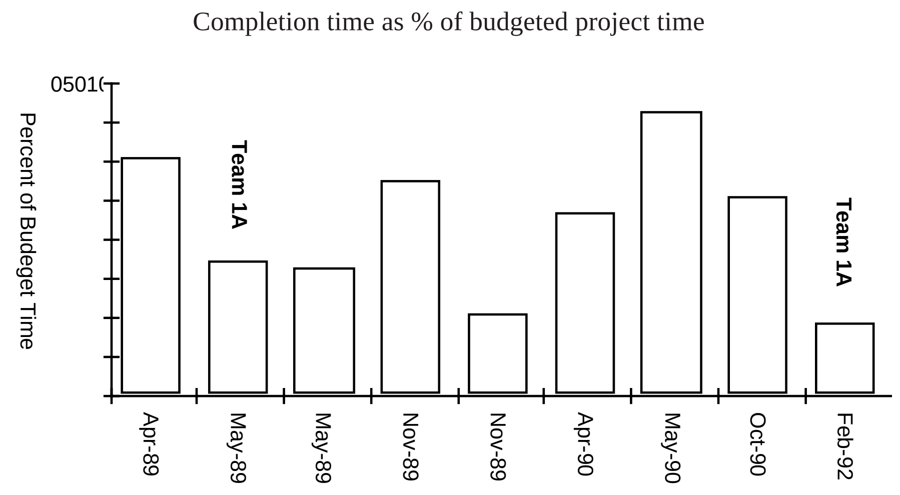


Figure 3

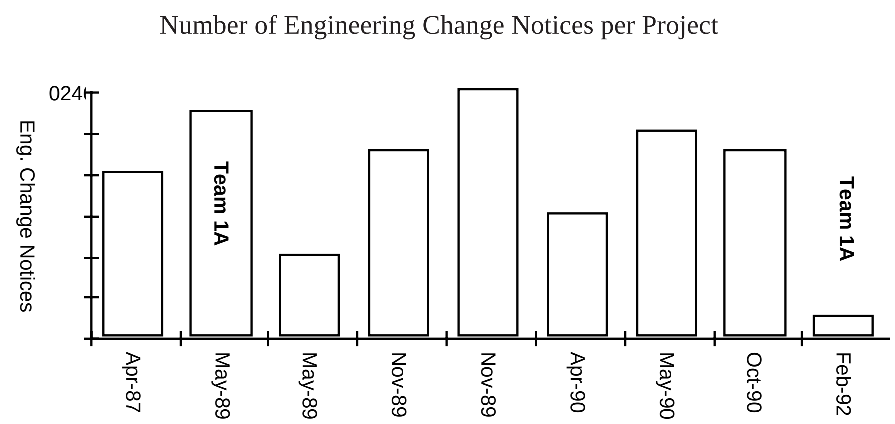


Figure 4

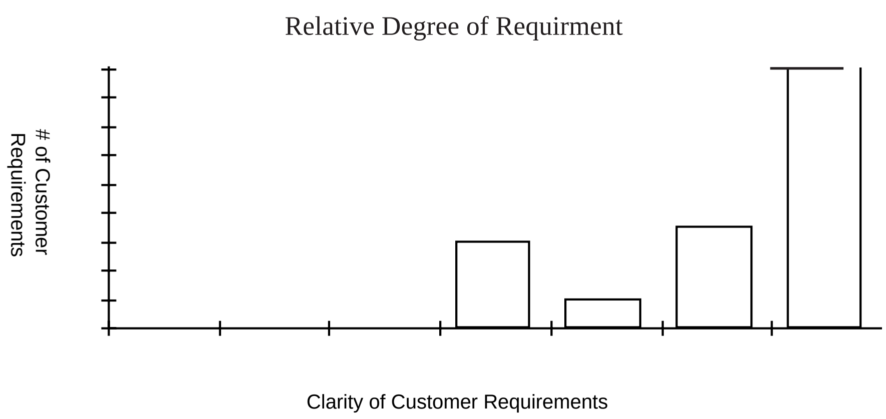


Figure 5

this evidence of Concept Engineering's effectiveness is collaborated by the fact that all companies which started a Concept Engineering project in the spring of 1992 had multiple projects underway one year later. By 1994, Concept Engineering was being applied to approximately two dozen concept development efforts in ten organizations within the Center for Quality Management. The expanded application base includes small start-up entrepreneurial concerns, a Fortune 50 company, and a variety of organizations including state and federal government agencies. Furthermore, a very active user group meets monthly to apply the Plan-Do-Check-and-Act cycle in pursuit of continuous process improvement.

2.4 Evidence of Improved Theory

In this research effort, the problems investigated were those which product development professionals in the firms were facing. As a result of the collaboration and the investment made by the organizations toward researching "their" problems, the desire to implement "their" solutions became a built-in incentive. This provided the opportunity for a detailed inter/intra company comparative analysis of the product concept decision process.

This comparative study observed that there existed a fundamental difference between the product concept decision processes for teams focused on the "time" in "Time to Market" and teams focused on "market." After more than a year and a half of field observations, interviews, and analysis, key variables associated with the product concept development decision process and Time-to-Market dynamics were identified using the inductive system diagram process (Burchill and Kim 1993).

"Time" Over "Market"

Decreased time-to-market has been identified as a key ingredient in successful new product development (Takeuchi and Nonaka 1986, Mansfield 1988, Gupta and Wilemon 1990). There are significant market share benefits to early-market entrants (Urban et al. 1986), as well as considerable penalties for being late to market. For example, McKinsey and Company claims that shipping a product six months late can reduce lifecycle profits by one third in high-growth, short lifecycle markets (Reinertsen 1983). Additionally, competitive pressures reduce product life cycles, further increasing the pressure to reduce product development time (Mansfield 1988, Schmenner 1988, von Braun 1990).

A team focused on the "time" of "Time to Market" is one which attempts to specify the design objectives in an accelerated period of time. This team is under a great deal of pressure for progress, and it displays a willingness to make decisions with recognized data deficiencies in order to meet the (usually aggressive) development schedule. Participants orient their analysis of the issues to support their often preconceived perspectives of the product concept. Partisan behavior, in which individuals stake out positions and vigorously defend them, dominates the development team meetings. The engineers discuss product attributes from the perspective of technology opportunities and constraints. Marketers discuss product attributes with respect to market segments and competitors. Although both groups are at the same meeting, they aren't participating in the same process: The languages are different, the relative emphasis on product attributes is often different, and individuals will periodically disengage from the decision-making process based on discussion subject matter. Ultimately product concept decisions are ultimatly made, but it is difficult for the entire team to recreate and defend the decision choices to the management review board. When all is said and done, one or more groups lack commitment to the product concept, and team members already have a high expectation that the final product will differ from the initial concept.

"Market" Over "Time"

Considerable research on recent successes in product development highlights the central importance of understanding user needs, orthe market. (See, for example, Rothwell et al. 1974, Cooper and Kleinschmidt 1986, Pavia 1991). Houston (1986) states that customer focus, profits, and organizational integration are frequently associated with the marketing concept and have become synonymous with having a customer orientation. Shapiro (1988) describes the characteristics of the market-driven company to include widespread dissemination of important buying influence information, interfunctional decision making, and committed coordinated decisions. Narver and Slater (1990) state that marketing orientation consists of three behavioral components: customer orientation, competitor orientation, and interfunctional coordination. In an extensive review of the literature, Kohli and Jaworski (1990) found three fundamental themes related to market orientation: customer focus, coordinated marketing, and profitability. Their 62 field interviews, however, conducted with a diverse cross-section of managers, found that managers felt profitability was a consequence—

not a condition—of market orientation.

A team focused on "market" is one which attempts to develop credible design objectives that reflect a deep appreciation of the customer's requirements. The team is characterized by an orientation of decision analysis that maximizes customer benefit. In development team meetings, every individual participates in all aspects of the decision process. Members frequently put their statements into the context of specific customer encounters to clarify or emphasize their positions. Relevant issues and information regarding design objectives are considered to everyone's satisfaction before the team moves on to subsequent development activities. This cross-functional collaboration, which creates a common appreciation of the design objectives, is apparent when the team presents the product concept to the management review board. All team members display a commitment to the product concept . When required to justify their choices, they can credibly trace the decision process.

The observed variable relationships are outlined in the table below. (See Burchill and Fine [1994] for a more complete description of these variables and their relationships.) (See table at top of next page.)

The dynamics of a "time" versus "market" orientation in the expression "Time to Market" may be easier to understand by representing the data in the table above as a high-level inductive system diagram.[5] (See figure at bottom of next page.)

A relative emphasis on time increases pressure for progress and reduces the opportunity for systematic concept analysis. This reduction in systematic analysis decreases the labor requirement and consequently the concept development time. However, it also decreases the supporting evidence needed to justify concept decision choices. The resulting reduction in design objective appreciation subsequently reduces substantive accomplishments, since time and resources are spent on tangents and detours in downstream development efforts. The net result is increased development time and increased pressure for progress.

A "market" orientation decreases pressure for progress (relative to the time-oriented development teams) and increases systematic concept analysis. The increase in systematic concept analysis increases supporting evidence, but this simultaneously increases the labor requirement and concept development time. However, the resulting increase in design objective appreciation focuses development efforts, thereby increasing substantive accomplishments. This will in turn decrease development time and pressure for progress.

This inductive system diagram can describe a vicious or virtuous cycle of product concept development, depending on which decision variables are emphasized. A vicious cycle begins when pressure for progress leads to incomplete concept analysis; the resulting lack of requirement clarity and credibility leads to low concept commitment and misdirected development effort. Ultimately, the waste and reworking increases development time further, which increases pressure for progress. The diagram can also describe a virtuous cycle in which an increase in market orientation leads to a more thorough analysis, which is grounded in the context of the customer'' environment. In turn, commitment to the product concept is higher, and misdirected development effort is reduced. Ultimately development time is reduced, thus decreasing pressure for progress and labor requirements.

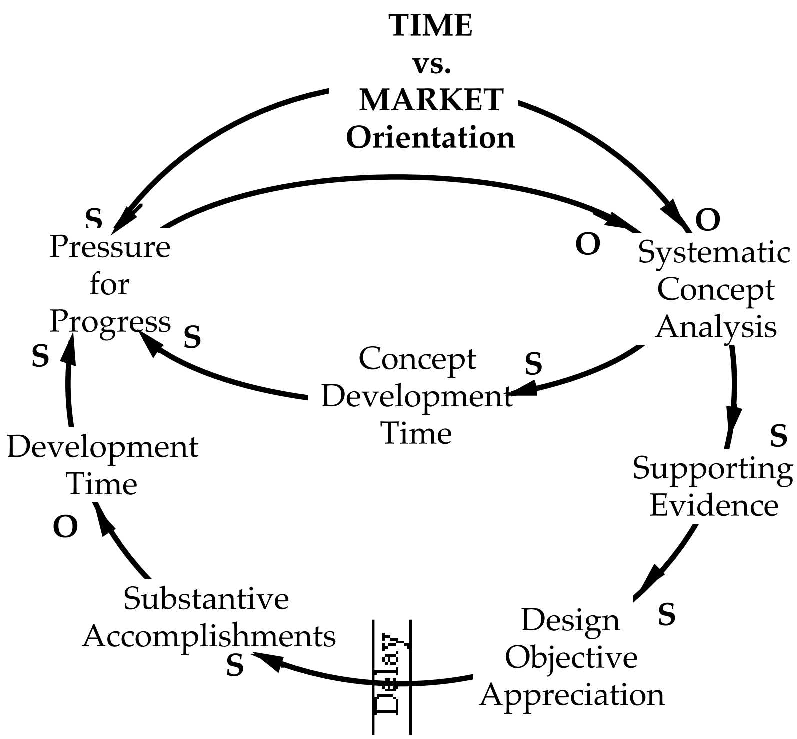
The dynamics described in the diagrams above represent a classic "Fixes that Fail" archetype (Senge 1990) in which the unintended consequence of a problem solution over time contributes to the problem it was trying to solve. In this case the emphasis on reducing the time to market decreases concept development time but inadvertently reduces design objective appreciation, resulting in waste and rework in downstream development activities: increasing total development time. On the other hand, the fundamental solution, an emphasis on market, can lead to a common appreciation of the customers' requirements, reducing total time by saving the time otherwise spent on misdirected downstream development efforts. (The data from Team 1A, presented in Section 2.3, is consistent with these dynamics.)

3.0 Research Agendas of Collaborating Partners: Benefits and Pitfalls

In the previous section we presented the Concept Engineering case study, illustrating the benefit of mutual learning in action: an improved product development outcome as a result of an improved product development process. Additionally, we presented some significant insights from this study that have implications and applications beyond Concept Engineering. Our study developed concepts and showed preliminary evidence of the validity of these ideas; however, despite

[5] Each pairwise variable arc is annotated with an indication of the causal change between two factors. An "S" indicates that two factors move in the same direction; that is, as one variable increases, the other variable also increases (all other things being equal). An "O" indicates that variables move in opposite directions: as one factor increases, the other factor decreases.

	TIME to market orientation	time to MARKET orientation
Decision Variables		
Pressure for Progress	Higher	Lower
Systematic Concept Analysis		
Prejudiced Perspective	Higher	Lower
Functional Integration	Lower	Higher
Analysis Depth	Lower	Higher
Objective Function		
Supporting Evidence		
Contextual Awareness	Lower	Higher
Process Participation	Lower	Higher
Traceability	Lower	Higher
Design Objective Appreciation		
Requirement Clarity	Lower	Higher
Requirement Credibility	Lower	Higher
Substantive Progress		
Concept Commitment	Lower	Higher
Misdirected Effort	Higher	Lower
Constraints		
Labor-hour Requirement	Higher	Lower



its original intentions, the study did not meet the requirements of rigor traditionally applied to scientifically validating hypotheses.

A potential conflict exists for the partners in a collaborative research effort. Organizations which are under competitive pressures to improve performance will readily sacrifice research rigor for positive business performance. Industry is willing to accept a level of proof which is considerably less than that required by the academic community. One successful "live" case study—or even a good story from a respected "guru"—can convince an executive to adopt a particular process or strategy innovation. On the other hand, in academia one desires many case studies under very controlled conditions in order to obtain the statistical significance required to truly demonstrate validity for publication in academic journals. In the Concept Engineering case, the company sponsors were committed to supporting the research agenda and understood the importance of rigor in order to achieve valid and reliable research results. Nevertheless, all participants clearly understood up front that research rigor was secondary to business performance.

In this research effort, one primary objective was to develop a substantive theory to clarify the product concept decision process. In the proposed design, each of three participating companies would identify two pairs of development teams. Each pair would be approximately similar in scope, demographics, and history. One team from each of the six pairs would be randomly assigned to use the Concept Engineering process, while the other team would use Pugh's Concept Selection process (Pugh 1981), which is similar to Stage 5 of the Concept Engineering process. Every team would be observed and assessed using methodologies and instruments consistent with valid and reliable field-based research. The actual implementation fell far short of the research design. While this clearly has implications for the Concept Engineering validation efforts that were originally designed for the study, it did not seriously disrupt the research objective of developing a grounded, substantive theory for the product concept decision process. However, the challenges and problems experienced in this study were valuable toward highlighting some of the difficulties associated with experimental research designs in organizational settings.

All three companies that agreed to participate in the study in the fall of 1991 sent representatives to the two-week training session in January 1992. One company (hereafter referred to as Company 1) began their first CE effort in February 1992; the second company (Company 2) began their first CE effort in April 1992; and the third company (Company 3) began in May 1992. It was immediately obvious that the first of each company's two development team pairs were not put together randomly. In Companies 1 and 2, the appropriate managers selected for their initial team pairs members they believed had a high likelihood of success. In Company 3, although it was not immediately apparent, the selection and staffing of the first of the pair of teams created a high likelihood of failure. This conclusion is validated by senior managers in Companies 1 and 2, who specifically stated that they needed an initial success, and also by the vice president of engineering in Company 3, who "felt" Concept Engineering was a ploy by Marketing to shift their work to Engineering. In short, there was no random assignment in this study to address some of the traditional threats to validity (selection, maturation, etc.).

The original design of our research assumed that many teams would be working simultaneously; the calendar time associated with each team was estimated to be approximately four months. In execution, each company started the first Concept Engineering effort and then waited for preliminary results before committing itself to support a second team. In hindsight, it became clear that companies would be hesitant to commit a second team until the first team could be evaluated, at least provisionally. (This illustrates what might be a fundamental problem with the way companies approach process improvement: they either don't understand or are unwilling to make the investment for statistical validation of "improvements.") Furthermore, the length of time required for each team to complete its work was a surprise; each team took about six calendar months to complete its work. Given the amount of time available to the researcher, this delay had enormous implications for the scope of the research. The largest contributing factor to the increase in project time was the delay before starting. Once a team decided to apply Concept Engineering, several months might pass before meaningful effort was applied to the project, primarily due to other the participants' commitments to other projects. This problem resulted in fewer Concept Engineering teams to be available for the study than had been intended in the design.

With respect to the control groups, Companies 1 and 2 also provided non-CE comparison teams in the spring of 1992. These teams were assigned on the basis of availability rather than on matching characteristics of scope, demographics, etc. In company 1, the comparison investigation was short-lived; the project practically exploded into the laboratory after two months. Subsequently the division director was impressed enough with the results of the first CE development team that he declared that all subsequent sponsored development efforts would use Concept Engineering. In Company 2, the investigation of the comparison team (not well matched in scope to the prior team's effort) did proceed through to design approval, although the team did not use Pugh's concept selection process. In Company 3, the chief operating officer carried out an extensive week-long study of Concept Engineering and declared that all company-sponsored development efforts would be required to use it in order to proceed through the company's Product Review Board process. Because of these three different company approaches, the study of matched comparison groups in the research design did not materialize. Note that in Companies 1 and 3, validation in the form of replication was not required to declare the method "valid by management decree." It is also worth noting that in Company 3, other divisions of the company which did not participate in the study ignored the chief operating officer's direction.

Ultimately, therefore, the number of cases investigated proved significantly smaller than anticipated. Any attempts to evaluate the relative effectiveness of Concept Engineering were now subject to considerable threats from rival plausible hypotheses. Still, the primary researcher was able to extensively observe five development teams in four companies that used Concept Engineering and two development teams in two companies that did not. In addition, in Companies 1 and 3, it was possible to make historical comparisons with the previous project completed by the development teams assigned to use Concept Engineering. For each development team studied, the primary researcher typically attended every scheduled meeting, approximately 80 hours per team, and conducted two to three in-depth, open-ended, individual interviews with team members and their managers; each interview lasting at least one hour. Therefore, although they lacked random assignment, the available teams did provide a rich comparative setting—with many noteworthy similarities and dissimilarities—to explore for generating theories if not for the validation of theories.

This case study illustrates how the demands (realities) of the organizational setting can easily override the rigor requirements for statistical conclusion validity; however, this case also illustrates how the willingness of corporate collaborators to fulfill the spirit, if not the letter, of their commitment can produce unexpected benefit to both the corporation and the researcher. The readiness with which corporate sponsors made their time available is best illustrated by one instance in which the researcher was able to follow an investigative trail from a team member to a team leader, to the vice president of engineering, to the group president, and to the chief operating officer, during which one to two hours was spent with each individual no more than two days after a request for an interview. Additionally, the researcher was granted extensive access to highly sensitive (company confidential) information in all of the participating companies. The development of new knowledge regarding the product concept decision process is a direct result of the extensive insight and information provided by the company collaborators.

4.0 Conclusion

This research effort realized improvements in practice and theory through mutual learning. None of the participants in this initiative could have predicted the outcome or the path this project took. In the beginning the individual collaborators may have had a clear idea of what they and/or their company intended to gain from this effort, but it had not been clear if the individual objectives would be aligned to form a consistent group goal. By understanding the "floors and ceilings" on our individual goals, it was possible to introduce flexibility into our approach with no significant sacrifice to the participants. These floors and ceilings allowed us to constrain (although admittedly not always easily) the changes in direction which the teams took such that all of the participants could recognize we were consistently making substantive progress.

Steady progress was achieved through disciplined use of the Plan-Do-Check-Act cycle, establishing meaningful deadlines to create a sense of urgency and acknowledging the substantive contributions of all participants. Because each company and/or individual brought different competencies to the team at any given time an imbalance existed between what some participants were giving and what other participants were taking; however, in the spirit of mutual learning, everyone understood that in the long run each participant would make his or her contributions as appropriate. This effort was a lot like a relay race: The participants took hold of the baton when it was their turn and then worked to stay ahead of the rest of the pack. The commitment to mutual learning is what created the participants' sense of duty to actively seek out opportunities to make substantive contributions to the effort. It was the collective contributions which allowed the participants as a whole to achieve more than any one of us could have accomplished individually—and to do so relatively quickly.

Additionally, we learned much about the requirement for successful mutual learning. Mutual learning required the collaborators to be pragmatists, to understand which differences in intent and approach really make a difference. Academic research needs to understand the realities of business environments; business people need to appreciate the value of academic rigor. In fact, this observed implicit tension between practitioners in business and academic researchers leads us to the following thoughts about possible ways to discover, validate, and diffuse improved methods.

Without paying explicit attention to improving methods, development tends to take place in isolation, with each company or development team using its own frequently ad hoc methods. Through trial-and-error and occasional informal reflection variations on the team's methods are somtimes found. Sometimes these variations will come into common use within the group, perhaps based only on the subjective impression that the methods are an improvement. Such approaches are typically conservative, maintaining the use of "tried and true" methods, rather than searching for dramatic improvements. Improvements may happen over time, but they typically come from almost "accidental" variations in application. While there may be many such development groups at different companies in a geographic region or within an industry sector each group operates more or less in the isolated way described above. When the separate or isolated groups do learn from each other, it is often the result of passive or even negative collaboration. For example, Group A may notice how Group B is doing something in a better way without the active help of Group A; perhaps Group B is also trying to hide its efforts from Group A. We characterize this approach as "local learning", with "passive diffusion," and "minimal validation." This approach is illustrated in quadrant A of figure 6 (see facing page). (The two axes in figure 6 indicate the degrees of collaboration among companies and of participation of formal researchers.)

As the academic researcher tries to validate a hypothesis about methods that are particularly effective, he/she often observes a number of such isolated groups. This situation is illustrated in quadrant B of Figure 6. In observing these groups, the academic researchers usually take pains not to transfer information among the groups or to "taint" the groups by providing them with the researcher's theoretical ideas; to do so would jeopardize the validity of their academic research conclusions. However, the researchers do actively publish their results, and thus isolated development groups may study and learn improved methods from these publications. Thus, the academic researchers provide communication between the isolated groups, actively sharing those methods that the groups don't otherwise provide among themselves. However, the methods that the researcher validates tend to be only those methods that have somehow evolved "organically," i.e., this research approach is often not aimed at initiating rapid improvement in development methods; it is more often aimed at proving which of those methods already in use actually work. Also, while the results may be actively published, the researcher may be passive about whether any group learns from the publications. We characterize this approach as "limited learning" with "thorough validation" of a limited set of ideas and "limited diffusion" primarily through academic journals and university classrooms.

Today, many development groups are recognizing the need to rapidly change and improve their development methods, rather than waiting for academic validation of some of the methods that are already in use. This situation is illustrated in quadrant "C" of figure 6. Thus, consortia like the Center for Quality Management explicitly and rapidly share their development methods, successes, and failures, together looking for improved methods. We call this a "mutual learning" situation. If one company aggressively sought improvement rather than conserving existing methods, there is a significant speed-up in the generation and development of new ideas and methods; having a number of companies working together, aggressively seeking improvement, and sharing experiences and results further speeds up the development of new ideas and methods. In these situations, the collaborating companies also have the ability to develop common mental models about how development should be done. Unfortunately, in such situations the formal validation of methods developed and used may be weak.

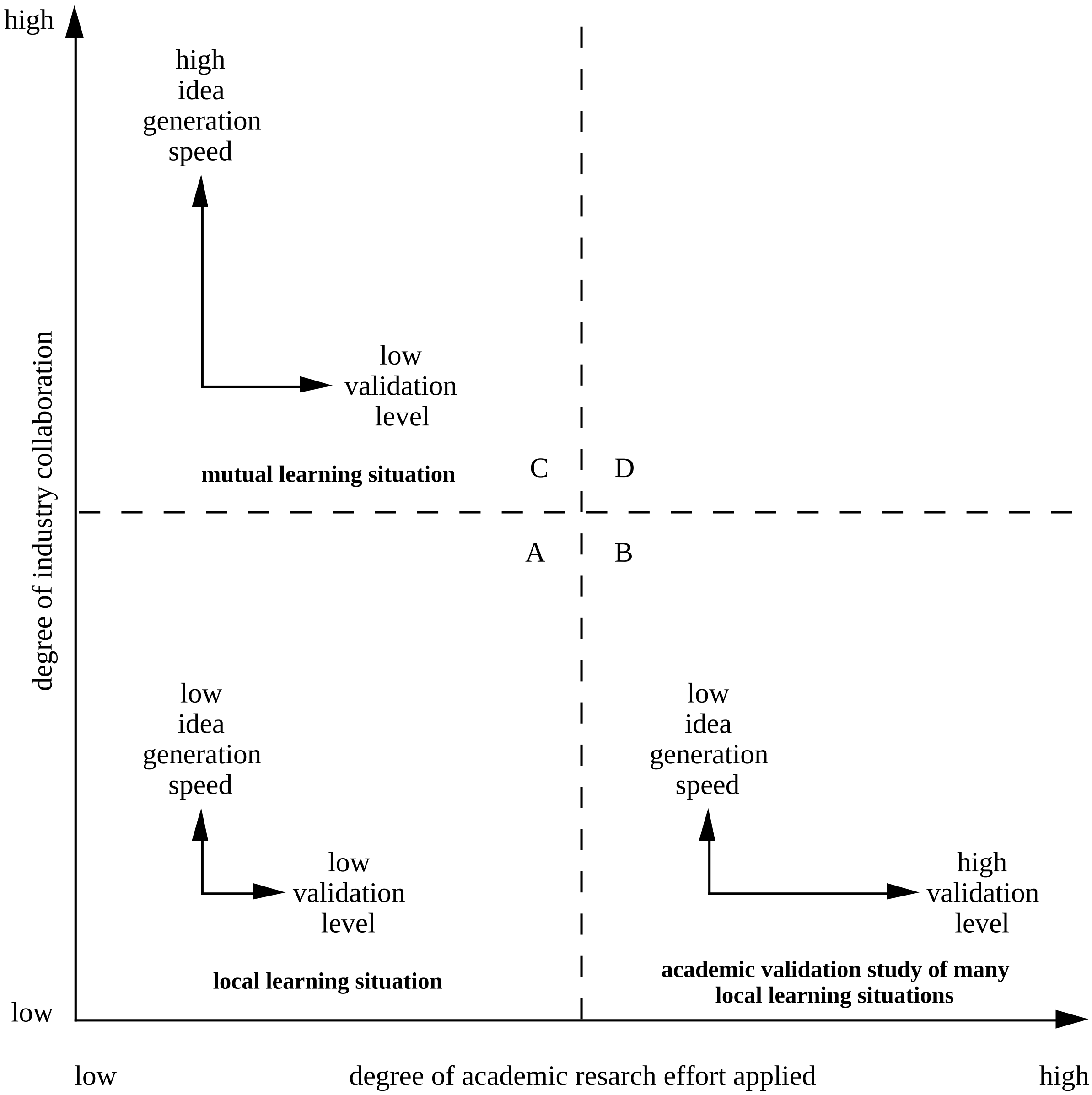


Figure 6

Returning to quadrant A, when there is local learning without academic participation, the speed of generation of new ideas and methods is slow (there is essentially a conservation approach), and little effort is made to validate the methods that are used. In this case, the overall speed of learning of valid methods is low as shown in figure 7 (next page). Moving to quadrant B of figure 7, traditional academic study of many local learning situations leads to big gains in validation and some gains in speed of idea generation by helping cull bad methods and diffusing valid methods and thus some increase in speed of valid learning. If one instead moves from quadrant A to quadrant C of figure 7, one sees a great increase in the speed of idea generation and some improvement in validation, because companies are able to share new ideas and benchmark their results against each other. In this situation there is also some increase in speed of valid learning.

A study of figures 6 and 7 compels one to comtemplate a move to quadrant D. We believe there will be great benefit if business practitioners and academic researchers can work together to move to quadrant D of figure 7. In this situation, the companies generate the ideas quickly, and the academic researchers are there to vali-

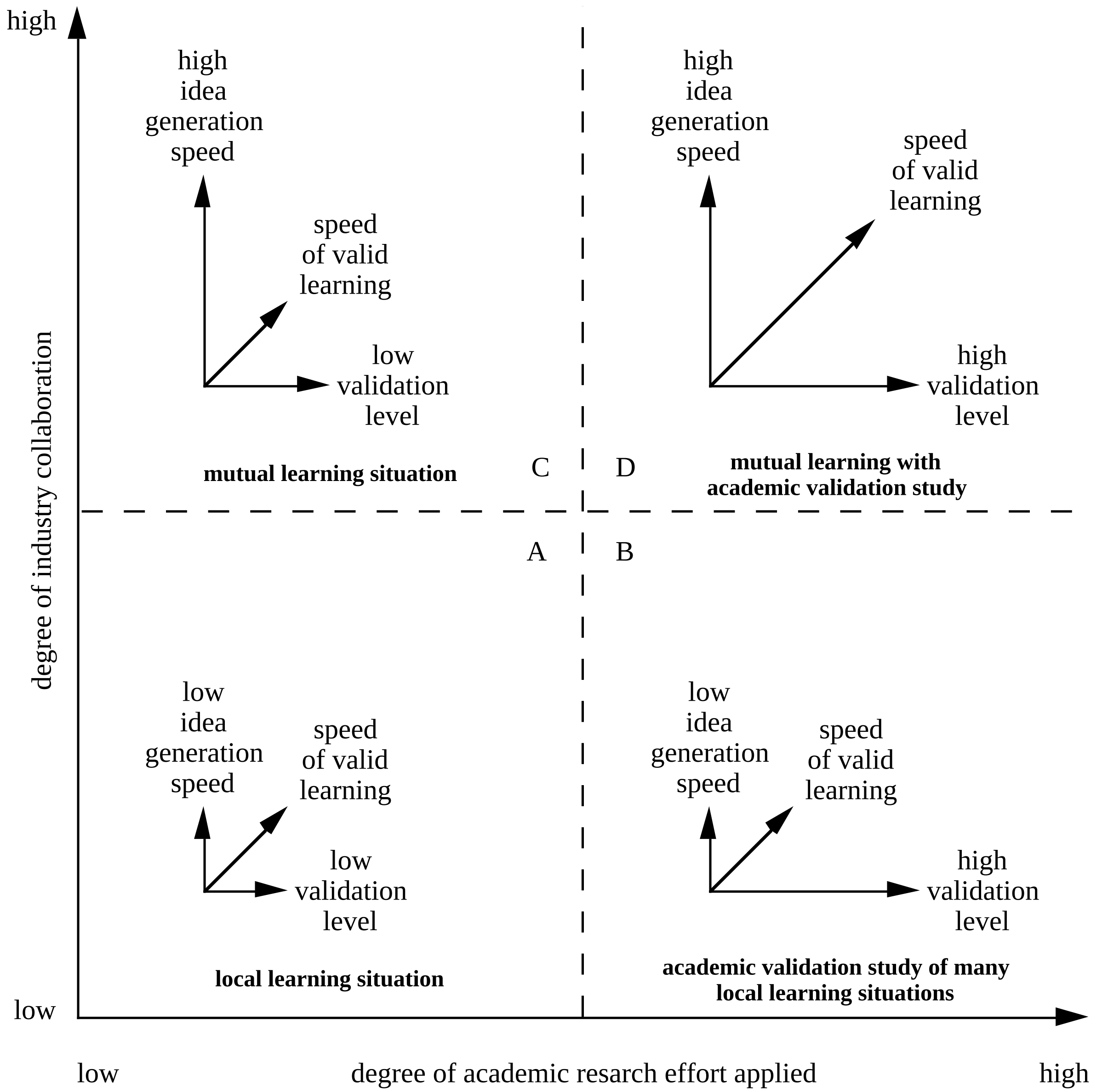


Figure 7

date the findings, especially if the companies are supportive of the requirements for validation, such as setting up objective comparative studies. By this business/academic collaboration, new ideas may be generated quickly, validation levels will be high, and this will in fact make idea generation more effective, by culling out the bad ideas more quickly.

In this paper we have described a case study that indicates the potential large gains possible through mutual learning among businesses. We hope this collaboration can be extended to include academic researchers with the explicit goal of helping generate beneficial change while maintaining scientific objectivity, thus taking a quantum step ahead in how our development methods are improved.

Comments are both welcomed and appreciated. All comments may be forwarded to the Center for Quality Management. ■

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