Knowledge Creation in New Product Development Projects[†]

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In this article, the authors develop and test hypotheses relating the four knowledge creation modes of socialization, externalization, combination, and internalization as performed during the concept and the development phases of new product development projects to new product success. Using data from 94 new product development projects, they find that socialization during the concept phase and combination during the development phase are positively related to new product success but that externalization during the concept phase as well as socialization and internalization during the development phase are negatively related to new product success. Implications for theory and practice are discussed.

Keywords: *knowledge creation; new product development*

The knowledge management literature has largely focused on understanding how *existing* knowledge should be located, stored, shared, and so on, within new product development (NPD) projects. However, the development of innovative products depends on the creation of

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new knowledge (Madhavan & Grover, 1998). As Nonaka and Takeuchi pointed out, "Understanding how organizations create new products . . . is important. A more fundamental need is to understand how organizations create new knowledge that makes such creations possible" (1995: 50). From this perspective, returns can be appropriated by the firm when the creation of new knowledge leads to successful new products (von Krogh & Grand, 2002).

Management scholars have repeatedly argued that innovativeness is driven by new knowledge and that new scientific and technological knowledge coevolve with new products (Johannessen, Olaisen, & Olsen, 1999; Leonard-Barton, 1992; Madhavan & Grover, 1998; Pitt & Clarke, 1999; Un & Cuervo-Cazurra, 2004). Similarly, a recent survey indicates that companies expect the management of knowledge to "strengthen their capability to innovate" and to "shorten the time to respond to market needs" (Knowledge Bridge Consulting, 2000: 13). Hence, practicing managers and researchers alike perceive a link between knowledge creation and innovation processes. The underlying proposition is that the better a company is at creating knowledge, the more value it can deliver through the generation of superior products.

Nonaka and colleagues (Nonaka, Byosiere, Borucki, & Konno, 1994; Nonaka & Konno, 1998; Nonaka & Takeuchi, 1995; Nonaka, Toyama, & Konno, 2000) conceptually link four knowledge creation modes (i.e., socialization, externalization, combination, and internalization; we provide more detail on these below) to the various steps of the product innovation process, largely sequentially. For example, their analysis stresses the importance of externalization in the concept phase and of combination in the development phase of the process. The possible effects of the other three knowledge creation modes as performed in each phase, however, are not considered in their discussions. This leaves important questions open:

First, beyond the one mode specified for a certain phase, how are the other knowledge creation modes related to new product success? Research in the innovation management and knowledge management literatures points to, for instance, the relevance of socialization in the concept phase (Crawford, 1997) and the importance of externalization in the development phase (Leonard & Sensiper, 1998; Madhavan & Grover, 1998). Second, are the four knowledge creation modes as performed in the concept and development phases of NPD projects always *positively* related to new product success? Where Nonaka and colleagues argue that a particular knowledge creation mode is important in a particular phase of the product development process, they generally imply that it has positive effects.

This research addresses significant gaps in the literature. First, although some contributions have begun to conceptually focus on aspects of the knowledge-innovation link (Helfat & Raubitschek, 2003; Nonaka, 1994; Nonaka & Takeuchi, 1995; Pitt & Clarke, 1999; von Krogh, Ichijo, & Nonaka, 2000), a detailed theoretical concept and necessary empirical evidence are still missing (Alavi & Leidner, 2001). Our research builds on Nonaka's theory of knowledge creation by specifying how all four knowledge creation modes operate in the concept and the development phases of NPD projects to increase or decrease new product success. Hence, our analyses go beyond sequentially and positively equating one knowledge creation mode with one phase of the NPD process.

Second, Nonaka's discussion of the four knowledge creation modes pertains chiefly to the organizational level of analysis, that is, organizations as innovation systems with a generic product development process from idea generation to market launch. For the purposes of this

article, we focus our conceptual and empirical analyses on the project level, recognizing that the project provides the primary context for the performance of the knowledge creation modes. Moreover, this study's dependent variable (i.e., new product success) is also a project-level outcome.

Third, this research provides, to our knowledge, the first quantitative empirical test relating Nonaka's knowledge creation modes to the success of organizational NPD efforts, thereby also creating and validating measurement scales for assessing the knowledge creation modes. Prior empirical research in the area of knowledge creation and innovation processes has focused on other issues, such as knowledge creation during idea generation (Lee & Choi, 2003), technical problem solving (Corti & Lo Storto, 2000), or the effect of networks and networking on knowledge creation in NPD (Hansen, 1999; Swan, Newell, Scarbrough, & Hislop, 1999). Furthermore, prior research has investigated the transfer and recombination of existing knowledge as one option for organizational-level knowledge creation and innovation (Boisot, 2002; Dougherty, 1992; Galunic & Rodan, 1998; Gupta & Govindarajan, 2000; Kogut & Zander, 1992; Kostova, 1999; Zander & Kogut, 1995).

Beyond these contributions from the knowledge management literature, our work also builds on the research stream of organizational learning (Fiol & Lyles, 1985; Levitt & March, 1988) and its relationship to innovation (Adams, Day, & Dougherty, 1998; Brown & Duguid, 1991; Garvin, 1993). Core concerns of this literature are the sharing, transfer, and dissemination of knowledge at a corporate level, enabling the organization to improve its adaptation to the environment (Crossan, Lane, White, & Djurfeldt, 1995; Magalhaes, 2001). Drawing on such prior work, this research investigates knowledge creation at the project level, linking the behavioral characteristics of the four knowledge creation modes to the success of new products.

The following discussion starts with a brief characterization of the concept and the development phases of NPD projects. Next, we derive hypotheses linking the knowledge creation modes as performed in these two phases of an NPD project to the success of the new product (i.e., the degree to which the new product reaches revenue and profit objectives). Our analysis does not address possible intertemporal relationships between the knowledge creation modes in both phases. Moreover, the arguments regarding the relationship between the knowledge creation modes and new product success are independent of how successful preceding steps of the innovation process were. We test our hypotheses using data from project members and managers of 94 NPD projects.

Theory

The Concept and Development Phases of NPD Projects

For this research, we distinguish between the concept and the development phases of NPD projects in arguing for the effects of the four knowledge creation modes on the success of the developed product (Chiesa, Coughlan, & Voss, 1996; Clark & Fujimoto, 1991; Cooper, 2001; Souder & Moenaert, 1992).

In the *concept phase*, initial product ideas are developed into product specifications, that is, a product concept in the form of descriptions of the future product's major properties such as functionality, durability, cost, and so on. A number of strategic decisions are being made during this phase regarding such aspects as product features, target markets, competitive positioning, and so forth (Di Benedetto, 1999). The aim is to move from a more general idea, such as to develop a mobile phone with an inbuilt camera, to a set of desired product characteristics, such as phone and camera functionalities, weight and size, and optical design properties. This regularly entails the creation of concept alternatives and their evaluation for economic and technical feasibility (Cooper, 2001; Souder & Moenaert, 1992). The emphasis, however, remains on describing the future product in its key dimensions (i.e., important features for market success), rather than identifying technical solutions to their implementation.

In the *development phase*, the product concept's specifications are translated into design plans, and the actual technical development work is carried out (Souder & Moenaert, 1992). This phase is thus characterized by the search for, and implementation of, concrete technical solutions to meet the demands set out by the product concept (Cooper, 2001). Extending the example of the mobile camera phone, the NPD team now considers various materials, colors, and shapes to implement the set specifications regarding optical and tactile properties of the new product. Given the company's desire to launch the new product on the market, the project team is now "under the gun" to solve technical problems and develop and test prototypes, while meeting goals regarding schedule, budget, and quality specifications. This phase regularly involves much larger resource commitments than the concept phase (e.g., prototype building and testing) and is therefore generally characterized by tight project management with frequent milestones and budgetary controls.

It should be pointed out that these project phases are not always entirely distinct, and activities characterizing one phase do not necessarily cease completely in another. It is, however, the primary objectives and the project characteristics that shift sequentially. The concept phase is about defining a new product that differentiates itself from existing products and thus offers new value propositions to users. The development phase is about meeting budget and schedule constraints as the concept is being translated into the marketable product. The transition from the concept to the development phase is typically formalized, involving (comparative) evaluation of product concepts and resource allocation commitments to those concepts that are being pursued for development.

As we argue in detail below, these differences between the concept phase (i.e., defining new value propositions; less resource commitment) and the development phase (i.e., implementing technical solutions; high resource commitment) provide the basis for our hypothesized relationships between the knowledge creation modes and new product success.

Knowledge Creation in NPD Projects

This research builds on the conceptualization of knowledge creation as proposed by Nonaka and several coauthors (Nonaka, 1994; Nonaka et al., 1994; Nonaka et al., 2000; Nonaka & Takeuchi, 1995). These authors specify four knowledge creation modes as the processes of interplay between tacit and explicit knowledge that lead to the creation of new

knowledge: socialization (tacit to tacit), externalization (tacit to explicit), combination (explicit to explicit), and internalization (explicit to tacit). This conceptualization is often referred to with the acronym SECI.

Socialization yields new tacit knowledge that is built through *informal* interaction, that is, through an exchange of tacit knowledge. It occurs by spending time together, sharing joint hands-on experience, working in the same environment, and in informal social meetings (even outside the workplace) between members of an organization or, beyond organizational boundaries, with customers, suppliers, and affiliated firms. *Externalization* is an act of codifying or converting tacit knowledge into explicit knowledge, characterized by more *formal* interactions such as expert interviews or the sharing of lessons learned in a previous project. *Combination* refers to the process by which sense is made of the relationships between previously unrelated knowledge domains. It involves collecting, editing, sorting, and synthesizing existing explicit knowledge and subsequently disseminating the new knowledge. *Internalization* is the process of applying explicit knowledge, thereby absorbing, embodying, and converting it into individually held tacit knowledge (Nonaka et al., 2000; Zahra & George, 2002). Lessons from experience and experimentation become implicitly embedded into the minds of individuals within the firm (Kale & Singh, 1999).

It is important to note that our arguments pertain to the different knowledge creation modes as sets of behaviors (Cyert & March, 1963), rather than to the benefit or detriment of tacit or explicit knowledge in any phase of the NPD process. As our discussions below highlight, both tacit and explicit knowledge are important in the concept and the development phases. However, we argue that the modes by which new knowledge is created have differentiated effects depending on the phase of the innovation process. Hence, the basis for our arguments is not the distinction between tacit and explicit knowledge but instead the different behaviors characterizing the four knowledge creation modes as described by Nonaka and Takeuchi (1995).

Hypotheses

Socialization. A central challenge in the concept phase is fostering the wide involvement of various functional units of the organization and important external parties such as future customers and key suppliers (Clark & Fujimoto, 1991; Leonard & Sensiper, 1998). We argue that socialization of a variety of individuals from such groups both inside and outside the organization, and with different knowledge and expertise, plays a key role during the concept phase. Such informal interaction allows the team members to develop a common understanding of the new product idea and thus to specify features or characteristics other than those known from existing products (Clark & Fujimoto, 1991). Team members who have together built up a shared understanding of the product idea and its objectives are in a better position to integrate their diverse knowledge bases and, with this, to develop an innovative product concept. For instance, team members gain a better comprehension of each other's and the customers' perspectives on the product idea and can thus explore new product characteristics that can satisfy such different viewpoints. Therefore, socialization is a key knowledge creation mode that gives rise to innovative and well-orchestrated product concepts.

Hypothesis 1a: Socialization during the concept phase is positively related to new product success.

Although we argue for a positive role of socialization in the concept phase, we suggest that it will play a negative role in the development phase. In this phase, the focus is on the efficient implementation of the product concept, the design of all product modules, and the assembly of initial prototypes to arrive at a new product ready for market launch. Given this phase's emphasis on meeting quality, time, and schedule objectives (Griffin & Page, 1993; Montoya-Weiss & Calantone, 1994), formal project planning and control (e.g., the specification of deliverables and deadlines) ensures project progress. Socialization, characterized by informal colocation and observation, seems less fitting given the requirements of this phase (Madhavan & Grover, 1998; von Krogh et al., 2000). If, however, a project team does display this knowledge creation mode in the development phase, it is likely to indicate that the team members have not been able to commit to a specific product concept and successfully transition into the development phase with its requirements regarding project progress (Hoegl, Weinkauf, & Gemuenden, 2004). This, in turn, seems most relevant for new product success in terms of revenue and profits as it likely delays market launch, increases costs, and/or limits qualitative features of the product such as functions and performance characteristics. Hence, we propose the following:

Hypothesis 1b: Socialization during the development phase is negatively related to new product success.

Externalization. The key objective of the concept phase is the definition of a new product that is differentiated from existing products. An emphasis on externalization in this early phase is likely to be counterproductive as formal meetings with customers or technology experts will likely produce descriptions of current customer requirements and technological possibilities, rather than new and different value propositions. For instance, as representatives from R&D, manufacturing, and marketing gather in a meeting room to discuss what is believed to be a promising product idea, the thoughts expressed are likely to represent only the present state of the art. Such formal settings may intimidate participants, who, wanting to avoid appearing ridiculous, put forward merely "generally accepted knowledge" (Nonaka & Takeuchi, 1995). This, in turn, is likely to leave the participants with a sense of confusion and a lack of direction, resulting in less engagement and interaction among key knowledge contributors from different areas. The notion that a strong emphasis on externalization during the concept phase is counterproductive was also predicted by Crawford (1997). He describes an "untrue truism," the requirement for a financial analysis to be carried out as early as possible to avoid wasting money on poor projects. He argues that this philosophy leads firms to make complex financial analyses early in the concept phase, although the numbers still are inadequate. This information deficit, however, is likely to be compensated for by decision makers' cognitive heuristics and biases (Schwenk, 1986). From this perspective, such "forced codification" provides an unreliable information basis. Hence, we propose:

Hypothesis 2a: Externalization during the concept phase is negatively related to new product success.

In the development phase, however, the product concept must be translated into technical solutions and subsequently prototypes ready for testing. Moreover, design specifications need to be converted into explicit knowledge assets—the tools, equipment, and standard operating procedures that will be deployed in the production process (Clark & Fujimoto, 1991). We argue that externalization is likely to be effective in this phase as the formal interactions characteristic of this knowledge creation mode support project progress. Given this phase's emphasis on schedule and budgets, the team members can foster project efficiency by consciously and formally explicating all relevant elements of the product concept in detail, conducting more formal exchanges among themselves and with others (e.g., experts in different functional areas, suppliers, customers, etc.), asking purposeful questions, and so facilitating the expeditious development of the new product. Externalization thus supports this phase's requirement of efficiently implementing product properties specified in the product concept. The more formal interactions with clear agenda and time allocation correspond to this key objective. Hence, we hypothesize the following:

Hypothesis 2b: Externalization during the development phase is positively related to new product success.

Combination. A new product concept does not arise in a vacuum. The project team can create valuable new knowledge from available explicit knowledge (Clark & Fujimoto, 1991; Corti & Lo Storto, 2000; Madhavan & Grover, 1998; Monteverde, 1995). As such, combination refers to the systematic gathering and imaginative and insightful analysis of knowledge to create an innovative new product concept (Crawford, 1997). Such purposeful exploration and synthesis of diverse knowledge domains is likely to support the concept phase's main objective of specifying requirements for a differentiated new product. For instance, a synthesis of reports on consumer trends (e.g., increasing use of small digital cameras) and new technological capabilities (e.g., fast access data storage chips) may well lead to the specification of new product characteristics providing new value propositions to users. Moreover, combination helps ensure that the new product builds on the firm's existing capabilities and that the implications that the new product is likely to have for operations and other products are examined (Dougherty, 1992). Furthermore, by building on and integrating existing knowledge (e.g., from experience with the development of a prior new product), the project team is better able to assess the technical and economic feasibility of its initial concept quickly and thoroughly (Crawford, 1997). Thus, we hypothesize the following:

Hypothesis 3a: Combination during the concept phase is positively related to new product success.

In the development phase, the project team is charged with translating the concept into a marketable product within schedule and budget constraints. Designing solutions that are new combinations of existing ones is likely to provide an efficient way of identifying and implementing suitable technical answers to the challenges posed by the concept. Closely related to combination as a knowledge creation mode is Kogut and Zander's (1992) notion of a "combinative capability," which they define as the ability to synthesize and apply current and acquired knowledge. For example, viewing existing technological solutions from a new frame

of reference allows the team to recognize certain useful characteristics such as materials, design, or flexibility and to ignore other less transferable features, such as perhaps shape, size, or original use (Corti & Lo Storto, 2000). As a result, the team may be in a position to recognize potential connections between their current engineering problem and technologies that they have seen before. This can also include reports of unsuccessful projects that may help the team avoid "old" mistakes (Hargadon & Sutton, 1997). Thus, combination of existing knowledge from different domains can lead the team to innovative solutions rather expeditiously (e.g., adapting technical design options from optical signal processing for new mobile phone systems), adding value by providing features at lower cost and within the given development budget and schedule. In sum, and corresponding to Nonaka and Takeuchi (1995) who saw the development phase ideally as characterized by combination, we posit the following:

Hypothesis 3b: Combination during the development phase is positively related to new product success.

Internalization. This knowledge creation mode entails gaining a deep-rooted understanding of the logic or the properties of a phenomenon through "trial-and-error" simulations or the "learning by doing" of individuals (Helfat & Raubitschek, 2003; Leonard & Sensiper, 1998). We argue that such individual processes of gaining tacit knowledge are counterproductive in the concept phase. Instead of generating a common understanding of the product idea and thus developing a coherent concept, mental images of a new product are created individually. This implies that team members (often from various functional areas such as R&D, manufacturing, logistics, and marketing) are pursuing the new product idea largely independently of each other. The consequence is that the various individual mental images of the new product are likely to be difficult to reconcile with one other because they each fail to take account of considerations from other areas. Moreover, if, during the concept phase, the team members are individually aiming to gain a fundamental understanding of the idea itself, then other critical functions of the concept phase are likely to be performed inadequately. For instance, comprehensive technical and market feasibility assessments seem very difficult or might be inadequate. In sum, the behaviors characterizing internalization seem counterproductive in the concept phase, where the aim is to devise well-orchestrated and sound product specifications offering an innovative value proposition to users. Consequently, we propose the following:

Hypothesis 4a: Internalization during the concept phase is negatively related to new product success.

Consistent with our prediction regarding the concept phase, we also argue for a negative relationship between internalization as performed during the development phase and new product success. Our basic argument remains the same as for the concept phase: If, in this phase, team members are experimenting in an attempt to individually gain a deep-rooted understanding of the product, it seems unlikely that the team is able to efficiently move the design and development of the final product forward. The development phase's focus on efficiency is in stark contrast to the largely unstructured and less goal-oriented nature of (individual) internalization. As such, team members' displaying internalization behaviors is likely to lead to budget and schedule overrun. Late market launch of the new product allows possible

competitors an advantage and compromises the new product's ability to reach revenue and profit objectives. Hence, analogous to Hypothesis 4a, we posit the following:

Hypothesis 4b: Internalization during the development phase is negatively related to new product success.

Method

Sample and Data Collection

A total of 33 firms from Germany, Austria, and Switzerland participated in this research. The companies span multiple industries including industrial/mechanical equipment (11), electrical products (9), medical devices (2), automotive/transportation (9), and information and communication technologies (2). We collected data on 94 projects that designed and developed physical, rather than software, products. In addition, all projects concerned the design and development of new products, rather than upgrades of existing ones. Likewise, the projects considered in this study entailed the development of generally complex products, rather than, for instance, rivets and screws as simple components for other products.

The companies provided us with lists of NPD projects completed within the past 3 years. On average, the new products from our sample were on the market for 14.6 months at the time of data collection. This time frame was chosen so that the new product's success on the market could be assessed, while the NPD project was still recent enough for project members to evaluate knowledge creation activities performed. The project lists included contact details of the project members involved in the different phases, that is, the concept and the development phases. We provided definitions of the concept and the development phases to the 33 firms, all of which were able to identify these two phases as separate stages in their product development processes. The concept phase was defined as the stage in which detailed product specifications are established and evaluated for technical and economic feasibility, whereas the development phase was defined as the stage in which the actual technical development of the product and all its components takes place. From these lists, an average of three projects per firm (ranging from one to five) were randomly chosen for data collection based on the above criteria with an upper limit of five projects per firm. Some companies had only one or two projects that fit the criteria, whereas the upper limit was intended to ensure that no firm dominated the sample. Data were collected using standardized questionnaires. This research draws on data from multiple respondents. We contacted project participants of the concept and the development phases for evaluations of the four modes of knowledge creation in these phases. Managers overseeing the NPD projects were asked for assessments of the projects' and the new products' success. For 36 (of 94) projects, one respondent provided assessments on both the knowledge creation modes and new product success because this individual was the person best qualified to provide valid information on both sets of variables.

Prior to data gathering, the companies informed their employees that a study about knowledge management in product development was to be conducted. Both this company communication and the cover pages of the questionnaires emphasized the confidentiality and anonym-

ity of this study. A total of 282 questionnaires were sent out via e-mail (i.e., 94 for the concept phase, 94 for the development phase, and 94 for project and product success). After about 4 weeks, one round of follow-up phone calls was conducted to remind those respondents who had not yet returned questionnaires. At the close of data collection, 275 usable questionnaires were returned, giving a response rate of 97.5%. Three of the missing (i.e., not returned) questionnaires were managers' evaluations of product and project success, whereas 4 nonresponses pertained to the knowledge creation modes in the concept phase (2 questionnaires) and the development phase (2 questionnaires).

Measures

Dependent variable: New product success. The main dependent variable of this research is *new product success*. We employed a four-item measurement scale that captures the degree to which the new product achieved revenue and profit objectives (four items, Cronbach's α = .89). As such, this measurement does not refer to absolute or relative levels of revenue or profit achieved. This is because companies may have very different strategic objectives for introducing new products, including making an entry into a new market or defending against the entry of new competitors. In such cases, profit expectations may be fairly low or even negative.

Beyond this measure assessing the attainment of organizational objectives for the new product, we also consider two common measures of NPD project success, that is, product quality and project efficiency (Hoegl et al., 2004; Madhavan & Grover, 1998). *Product quality* was assessed by the managers based on a nine-item index adapted from the index used by Hoegl et al. (2004). The nine items (all on a 5-point rating scale) refer to qualitative aspects of the product developed, such as functionality, durability, compatibility, and design. These items were combined by calculating their arithmetic mean to form a product quality index. *Project efficiency* was measured using three items pertaining to the project's adherence to schedule objectives (e.g., time-to-market, project deadlines) and cost-efficiency considerations (three items, Cronbach's α = .82). Translations of the items used for these three measurement scales are included in Appendix A.

Given that all projects were completed and the products launched onto the market for an average of 14.6 months, all managers surveyed had relevant project performance data (regarding, e.g., cost, schedule, and quality) as well as product success data (regarding, e.g., revenue, profit, and market share) available to them as the basis for their assessments.

Knowledge creation modes. Given the lack of prior empirical research into knowledge creation in product development, we generated measurement scales for the four knowledge creation modes on the basis of the conceptual descriptions and discussions by Nonaka and colleagues (Nonaka et al., 2000; Nonaka & Konno, 1998; Nonaka & Takeuchi, 1995). Four items were used to measure each of the four knowledge creation modes. The items pertaining to socialization assess informal interactions and exchanges within the project team, as well as with relevant departments in the organization (Cronbach's α = .77). The measurement scale for externalization refers to formal knowledge gathering, including interviews with knowledgeable individuals (Cronbach's α = .80). The four indicators for combination highlight the

systematic collection and processing of explicit knowledge from various sources (Cronbach's $\alpha = .80$), whereas the items for internalization assess the creation of tacit knowledge via, for instance, trial-and-error experimentation (Cronbach's $\alpha = .79$). Appendix B details how the individual items pertain to salient activities and characteristics associated with the four knowledge creation modes as described by Nonaka and colleagues.

To test the reliability and validity of the measurement scales of the four knowledge creation modes, we used confirmatory factor analysis including all 16 items. This analysis was conducted using the assessments of the knowledge creation modes from both the concept and the development phases ($N = 188$). In doing so, possible dependencies between observations from one phase (i.e., phase effects) must be dealt with. Following the partialing procedure outlined by Cohen and Cohen (1983: 402-427 and 487-518), we regressed all 16 items on phase and saved the standardized residuals. We used the standardized residuals as the basis for the confirmatory factor analysis. This method controls for all constant and unmeasured differences across phases.

The findings provide support for all four measurement scales. As documented in Table 1, all items show significant factor loadings (as indicated by *t*-values greater than 1.96), and the scales have satisfactory composite reliability ranging between .78 and .82 (Bagozzi & Yi, 1988; Fornell & Larcker, 1981). Although significant, two indicators show loadings below .50 (Items 1 and 13). Both items were retained for reasons of content validity, although the measurement scales show acceptable composite reliability. With the greatest common variance between the estimated factors at .69, the larger composite reliabilities indicate satisfactory discriminant validity.

Control Variables

We included the number of project team members (i.e., team size) as a control variable in our analysis. The size of a team is an important structural variable with potential influences on the quality of a team's collaborative task process and project success (Campion, Medsker, & Higgs, 1993; Gladstein, 1984). Large team sizes make it more difficult for team members to interact with all other team members given the dramatic increase of (possible) individual links between team members as team size grows.

Moreover, we control for project duration (i.e., number of months) in our analyses. This is based on the notion that the duration of a project from relatively short term (e.g., 6 months) to rather long term (e.g., 36 months) can affect social and task processes related to the knowledge creation modes (Katz, 1982; Pinto, Pinto, & Prescott, 1993; Sethi, 2000). Also, the duration of the project, combined with the headcount of the team, provides some indication of the size and complexity of the project task (Hansen, 1999). Project duration as well as team size were reported to us by the managers.

Given that this study includes projects from different industries, we control for any effect that industry might have by including dummy variables in our analyses. This procedure effectively controls for all constant and unmeasured differences across the industries (e.g., different products, market structures, etc.) that may explain differences in the variables and relationships investigated. We also checked whether possible variations across the 33 organizations

Table 1
Confirmatory Factor Analysis on the Knowledge Creation Modes

	Factor Loading	*t*-Value	Variance Extracted	Composite Reliability	Common Variance With Other Factors[a]		
					1	2	3
1. Socialization							
Item 1	.38	8.65	.14	.81			
Item 2	.81	15.03	.66				
Item 3	.87	16.59	.76				
Item 4	.77	15.60	.59				
2. Externalization							
Item 5	.72	18.07	.52	.82			
Item 6	.59	15.86	.35		.23		
Item 7	.78	18.98	.61				
Item 8	.83	20.19	.69				
3. Combination							
Item 9	.58	15.17	.34	.80			
Item 10	.81	19.11	.66		.16	.69	
Item 11	.61	15.78	.37				
Item 12	.79	19.04	.62				
4. Internalization							
Item 13	.49	10.10	.24	.78			
Item 14	.75	14.19	.56		.05	.28	.32
Item 15	.69	13.56	.48				
Item 16	.77	16.10	.59				

Note: $N = 188$. Method of estimation: unweighted least squares. Goodness-of-Fit Index (GFI) = .95; Adjusted Goodness-of-Fit Index (AGFI) = .94; root mean square residual (RMR) = .09; $p < .00$; $\chi^2 = 369.89$; $df = 98$.
a. Calculated on the basis of confirmatory factor analysis factor estimates.

would explain new product success. This test yielded nonsignificant results. Therefore, we control for industry rather than organization, which helps limit the number of covariates in the regression equations, thereby enhancing the precision of parameter estimation and preserving statistical power (Cohen & Cohen, 1983).

Table 2 provides descriptive statistics and intercorrelations among all variables, as well as the number of cases for each variable given complete and partial nonresponse.

Results

In testing our hypotheses, we conducted regression analyses with pairwise exclusion in case of missing data. Collinearity statistics calculated for all regression analyses do not indicate distortions of results because of correlation among independent variables (variance inflation factor is below 3).

Table 3 summarizes the results from the regression analyses entering first the control variables (Model 1), followed by the knowledge creation modes in the concept phase (Model 2) and the development phase (Model 3). The results of the full model (i.e., Model 3) including

Table 2
Descriptive Statistics and Correlations

	N	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11	12
1. New product success	80	3.48	0.95												
2. Product quality	74	4.22	0.45	.33**											
3. Project efficiency	92	3.40	0.97	.38**	.54**										
4. Socialization—concept phase	92	3.33	0.91	.20*	.02	.06									
5. Externalization—concept phase	92	3.58	0.84	–.14	–.07	.06	.54**								
6. Combination—concept phase	92	3.18	0.86	.05	.12	.12	.35**	.60**							
7. Internalization—concept phase	92	2.96	0.98	–.06	–.07	–.09	.25**	.48**	.54**						
8. Socialization—development phase	92	3.49	0.78	.10	.04	.05	.54**	.27**	.27**	.20*					
9. Externalization—development phase	92	3.42	0.81	.08	.03	.14†	.40**	.62**	.52**	.38**	.39**				
10. Combination—development phase	92	3.17	0.87	.11	.10	.19*	.33**	.57**	.63**	.32**	.35**	.67**			
11. Internalization—development phase	92	3.03	1.08	–.07	–.13	–.11	.07	.25**	.21*	.54**	.09	.36**	.34**		
12. Project duration (months)	85	31.38	22.21	.05	–.41**	–.24*	–.06	–.12	.05	.00	–.11	–.14†	.06	.11	
13. Project team members	86	9.72	9.93	–.07	–.10	.00	–.08	–.14	–.03	–.11	–.22*	–.21*	–.03	–.13	.44**

Note: N = the actual number of cases for each variable given the 94 projects surveyed.
† Significant at the .1 level
* Significant at the .05 level
** Significant at the .01 level

the knowledge creation modes in both phases provide support for five of our eight hypotheses. Reported are unstandardized regression coefficients that are corresponding to the underlying measurement scales of the independent variables. Specifically, the findings support Hypothesis 1a (positive relationship of socialization during the concept phase) and Hypothesis 1b (negative relationship of socialization during the concept phase), Hypothesis 2a (negative relationship of externalization during the concept phase), Hypothesis 3b (positive relationship of combination during the development phase), and Hypothesis 4b (negative relationship of internalization during the development phase). The results do not offer support for Hypothesis 2b (positive relationship of externalization in the development phase), Hypothesis 3a (positive relationship of combination during concept phase), and Hypothesis 4a (negative relationship of internalization during the concept phase).

Regarding our exploratory analyses for project efficiency and product quality, the results provide fewer significant findings. Externalization during the concept phase relates negatively to product quality, whereas combination during the development phase relates positively to both product quality and project efficiency. These significant and marginally significant ($p < .10$) results support the relationships found with regard to new product success. The results also indicate that the underlying knowledge creation in NPD processes is not captured as well through more traditional measures of NPD *project* performance such as adherence to quality, time, and cost expectations for the project. Instead, this may suggest that the benefits of knowledge creation in NPD processes become evident in more fundamental properties of the product, such as superior functionality and design, that help differentiate it in the market and thus achieve higher returns.

It should also be noted that the means of the four knowledge creation modes are similar across phases. This matches our expectations as we assumed all four modes to occur in both product development phases. Moreover, it indicates that the teams did not have implicit theories (Gladstein, 1984) of certain knowledge creation modes being most beneficial in certain phases with regard to new product success.

Discussion

This study has implications for both theory and practice. The following discussion is structured in three parts. First, we highlight broader implications of this research for the theory of organizational knowledge creation before integrating and contrasting our specific findings with existing conceptual and empirical contributions. Second, we outline relevant managerial implications derived from the results of this research. We conclude by acknowledging this study's methodological contributions and limitations along with directions for future research.

Theoretical Implications

This research contributes to the theory of organizational knowledge creation in several ways. First, it provides necessary quantitative empirical evidence for the many conceptual claims that lay particular emphasis on the role of knowledge creation and dissemination

Table 3
Regression Analysis

		Dependent Variables								
		New Product Success			Product Quality			Project Efficiency		
Hypothesis	Independent Variables	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
	Industry 1 (medical devices)	.21†	.32**	.33**	–.01	–.01	–.03	.04	.03	.02
	Industry 2 (information and communication technologies)	–.20†	–.26*	–.29**	.15	.10	.07	.09	.07	.05
	Industry 3 (industrial/mechanical equipment)	.15	.16	.24*	.16	.11	.14	.14	.12	.17
	Industry 4 (automotive/transportation)	–.01	–.04	–.03	.19†	.11	.11	.32**	.26*	.26*
	Project duration (months)	–.04	–.13	–.13	–.42**	–.47**	–.48**	–.30*	–.30*	–.30*
	Project team members	–.05	–.04	–.08	.10	.08	.05	.16†	.15	.13
Hypothesis 1a (+)	Socialization—concept phase		.47**	*.57***		.06	.08		.04	.05
Hypothesis 2a (–)	Externalization—concept phase		–.56**	*–.75***		–.27†	–.33*		–.01	–.11
Hypothesis 3a (+)	Combination—concept phase		.25*	.04		.33*	.22		.18	.04†
Hypothesis 4a (–)	Internalization—concept phase		–.08	.11		–.12	–.03		–.17	–.06
Hypothesis 1b (–)	Socialization—development phase			*–.24**			–.06			–.05
Hypothesis 2b (+)	Externalization—development phase			.17			–.05			.06
Hypothesis 3b (+)	Combination—development phase			*.34**			.25†			.25†
Hypothesis 4b (–)	Internalization—development phase			*–.25**			–.08			–.13
	R^2	.11	.33	.43	.22	.28	.30	.15	.18	.21
	F	1.42	3.20*	3.20**	2.90*	2.32*	1.72†	2.19†	1.53	1.26
	df	74	74	74	69	69	69	82	82	82

Note: The numbers in italics refer to the main dependent variable, whereas the other two dependent variables are additional measures.
† Significant at the .1 level
* Significant at the .05 level
** Significant at the .01 level

(Allard, 2003; Boisot, 2002; Choo & Bontis, 2002; Leonard & Sensiper, 1998). Even though these authors discussed knowledge creation as conceived by Nonaka and colleagues, most of them have not empirically investigated the SECI model and its underlying assumptions. An exception is the study of Lee and Choi (2003), who investigated the subject matter, albeit with regard to the idea generation phase of the innovation process. However, taken together, their study and the present research contribute to the development of a much needed empirical basis to further the theory of organizational knowledge creation in innovation processes.

Second, our study shows that all four knowledge creation modes have significant relationships (positive and negative) with new product success and that neither the concept phase nor the development phase are exclusively dominated or influenced by only one knowledge creation mode each, as Nonaka and Takeuchi's (1995) framework indicates. Therefore, the results critically challenge their assumption of a fully cyclical model, in which socialization would be followed by externalization and so forth. Although the cyclical model might adequately describe knowledge creation at the organizational level (Nonaka & Takeuchi, 1995), at the project level, it is likely that several (or all) knowledge creation modes occur within a single project phase (as documented by the mean values for all knowledge creation modes for both phases) and have positive and negative effects (as documented by the regression results).

Third, this study contributes to the theory of organizational knowledge creation by demonstrating its applicability in a new cultural context. Previous work has focused on knowledge creation activities in Asian, predominantly Japanese and South Korean, firms, with doubts being expressed regarding the transferability from an Asian setting to European and North American contexts (Essens & Schreinemakers, 1997). Because the firms participating in this study are located in Europe and their headquarters are all based either in Europe or North America, the doubts with respect to the transferability of Nonaka's theory could not be supported.

Beyond these more general implications for research on organizational knowledge creation in NPD, the results from this study provide support for five of our eight hypotheses. The following discussion integrates and contrasts our findings with the extant literature.

Socialization. Our results are consistent with previous research (Clark & Fujimoto, 1991; Corti & Lo Storto, 2000), demonstrating that socialization during the concept phase is important. As such, these results also support the conceptual claims by Leonard and Sensiper (1998), as well as Kogut and Zander (1992). Our findings relate also to Nonaka and Takeuchi (1995) as these authors postulate socialization as important for the early phases of product development. However, they refer specifically to the importance of socialization during the phase of idea generation, although we detected its importance during the concept phase.

Also consistent with our hypotheses, the findings from this study support a negative relationship between socialization in the development phase and new product success. As such, these results help substantiate the arguments put forth in the innovation management and knowledge management literatures, proposing that the scope and impact of issues discussed become increasingly constrained as the product concept needs to become a reality, requiring much more structured and controlled processes to effectively and efficiently organize technical development (Hoegl et al., 2004; von Krogh et al., 2000).

Externalization. Showing a negative relationship between externalization during the concept phase and new product success, our results underline Crawford's (1997) case analysis demonstrating how a firm rejected hundreds of product concepts before realizing that early far-reaching financial analysis was killing off concepts that would have eventually offered substantial economic success. By the same token, our findings seem to challenge the arguments of scholars who consider externalization during the concept phase helpful to substantiate whether the resources for the new product's development are available to the firm (e.g., Di Benedetto, 1999; Dougherty, 1999; Leonard & Sensiper, 1998). This study's results also appear to question the conceptual thinking of Nonaka and Takeuchi (1995), who highlighted the importance of externalization during the concept phase of the innovation process.

Although both lines of argument suggesting positive and negative relationships seem sensible, the different predictions may be attributable to the characterization, and perhaps definition, of the concept phase. Consistent with extant literature (Chiesa et al., 1996; Cooper, 2001), we consider the concept phase as a period in which, based on an initial idea, a future product is being described in its key properties such as functionality, optical design, and so on. Hence, the primary objective of this phase is not to explicate knowledge regarding the technical solutions to attain the required properties of the new product. Rather, this is the principal objective of the subsequent development phase. It is important to note, however, that the concept phase has also been characterized as predominantly involving the search for, and selection of, technical solutions based on product specifications. Under this terminology, the development phase is specified more narrowly as the implementation of these solutions and the physical building of prototypes (Hoegl et al., 2004). The different predictions outlined above may well derive from different notions regarding the nature of the concept phase.

Contrary to our predictions, this study fails to show that externalization during the development phase of NPD projects positively relates to new product success. Although we could only speculate on possible reasons for this result, it seems plausible to expect that on a larger sample, the positive association indicated in this study may show statistical significance.

Combination. This study provides no support for our proposition that combination is particularly important during the concept phase. This finding is contrary to the conceptual arguments of many innovation scholars (e.g., Clark & Fujimoto, 1991; Corti & Lo Storto, 2000; Dougherty, 1992). One possible explanation for this may be found when considering distant versus local search of explicit knowledge. We did not specify whether the knowledge being combined was gathered by distant or by local search, and people may have looked for explicit knowledge located close to them, that is, near the "problem" they were trying to solve (Cohen & Levinthal, 1990; Cyert & March, 1963). However, combining knowledge that is gathered by distant search (e.g., by spanning organizational or technological boundaries) may generate new knowledge that could be more valuable when combined with the firm's existing knowledge and might increase new product success. Thus, it may be that simply spending more time on editing available explicit knowledge is not a sure indicator of the creation of valuable new knowledge that results in successful NPD.

The postulated positive relationship, however, is demonstrated for the development phase. The results of this study thus support the views of Nonaka and Takeuchi (1995), who largely

equated this knowledge creation mode with the development phase. This research also provides necessary empirical evidence for the claims of numerous scholars (e.g., Hargadon & Sutton, 1997; Helfat & Raubitschek, 2003; Kogut & Zander, 1992; McEvily & Chakravarty, 2002; Spencer, 2003; von Krogh et al., 2000; Wielemaker, Volberda, Elfring, & Fuller, 2003).

Internalization. We argued for internalization to be negatively related to new product success. This hypothesis is supported by our investigation with regard to the development phase, but not with regard to the concept phase. As such, this study seems to indicate that internalization is counterproductive in the technical development phase (as we predicted), whereas it is neither negative nor positive in the concept phase. The latter may be attributed to the nature of the concept phase, which, in many instances, might have task requirements more characteristic of individual idea generation.

Managerial Implications

The results of our research also have practical relevance. First, on the basis of this study's results, leaders and members of NPD teams should be made aware of the different effects of the four knowledge creation modes in the concept versus the development phase. Hence, rather than employing all knowledge creation modes in all phases, the teams should carefully select and deploy the different knowledge creation modes depending on the project phase. This is particularly critical considering that team members (because of reasons such as habit, reward systems, and role expectations) generally tend to perform certain knowledge creation modes (e.g., internalization, socialization) regardless of the task context of the project phase.

As our findings document, socialization during the concept phase and combination during technical development have positive influences on new product success. Hence, for projects in the concept phase, managers should emphasize socialization, for example, by fostering informal face-to-face meetings inviting employees from all affected departments. Joint coffee or lunch breaks are good ways to do this because they foster a certain level of personal closeness (Corti & Lo Storto, 2000) and help to overcome distance, which renders sharing the tacit dimensions of knowledge difficult (Napier & Ferris, 1993).

For projects in the development stage, management should foster the combination of relevant explicit knowledge. This can be furthered by encouraging the active use of, for example, internal reports from former projects or current research reports from external sources such as research labs or articles about new technical developments from other companies. Also, company-internal best-practice cases have been cited as an effective vehicle to support combination in specific projects (Corti & Lo Storto, 2000). Moreover, providing employees with access to sources of internal and external (explicit) knowledge such as online research services or libraries can also be important tools for fostering combination in NPD processes.

Last, NPD team members and team-external managers must be aware of the possible detrimental effects of socialization and internalization in the development phase of the project. Hence, managers should take note of activities typical of socialization (e.g., informal face-to-face meetings without explicit agenda and objectives) and internalization (e.g., trial-and-error simulations to gain a fundamental understanding of the workings of an idea).

Methodological Contributions, Limitations, and Outlook

We employed a multi-informant research design aimed at avoiding common source bias while using appropriate respondents to obtain valid assessments of the variables investigated. Moreover, we operationalized and measured all four knowledge creation modes, demonstrating that they can be observed in the concept and development phases of the NPD process. Only very recently have researchers begun to empirically assess the validity of Nonaka and Takeuchi's (1995) knowledge creation model. The scales developed for this research pertaining to the domain of NPD projects are comparable with the scales employed by Lee and Choi (2003) with regard to idea generation, as well as to the knowledge creation activities described by Becerra-Ferndandez and Sabherwal (2001) with regard to software development.

Some limitations of this study should also be noted. First, this study employed quantitative empirical research methods in an effort to further our understanding of the relationship between knowledge creation modes performed during NPD projects and new product success. This, however, necessitated the interpretation of preceding conceptual work and qualitative research to create measurement scales that capture core elements of rather broad concepts such as the four knowledge creation modes. Moreover, the nature of our inquiry also required the distinction between two sequential phases of the NPD process. Although offering the benefits of quantitative empirical inquiry, this research methodology requires modeling of complex phenomena and thus cannot provide the "richness" of qualitative case studies. Second, the data for this research are cross-sectional rather than longitudinal. As this study demonstrates associations between variables, it cannot fully establish causality. A longitudinal research design measuring the independent variables during the projects and the dependent variables at a later time would further our knowledge toward causality of relationships. Third, the research method applied allowed the investigation of completed NPD projects only. Projects that were halted before completion could not be considered because the dependent variable (i.e., new product success in terms of achieving revenue and profit objectives) would be missing. Fourth, the scope of the empirical data gathered for this research allows generalization of the results obtained chiefly to the domain of teams with innovative tasks such as R&D teams, new venture teams, and so on. Fifth, the present study was conducted in Germany, Austria, and Switzerland, raising the question of transferability of results to other cultures such as those of North America or Asia. Although this study is not internationally comparative in nature and therefore cannot offer any answers to this question, the theoretical considerations presented in this article are not country specific but rather based on international scholarly work and empirical findings. Further research in other countries is encouraged to increase our understanding of the possible influences of country contexts on the relationships investigated here.

Given the dearth of empirical research on knowledge creation in innovation processes, there are a number of relevant questions to be addressed by further research. One example is the question of knowledge creation in successive NPD projects, that is, which knowledge creation modes of one project are of relevance for later projects? Also, because this study included NPD projects that were conducted largely in-house (i.e., without the involvement of suppliers, buyers, etc.), it would certainly be interesting to investigate knowledge creation in interorganizational collaborative product development, involving partner firms, potential cus-

tomers, suppliers, and others. Moreover, further research should address the antecedents that lead to the occurrence of the four knowledge creation modes in both phases of the innovation process. Why do the teams seem to practice all four SECIs in both phases, whereas only certain knowledge creation modes seem beneficial in specific phases? Organization-level variables (e.g., incentive systems), project-level variables (e.g., role expectations), and individual-level variables (e.g., habits, preferences) should be considered. The conceptual arguments and the empirical evidence from this study may provide a starting point for such necessary further inquiry, building on contributions from both the knowledge creation as well as the NPD literatures.

APPENDIX A
Measurement of Product and Project Success

New Product Success (four items, Cronbach's $\alpha = .89$)
- The new product achieved its . . .
  - turnover objectives.
  - growth of turnover objectives.
  - profit objectives.
  - return on sales objectives.

Product Quality Index (nine items)
- On completion of product development, . . .
  - all product specifications were fully implemented.
  - we were fully satisfied with the product's performance.
  - we fully met the quality expectations of our customers.
- The product fully met the requirements in terms of . . .
  - functionality.
  - compatibility with other systems.
  - reliability.
  - usability.
  - durability.
  - design.

Project Efficiency (three items, Cronbach's $\alpha = .82$)
- We can be satisfied with project performance.
- Compared to the development of competitive products, the time to market was short.
- On completion of product development, we had fulfilled the project on schedule.

APPENDIX B
Measurement of the Knowledge Creation Modes

	Variable/Item	Citations and References
Socialization (four items, Cronbach's $\alpha = .77$)		
Item 1	We spent a lot of time in personal interaction aside from organized meetings with other people in the team to discuss suggestions, ideas, or solutions.	"Socialization may also occur in informal social meetings outside of the workplace" (Nonaka, Toyama, & Konno, 2000: 9); "Team members shared their mental models and technical skills" (Nonaka & Takeuchi, 1995: 85); "Example of Socialization comes from Honda, which set up . . . informal meetings. . . . The meetings are not limited to project members but are open to any employees who are interested in . . ." (Nonaka & Takeuchi, 1995: 63).
Item 2	We spent a lot of time in personal interaction aside from organized meetings with people from other departments in the company in order to discuss suggestions, ideas, or solutions.	
Item 3	We spent a lot of time in intense discussions about suggestions, ideas, or solutions in face-to-face meetings with people from other departments in the company.	"Spending time together or living in the same environment . . . discussions are held" (Nonaka et al., 2000: 9).
Item 4	We spent a lot of time in the conscious creation of a common understanding of a problem with people from other departments in the company.	"World views, mental models, and mutual trust can be created and shared" (Nonaka et al., 2000: 9); "It reorients the mental models of all individuals in the same direction, but not in a forceful way" (Nonaka & Takeuchi, 1995: 63).
Externalization (four items, Cronbach's $\alpha = .80$)		
Item 5	We spent a lot of time reflecting collectively and framing our ideas or solutions with regard to customer needs.	"The Externalization mode . . . is triggered by dialog or collective reflection" (Nonaka & Takeuchi, 1995: 64); "Another example is a quality control circle, which allows employees to make improvements on the manufacturing process by articulating the tacit knowledge accumulated on the job floor over years on the job" (Nonaka et al., 2000: 9).

Item 6	We spent a lot of time interviewing competent people about ideas or solutions with regard to relevant technologies.	"An important practice . . . is the translation of the . . . highly professional knowledge of . . . specialists into explicit forms that are easy to understand" (Nonaka & Konno, 1998: 44); "Listening and contributing to the benefits of all participants strongly supports Externalization" (Nonaka et al., 2000: 9).
Item 7	We spent a lot of time interviewing competent people about ideas or solutions with regard to customer needs.	
Item 8	We spent a lot of time creating detailed descriptions (e.g., protocols, presentations, reports) containing newly developed knowledge about customer needs.	"Writing up concept descriptions in new product development is an example" (Nonaka et al., 2000: 9); "In practice, Externalization is supported by . . . translating the tacit knowledge of customers . . . in readily understandable forms" (Nonaka & Konno, 1998: 44).
Combination (four items, Chronbach's $\alpha = .80$)		
Item 9	Focusing on the project, we systematically edited the technical knowledge collected.	"Combination is the process of converting explicit knowledge into more complex and systematic sets of explicit knowledge" (Nonaka et al., 2000: 10); "Reconfiguration of existing information through sorting, adding, combining, and categorizing of explicit knowledge . . . can lead to new knowledge" (Nonaka & Takeuchi, 1995: 67); "Editing or processing of explicit knowledge makes it more usable" (Nonaka & Konno, 1998: 45); "In building a prototype, for example, the explicit knowledge to be combined could take the form of technologies or components" (Nonaka & Takeuchi, 1995: 87). "Explicit knowledge is collected from inside or outside the organization and then combined, edited or processed to form new knowledge" (Nonaka et al., 2000: 10); "Capturing and integrating new explicit knowledge is essential" (Nonaka & Konno, 1998: 45).
Item 10	Focusing on the project, we systematically edited the knowledge collected about customer needs.	

(continued)

APPENDIX B
Measurement of the Knowledge Creation Modes

	Variable/Item	Citations and References
Item 11	Focusing on the project, we systematically edited the knowledge collected about the procedure of creating, evaluating, and selecting a product concept/developing products.[a]	
Item 12	Within the organization, we distributed our newly gained insights about customer needs.	"The dissemination of explicit knowledge is based on the process of transferring this form of knowledge directly by using presentations or meetings" (Nonaka & Konno, 1998: 45); "The new explicit knowledge is disseminated among the members of the organization" (Nonaka et al., 2000: 10).
Internalization (four items, Cronbach's $\alpha = .79$)		
Item 13	We spent a lot of time in trial and error (experimenting), thereby developing a sense for the feasibility of our thoughts regarding the functionality of the technology.	"Explicit knowledge can be also embodied through simulations and experiments" (Nonaka et al., 2000: 10); "When experiences . . . are internalized into individuals' tacit knowledge base in the form of . . . technical know-how, they become valuable assets" (Nonaka & Takeuchi, 1995: 69); "GE, for example, documents all customer complaints and inquiries in a database . . . which can be used . . . by members of a new product development team to 're-experience'" (Nonaka & Takeuchi, 1995: 69); "By reading documents or manuals about their jobs and the organization, . . . trainees can internalize the explicit knowledge written in such documents to enrich their tacit knowledge base" (Nonaka et al., 2000: 10); "The process of internalizing explicit knowledge actualizes . . . methods about strategy, tactics, innovation, or improvement" (Nonaka & Konno, 1998: 45).

Item 14	We spent a lot of time in trial and error (experimenting), thereby developing a sense for the feasibility of our thoughts regarding customer needs.	
Item 15	We spent a lot of time in trial and error (experimenting), thereby developing a sense for the feasibility of our thoughts regarding the procedure of creating, evaluating, and selecting a product concept/developing products.[a]	
Item 16	We spent a lot of time systematically testing our theoretical knowledge about customer needs.	"Internalization is closely related to 'learning-by-doing'" (Nonaka et al., 2000: 10); "Expanding the scope of bodily experience is critical to Internalization" (Nonaka & Takeuchi, 1995: 70).

a. A questionnaire contained only one phase label, depending on whether it was referring to the concept or the development phase of the project.

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