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Abstract Title Core and overlapping knowledge, cross-functional integration, and process performance: An empirical study of the buyer-product engineer dyad

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Abstract

Despite the prominence that knowledge management theory holds within extant studies of operations and supply chain management, the role of knowledge within the concurrent execution of linked direct material sourcing and new product design projects has received little attention. Using primary data collected from direct material buyers and matched product engineers, we examine the causal linkages amongst knowledge, cross-functional integration, and process performance. Our conceptualization of knowledge incorporates both core knowledge and overlap knowledge; using a second-order construct, we operationalize these aspects of knowledge in terms of supplier, supply market, and technical knowledge. The results indicate that knowledge is significantly and positively associated with cross-functional integration. Further, we find that cross-functional integration significantly affects the success of both the direct materials sourcing and the new product design processes. These findings underscore the importance of core and overlap knowledge within cross-functional approaches to business process management.

1. Introduction

This study investigates the effects of buyer-product engineer cross-functional integration on both new product design and direct material sourcing performance. It is widely held that interdependencies in new product development require cross-functional integration (Brown and Eisenhardt, 1995, Novak and Eppinger, 2001, Novak and Stern, 2009, Ulrich, Sartorius, Pearson and Jakiela, 1993); yet, few studies have examined cross-functional integration between purchasing and engineering (Anklesaria and Burt, 1987, Mendez and Pearson, 1994, Naumann, McWilliams and Reck, 1982). We aim to address this gap in extant literature by examining the relationships amongst specialized knowledge, cross-functional integration, and process performance.

Drawing from Song and Montoya-Weiss (2001, pg. 71), we define cross-functional integration as "... the magnitude of the interaction and communication, the level of information-sharing, the degree of coordination, and the extent of joint involvement across functions in specific NPD tasks." In accordance with knowledge-based theory, we view cross-functional integration as a higher-order organizational capability that facilitates the incorporation of individuals' disparate, specialized knowledge into a firm's products and processes (Grant, 1996a). Building on the knowledge-based view of the firm, we suggest that two types of individual knowledge enable higher levels of cross-functional integration: core and overlap knowledge. Core knowledge is defined as the knowledge needed to perform the functional role. Similarly, we define overlap knowledge as the knowledge that assists cross-functional communication. These definitions are consistent with the notions that knowledge can be shared (Hoopes and Postrel, 1999, Postrel, 2002) or partitioned (Lee and Veloso, 2008, Takeishi, 2002). Our conceptualization of knowledge types also suggest that, within a particular context, some

knowledge is general (i.e., overlap knowledge), while other knowledge (i.e., core knowledge) is specialized (Jensen and Meckling, 1992).

We suggest that the study of cross-functional integration between purchasing and product engineering represents an important area of scholarly investigation. Current supply chain management philosophy suggests that internal (cross-functional) integration facilitates external (inter-organization) integration (Fawcett, Ellram and Ogden, 2007). Accordingly, integration across the buyer-product engineering interface may enable more effective product design through the assimilation of supplier ideas and incorporation of supplier technologies into the buyer's new product (Koufteros, Edwin Cheng and Lai, 2007, Petersen, Handfield and Ragatz, 2005, Swink, Narasimhan and Wang, 2007, Vickery, Jayaram, Droge and Calantone, 2003). Further, buyer-product engineering integration may facilitate both ex ante and ex post management of supplier relationships by enabling more effective supplier selection, negotiation, and evaluation (Smeltzer, Manship and Rossetti, 2003). In general, Droge et al. (2004), empirically demonstrate that internal integration moderates the relationship between external integration and performance. In line with previous research, we suggest that cross-functional integration, particularly between purchasing and product engineering, represents a strategically important firm-level competency (Stank, Keller and Closs, 2001).

This study contributes to existing operations and supply chain management research in several key ways. First, traditionally, the primary role of purchasing has been narrowly viewed as getting the best deal or terms often emphasizing cost for the organization (Ellram, 1996, Smeltzer, Manship and Rossetti, 2003). We suggest that the role of purchasing is much broader than that. While it has been suggested that buyers may play a supportive role in the new product development process (Atuahene-Gima, 1995, Mendez and Pearson, 1994, Wynstra, Axelsson

and van Weele, 2000), our findings suggest that purchasing plays an active and prominent role in new product design. Second, we find that, even though the role of product engineering has been stereotyped as being technically focused, product engineers' involvement in the direct material sourcing process substantially enhances direct material sourcing performance. Third, prevailing cross-functional team literature emphasizes team composition as key to performance (Henke, Krachenberg and Lyons, 1993, Kahn and McDonough, 1997, McDonough, 2000). Our results provide nuance to this perspective by suggesting that the level of core and overlap knowledge embedded within the cross-functional team, rather than cross-functional membership, per se, is a primary determinant of process performance.

This paper seeks to explore relationships amongst core and overlap knowledge, integration between the purchasing and product engineering functions, and process performance. To provide insights into these relationships, we have organized this paper in the following manner. In the following section (Section 2), we draw from extant literature to develop our focal constructs and advance our theoretical model. In the subsequent section (Section 3), we describe the methodology that we employed to collect dyadic survey response data from direct material buyers and their matched product engineers. In Section 4, we present the results of our empirical analysis and tests of hypotheses. In the final sections (Sections 5 and 6), we discuss the implications of our results, highlight our primary conclusions, and suggest an agenda for future research.

2. Theoretical model of cross-functional integration

A central thrust of the knowledge-based view of the firm (KBV) is that a firm's basic function is to coordinate (Kogut and Zander, 1996), integrate (Grant, 1996a, Grant, 1996b), and facilitate the transfer of knowledge within the organization (Kogut and Zander, 1992a) to

enhance firm performance. Accordingly, we advance a theoretical model that links knowledge, cross-functional integration, and process performance. To operationalize our general model, we focus on the buyer-product engineer interface and adopt a new product development project that requires direct material sourcing as our unit of analysis. Within our model, we conceptualize two types of knowledge: core and overlap knowledge. Core knowledge refers to knowledge specific to a functional area, whereas overlap knowledge is cross-functional and enables communication efficiencies and knowledge transfers across functions. Through empirical investigation, we identify three forms of knowledge (i.e., core and overlap knowledge) that are germane to the buyer-product engineer interface: supplier knowledge, supply market knowledge, and technical knowledge. Central to our model, we suggest that these forms of core and overlap knowledge form the basis of buyer-product engineer cross-functional integration. In accordance with KBV theory, we posit that buyer-product engineer integration facilitates higher levels of both new product design and direct materials sourcing performance. The following subsections develop a set of hypotheses that underlie the theoretical model depicted in Figure 1.

2.1 Dimensions of knowledge

We conceptualize knowledge as the understanding gained through learning by doing, learning by thinking, or learning by knowing (Hayes, Pisano, Upton and Wheelwright, 2005). In other words, an individual may know by gaining experience, through education, and from familiarity. According to the KBV, the primary function of the firm is to integrate specialist's knowledge (Grant 1996a, b). Further, KBV suggests that knowledge integration across functions constitutes a critical driver of sustainable competitive advantage (Grant, 1996a, Grant, 1996b, Kogut and Zander, 1992b). As such, a firm's operational capabilities are dependent upon its

ability to create (Nonaka, 1994), apply (Grant, 1996b), transfer (Szulanski, 1996), and integrate specialized knowledge (Grant, 1996a, Hoopes and Postrel, 1999).

Our review of extant literature, coupled with qualitative inquiries into the research domain, suggests that three forms of knowledge are particularly important to the direct material sourcing and new product design interface: supplier knowledge (Clark, 1989), supply market knowledge (Carr and Smeltzer, 1997), technical knowledge (Finger and Dixon, 1989a, 1989b).

Supplier knowledge refers to the breadth and depth of an individual's understanding of the idiosyncrasies and abilities of a particular direct material supplier. Supplier knowledge represents a form of knowledge that is core to the purchasing function and includes knowledge of a supplier's manufacturing capabilities, design capabilities, manufacturing costs, financial health, and prior sourcing performance. This conceptualization of supplier knowledge draws heavily from the supplier selection literature and is consistent with the widely held notion that a comprehensive understanding of supplier capabilities enables successful supplier exchange relationships (Choi and Hartley, 1996, Kannan and Tan, 2002, Sarkis and Talluri, 2002).

Supply market knowledge represents the breadth and depth of an individual's understanding of (i) the companies that manufacture a direct material, (ii) the current price for that direct material, (iii) existing manufacturing capacity for that direct material and (iv) future trends associated with that direct material. Supply market conditions will influence the level of supply risk (Ellegaard, 2008), the negotiated price (Quayle, 1998), and the transaction costs (Williamson, 2008) associated with the purchase of direct materials. The evaluation of a supply market is a core function of purchasing (Carr and Smeltzer, 1997, Carter and Yan, 2007). Supply market knowledge is essential to effective supply management as buyers select potential suppliers and manage existing suppliers in accordance with prevailing market conditions

(Kraljic, 1983). Therefore, knowledge about the supply market may improve the initial match and subsequent relationship between a buyer and supplier (Carr and Pearson, 1999).

Technical knowledge refers to the breadth and depth of an individual's understanding of the product and process technologies that underlie direct materials. Technical knowledge includes an understanding of the product and production systems performance requirements, cost-benefit tradeoffs, design tradeoffs, product technology, and processes needed to produce direct materials to specifications. Since technical knowledge encompasses product design and product systems (Finger and Dixon, 1989a, 1989b), it requires understanding about how the product functions, the material properties, the intended use, and specifications. Further, our conceptualization of technical knowledge explicitly recognizes the interdependencies between products and processes as these interdependencies increase uncertainty and reduce performance unless managed (Hui, Davis-Blake and Broschak, 2008). Knowledge of product and production systems reduces the uncertainty associated with the product development process (Song and Montoya-Weiss, 2001).

2.2 Knowledge facilitates cross-functional integration

The integration of specialized knowledge across functions is the primary purpose of cross-functional interactions (Henke, et al., 1993, Park, Lim and Birnbaum-More, 2009, Sherman, Berkowitz and Souder, 2005). There are several reasons why knowledge is critical to cross-functional integration. Knowledge aids integration by facilitating efficiencies in (i) communication (Daft and Lengel, 1986), (ii) knowledge transfers (Szulanski, 1996), and (iii) information processing (Tushman and Nadler, 1978). As such, core and overlap knowledge provide a platform for interaction across functions (Grant, 1996a).

Nonetheless, core and overlap knowledge may facilitate cross-functional integration in different ways. Core knowledge or specialization of functions increases the information processing ability within a self-contained task (Galbraith, 1977). Thus, through knowledge partitioning (Takeishi, 2002), tasks may be divided into smaller tasks where specialized knowledge can be applied and then reintegrated. However, the ability to effectively partition knowledge is limited as complicated and interdependent tasks may not be entirely separable (McDonough, 2000) forcing task coordination. Overlapping knowledge promotes shared understanding and is required to process information (Sherman, et al., 2005), assimilate, transform and apply existing organizational knowledge (Cohen and Levinthal, 1990, Szulanski, 1996) across functions.

Thus, core and overlap knowledge enable cross-functional integration because specialization increases the efficiency of self contained tasks (Galbraith, 1974), but the greater specialization and interdependence between functions requires more communication and information processing (Daft and Lengel, 1986, Tushman and Nadler, 1978). Therefore, we hypothesize:

H1: Knowledge has a direct positive effect on cross-functional integration.

2.3 Performance of integrated functions

Cross-functional integration has been linked extensively with product development performance (Dougherty, 1992, Gupta, Raj and Wilemon, 1985, Kahn, 1996, Kahn and McDonough, 1997, Sherman, et al., 2005, Sherman, Souder and Jensen, 2000). Two critical sub-processes are particularly important to new product development: product design (Gupta, et al., 1985, Kahn, 1996, Petersen, et al., 2005) and direct material sourcing (Atuahene-Gima, 1995, Droge, Jayaram and Vickery, 2004, Mendez and Pearson, 1994). Both of these sub-processes

require cross-functional integration. The cross-functional integration of product design enhances new product development by (i) allowing for concurrent process-product engineering, (ii) facilitating cost-benefit trade-off analysis during design, and (iii) enhancing customer market analysis (Kahn, 1996, Kahn and McDonough, 1997, Sherman, et al., 2005). While this literature firmly establishes the relationship between cross-functional integration and product design performance, it fails to address the critical the buyer-engineer relationship in cross-functional product design. We suggest that buyer involvement in the new product design process enables mutual adaptability between buyers and product engineers, which in turn, promotes the timely development of product designs that capitalize on supplier and supply market strengths and limit exposure to supply market and supplier risks. Therefore, we hypothesize that:

H2: Cross-functional integration has a direct positive effect on product design performance.

Similarly, we suggest that cross-functional integration also enables higher levels of direct material sourcing performance. Within extant supply chain literature, firm and product performance has been conceptually and empirically linked to supplier selection (Kannan and Tan, 2002, Vonderembse and Tracey, 1999, Wilson, 1994). Further, the purchasing and product engineering functions are central to supplier identification, evaluation, and selection. It follows that cross-functional tasks, which emphasize supplier selection as an outcome, will benefit from higher levels of integration. Thus, we propose:

H3: Cross-functional integration has a direct positive effect on direct material sourcing performance.

3. Methodology

3.1 Scale Development

Following the guidance of Churchill (1979), we employed a multi-stage approach to develop our scales and test the hypotheses associated with our theoretical model. Initially, we conducted a comprehensive review of the supply management and new product development literature; whenever possible, we adapted previously validated scales from previous literature. As such, we aggregate and adapt two scales from Xie et al. (2003) and Song and Montoya-Weiss (2001) to form a seven-item scale that measures the level of cross-functional integration with the buyer-engineer interface. Further, several studies provided guidance for our initial conceptualizations of the sourcing performance (e.g., Dobler and Burt, 1996, Kraljic, 1983, Stanley and Wisner, 2001, Wisner and Stanley, 1999) and new product development performance (Sherman, et al., 2005, Song and Xie, 2000, Song and Parry, 1997, Xie, Song and Stringfellow, 1998) constructs.

In addition, we supplemented the development of our constructs and scales with a series of interviews of purchasing agents and product engineers working within the automotive industry. The interviews were used to identify and develop constructs germane to the purchasing and product engineering interface. Engineering and purchasing interview participants were selected based on their relevant knowledge and held position titles such as chief engineer, product engineering manager, senior product engineer, purchasing director, purchasing manager, and senior buyer. The participants were interviewed through a series of in-person, phone, and e-mail communications. In the interview process, we asked engineering participants to identify a new product develop project that they recently completed. Using this NPD project as the context for the remainder of the interview, we then asked chief engineers, engineering managers, and

senior engineers to describe: (1) the purchased and end products, (2) their interface with purchasing and the associated direct material supplier, and (3) salient issues that affect the timing, cost, and quality of product launch. Subsequently, we conducted interviews with purchasing participants to obtain their complementary views.

Our interviews led to two important insights that influenced the methodology of our study. First, using interview feedback, we bolstered the face validity of our focal constructs and the initial scales for these constructs (Haynes, Richard and Kubany, 1995). Second, interview feedback suggested the importance of adopting a dyadic view of the buyer-engineer interface; according to our participants, linked new product design and direct material sourcing projects require considerable buyer – engineer interface. Both buyers and product engineers recognized such linked projects as critical for successful new product launch.

Following our interviews, we developed four q-sort instruments that incorporated measurement items and construct definitions for more than 50 constructs, including the knowledge, interface, and performance constructs used in this study. Initially, we administered the Q-sort instruments to graduate students to gain initial insights into the quality of the instrument and validity of the constructs. In a subsequent round, the q-sort instruments were refined and administered to 14 direct material buyers and 14 product engineers. Results from the Q-sort exercise indicated that buyers and engineers generally associated measurement items with their intended constructs, with match rates ranging from 76% to 79%. The qualitative feedback from the Q-sort responses enabled us to: (1) refine the operational definitions of our constructs, (2) judge the validity of the items that formed our construct scales, and (3) capture dimensions of constructs that were not adequately measured by our items (Menor and Roth, 2009).

We incorporated the results of the interviews and q-sort exercises into the development of three pilot surveys, two of which are germane to this study. For each buyer-engineer dyad, the survey questions were customized such that buyers and matched engineers answered questions with regard to the same purchased product, supplier, and end-product combination. We administered our pilot survey instruments to 12 direct material buyers and 8 matched product engineers of a global automotive components manufacturer. Participants of pilot study were drawn from global operations and were based in the U.S., England, China, Germany, Mexico, and Singapore. Using the response data, we assessed the reliability of each construct (see Table 1). Feedback from participants facilitated further refinement of scales that exhibited poor reliability. The final measurement scales for the focal constructs of this study are presented in Tables 2a and 2b.

Insert Table 1 Here

Insert Table 2a Here

Insert Table 2b Here

3.2 Survey Administration

The primary dependent variable for this study is process performance; accordingly, the unit of analysis is a process. To understand process performance from a cross-functional, dyadic perspective, we examined linked direct material sourcing-new product design projects. More specifically, we asked buyers to identify (i) a recently sourced direct material, (ii) the supplier of the direct material, and (iii) the product engineer responsible for design of end-product that requires the direct material (Kumar, Stern and Anderson, 1993). Subsequently, we asked the

product engineers to confirm their working relationship with their matched buyers and describe the nature of their product development project. Using this data, we constructed customized questionnaires that asked buyers and their matched product engineers to describe the nature of their interaction for the same (i) direct material, (ii) supplier, and (iii) end-product. Using an online approach, this respondent-specific information was embedded into the questionnaire. We invited 180 buyers (16 buyers left their position prior to survey administration) and 196 matched product engineers of a global automotive components manufacturer to complete the online questionnaire over a 10-week period. Prior to survey administration, we sent letters from the corporate vice-presidents of purchasing and engineering of the focal manufacturer to the potential respondents; the letters introduced the study and encouraged participation in the forthcoming study. Two days later, we sent an email to each potential participant; the email (i) provided an overview of the study, (ii) encouraged participation in the study, and (iii) provided individualized hyperlinks that allowed access to the customized online survey. Subsequently, we sent email reminders to non-responders during the second, fourth, sixth, and eighth weeks of the survey administration period. We sent all email correspondence to potential participants using an internal email account provided by the focal manufacturer.

4. Analysis and empirical results

4.1. Respondent profile and survey biases

We received useable responses from 175 direct material buyers and 194 product engineers; this resulted in response rates of 97% and 99%, respectively. In general, respondents represented purchasing and product development operations in 13 countries across four continents. On average, buyers were responsible for 20M USD of annual purchases, had eight years of purchasing experience, and were in their current position for roughly three years.

Largely, buyers who responded to this survey were based in North America (40.5%), Europe (34.9%), and Asia (19.4%); the remaining buyers were located in South America (4.6%) and Australia (0.6%). The engineering respondents maintained, on average, nearly 16 years of engineering experience and held their current position for six years. Similar to buyers, engineering respondents were based in North America (47.0%), Europe (32.5%), Asia (15.5%), South America (4.5%), and Australia (0.5%).

The high level of participant response to our survey questionnaires suggests that non-response bias is not problematic. However, we do rely on data from a single respondent to assess the relationships amongst knowledge, cross-functional integration, and process performance; consequently, common method bias may exist. We assessed the potential effect of common method bias using Lindell and Whitney's (2001) marker variable approach. In accordance with this approach, we identified the minimum correlation between our marker variables and measurement items that form our construct scales. For both the buyer and engineer response datasets, this correlation was negligible ($r = -0.007$ and $r = 0.000$, respectively). These results suggest that, after partialling out the effects of common method bias, our results remain materially unaffected.

4.2. Construct Validity

We used confirmatory factor analysis (SEM-AMOS v.6) to assess the validity of our constructs. As indicated in Table 2a and 2b, the results of our analyses show acceptable fit for both the buyer ($\chi^2 = 641.170$, $df = 314$, $p < .000$; $RMSEA = 0.077$; $CFI = 0.859$; $TLI = 0.830$) and engineer ($\chi^2 = 580.287$, $df = 289$, $p < .000$; $RMSEA = 0.072$; $CFI = 0.913$; $TLI = 0.895$) factor models (Hu and Bentler, 1999). In addition, all factor loadings are significant ($p < .001$) and substantive ($\lambda > 0.4$). We assessed the reliability of our construct measures using

Cronbach's alpha. As indicated in Tables 2a and 2b, the reliability of each of our scales exceeds the generally accepted threshold of 0.7. In aggregate, these results provide support for the convergent validity of our constructs.

Following the approach of Bollen (1989), we assessed the discriminant validity of our construct. Using the measurement model as baseline, we sequentially constrained each inter-construct correlation to one and assessed the concomitant change in model fit. For both the buyer and product engineer factor models, the imposition of each inter-construct constraint led to a significant increase in chi-square ($p < .001$). These results suggest that our constructs exhibit acceptable levels of discriminant validity.

4.3. Second-Order Factor Model of Knowledge

In our conceptual development, we suggest that multiple dimensions of knowledge are particularly relevant to the buyer-engineer interface. The results from our CFA support this view and indicate that knowledge is appropriately represented as a second-order construct with three first-order dimensions: supplier knowledge, supply market knowledge, and technical. In particular, for both the buyer and product engineer datasets, we find that the correlations between these dimensions of knowledge are significant ($p < .001$) and substantive ($r > 0.5$). Further, as shown in Figures 2a and 2b, all second-order factor loadings are significant ($p < .001$) and substantive ($\lambda > 0.7$) as well. Taken together, these results support the validity of our second-order knowledge construct.

Insert Figure 2a Here

Insert Figure 2b Here

4.4. Empirical Results – Buyer Response Data

To assess the validity of our causal model, we first subjected the buyer response data (n = 175) to SEM-AMOS (v.6) analysis. In accordance with the guidelines of Hu and Bentler (1999), our causal model demonstrates acceptable fit ($\chi^2 = 661.254$, $df = 319$, $p < .000$; RMSEA = 0.079; CFI = 0.852; TLI = 0.825). Overall, the results of our analysis support the causal linkages amongst knowledge, cross-functional integration, and sourcing performance. As indicated in Figure 2a, we find a positive and significant association between knowledge and cross-functional integration ($\beta = 0.607$, $p < .001$); as such, knowledge explains 36.8% of the variance in cross-functional integration. These results provide support for Hypothesis 1 and suggest that core and overlap knowledge play a formative role in developing higher levels of cross-functional integration. We also find that cross-functional integration is positively and significantly associated with sourcing performance ($\beta = 0.171$, $p = .067$). Cross-functional integration accounts for 2.9% of the variance in sourcing performance. These findings support Hypothesis 2 and suggest that higher levels of cross-functional integration facilitate improved sourcing performance.

4.5. Empirical Results – Engineer Response Data

We assessed the causal linkages amongst knowledge, cross-functional integration, and process performance a second time using response data from product engineers (n = 194) and SEM-AMOS (v.6). Overall, we find an acceptable level of fit between our theoretical model and the underlying data ($\chi^2 = 597.554$, $df = 294$, $p < .000$; RMSEA = 0.073; CFI = 0.909; TLI = 0.892). The results of our analysis provide further support for hypothesis 1 (see Figure 2b); knowledge is positively and significantly related to cross-functional integration ($\beta = 0.673$, $p < .001$) and explains 45.4% of the variance. Further, we find that cross-functional integration is

positively and significantly associated with new product design performance ($\beta = 0.376$, $p < .001$), accounting for 14.1% of the variance. These results support Hypothesis 3 and suggest that cross-functional integration is critical to the success of the new product design.

5. Discussion

5.1 Product design and direct material sourcing performance

Our findings support the general notion that cross-functional integration enhances functional performance. While extant cross-functional literature provides support for this relationship (Henke, et al., 1993, Sherman, et al., 2005), the dominant view within the purchasing literature holds that sourcing performance is the result of functional actions (Di Benedetto, Calantone, VanAllen and Montoya-Weiss, 2003, Wynstra, van Weele and Axelsson, 1999) rather than cross-functional interaction (Pagell, 2004). However, our results suggest that product engineering plays a critical role in the outcome of direct material sourcing efforts. Similarly, our results demonstrate that purchasing, which has traditionally focused on obtaining the best deal (Smeltzer, et al., 2003), significantly contributes to product design performance. As such, our findings extend the examination of internal integration to include new product design and direct material sourcing.

Our results also complement studies of innovation within the strategic management literature. In accordance with this stream of literature, innovation requires both exploration and exploitation of knowledge (Almirall and Casadesus-Masanell, 2010). The assimilation of new knowledge requires an extensive search process in which (i) an organization first conducts an internal search of their existing knowledge and then (ii) expands their efforts to exploratory activities (March, 1991). Through the search process, new knowledge is identified, and, subsequently, acquired, assimilated, and transformed so that it may be exploited by the firm

(Cohen and Levinthal, 1990). Our results lend new insights into processes associated with the search for novel product innovations. In particular, we show that cross-functional integration enables both successful new product design (i.e., the exploitation of existing knowledge) and direct material sourcing performance (i.e., the exploration and acquisition of external knowledge).

Moreover, we find that cross-functional integration activities have a greater effect on new product design performance as compared to direct material sourcing. We suggest that the stronger relationship between cross-functional integration and new product design performance may be attributable to the difference in nature of these processes. In general, the new product design process is characterized by the integration of disparate knowledge (Almirall and Casadesus-Masanell, 2010, Lee and Veloso, 2008, Sherman, et al., 2005, Takeishi, 2002) and freedom in design decisions, such that different designs may accomplish the same goals. Conversely, the direct material sourcing process, which occurs in subsequent stages of the new product development process, is constrained by prevailing supply market factors and product design specifications (Almirall and Casadesus-Masanell, 2010, Hui, et al., 2008, Williamson, 2008). In accordance with our results, the benefits attributable to cross-functional integration may be stronger when the cross-functional task is characterized by fewer constraints and increased freedom in decision-making.

Overall, our findings confirm the widely held belief that cross-functional integration increases performance (Hayes et al. 2005, Pagell, 2004). Further, our results contribute to existing research that considers the effect of cross-functional integration on new product development (Kahn, 1996, Kahn and McDonough, 1997, Sherman, et al., 2005, Sherman, et al.,

2000, Song and Montoya-Weiss, 2001, Xie, Song and Stringfellow, 2003) by enlarging the scope to include the purchasing and product engineering interface.

5.2 Impact of cross-functional knowledge and integration

This study upholds the linkage between knowledge and cross-functional integration. Using primary response data from both buyers and engineers, we find that knowledge has a positive and significant effect on cross-functional integration. As such, our findings suggest that both the core and overlap knowledge embedded within the buyer-engineer relationship act as integrating mechanisms across functions. This is a subtle point as the existing literature focuses on the role of core knowledge as a determinant of integration (Lawrence and Lorsch, 1967, Pagell, 2004) largely overlooking overlap knowledge.

When a perspective of cross-functional integration incorporates core and cross-functional knowledge, several implications for existing operations management and supply chain literature emerge. First, the existing research advocates the use of cross-functional teams to enhance performance (Guzzo and Dickson, 1996, Postrel, 2002, Sherman, et al., 2005). Our findings suggest a mechanism behind cross-functional team performance: the integration of knowledge embedded within the teams. More broadly, our findings suggest functional and cross-functional knowledge rather than team composition facilitates effective cross-functional integration and subsequently performance.

Second, core knowledge or functional specialization is widely recognized as a means to reduce uncertainty and increase performance (Galbraith, 1974, Lawrence and Lorsch, 1967). However, the notion that a common knowledge must be shared across functions (Brusoni, Prencipe and Pavitt, 2001, Postrel, 2002) is less prevalent. Our findings advocate the development of cross-functional relationships that embody cross-functional knowledge and

suggest that human resource policies and procedures that enable the development of cross-functional knowledge may be particularly important to the success of key business processes. In particular, human resource management activities such as job rotation (Ortega, 2001), recruiting personnel with shared background (Anklesaria and Burt, 1987) and reduction of employee turnover (Droege and Hoobler, 2003) may be critical organizational learning and cross-functional integration mechanisms.

Lastly, our study implies firms largely employ cross-functional teams to create synergies from integrating pockets of shared knowledge (Henke, et al., 1993, Sherman, et al., 2005). A primary goal of the buyer-engineer relationship is to source a high quality direct material component with the best possible terms while supporting the development of an innovative end product (Smeltzer, et al., 2003). Consequently, traditional purchasing tasks, such as supplier selection and negotiation, benefit from the supply, supply market, and technical knowledge of the product engineer. Similarly, product design is enhanced by the supply, supply market, and technical knowledge of the direct materials buyer.

6. Conclusions, Limitations and Future Research

Previous literature has examined the integration of marketing and R&D (Gupta, et al., 1985, Sherman, et al., 2005, Song, Dyer and Thieme, 2006), marketing, manufacturing and R&D (Kahn, 1996, Kahn, 2001, Kahn and McDonough, 1997, Sherman, et al., 2000, Xie, et al., 2003, Xie, et al., 1998), and operations, purchasing and logistics (Pagell, 2004). However, this literature has not specifically addressed the relationship between purchasing and product engineering. Our work addresses this gap by scrutinizing this relationship.

There are several managerial implications brought to light by this study. First, cross-functional integration mediates the relationship between core and overlap knowledge and direct

material sourcing and product design performance. It may be detrimental for organizations to emphasize core or functional in lieu of overlap knowledge. In accordance with our results, core knowledge is a necessary but not sufficient condition for sourcing tasks that require the interface of two or more functions. Second, concomitantly, human resource management programs should focus on the development of core and overlap knowledge. Third, since internal integration is a prerequisite for integration with suppliers (Droge, et al., 2004), the integration between purchasing and product engineering should not be neglected as it will effect integration with suppliers.

Though our study contributes the existing literature, it has limitations. First, the respondents for this study were drawn from a single organization. This constrains our ability to generalize our findings. Yet, this may be a strength as a single firm sample may serve as a control for other extraneous factors that influence the buyer-engineer relationship. Secondly, tests of association within our model are based on data from single respondents. While such an approach may bias our results, our assessment of common method bias suggests that the effects are negligible.

Despite these limitations, our research serves as a basis for future avenues of research. One possibility is an exploration of how functional roles differ based upon the particular interface and factors surrounding the task at hand. In particular, the amount of integration needed within purchasing-product engineering relationship may be moderated by contextual factors such as type of part, part complexity, supply market, and firm and supplier capabilities. Next, studies within the operations management literature suggest that a firm's structure and infrastructure will influence cross-functional integration. Thus, future research may examine how a firm's structure and infrastructure affect buyer-engineer integration.

In conclusion, this study investigates the factors that influence cross-functional integration between purchasing and product engineering functions. We introduce a broader view of cross-functional integration by considering the role core and overlap knowledge as antecedents. By operationalizing dyadic models of cross-functional integration, our study offers novel insight into new product design and direct material sourcing performance that may play a pivotal role in future studies.

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Tables & Figures

Table 1. Pilot study – scale reliabilities

Construct	Reliability (α)	
	Buyer Data	Engineer Data
Supply Market Knowledge	.834	.903
Supplier Knowledge	.627	.954
Technical Knowledge	.537	.900
Cross-Functional Interface	.868	.952
Sourcing Performance	.893	--
New Product Development Performance	--	.283

Table 2a. Construct measurement scales and related statistics for buyer survey items ^{1,4}

Constructs & Items	CFA Loadings
Engineer's Overlap (Supply Market) Knowledge ($\alpha = .821$) ²	
<i>Please indicate the extent to which your Product Engineer is knowledgeable about the following supply market issues:</i>	
M1 Specifics about what other firms are paying for [DIRECT MATERIALS] (or similar items)	.655
M2 Companies that manufacture [DIRECT MATERIALS]	.673
M3 Likely future price trends for [DIRECT MATERIALS]	.807
M4 Supply conditions in the [DIRECT MATERIALS] industry (e.g., the availability of raw materials, labor rates, government interactions, etc.)	.783
M5 <<MFGR>>'s future volume requirements for [DIRECT MATERIALS]	.591
Engineer's Overlap (Supplier) Knowledge ($\alpha = .869$) ²	
<i>Please indicate the extent to which your Product Engineer is knowledgeable about [SUPPLIER]'s...</i>	
N1 ... manufacturing capabilities	.764
N2 ... design capabilities	.719
N3 ... costs to manufacture [DIRECT MATERIALS]	.771
N4 ... financial health	.666
N5 ... past (historical) performance	.818
N6 ... future products	.631
Engineer's Core (Technical) Knowledge ($\alpha = .883$) ²	
<i>Please indicate the extent to which your Product Engineer is knowledgeable about the following aspects of [DIRECT MATERIALS].</i>	
O1 <<MFGR>>'s long-range performance requirements for [DIRECT MATERIALS]	.827
O2 Cost-benefit trade-offs associated with variants of [DIRECT MATERIALS] technology	.845
O3 Manufacturing processes used to produce [DIRECT MATERIALS]	.751
O4 Technology that underlies [DIRECT MATERIALS]	.692
O5 How the design of [DIRECT MATERIALS] impacts <<MFGR>>'s total costs	.762
Buyer-Engineer Interaction ($\alpha = .838$) ³	
<i>Please indicate the extent to which you agree with the following statements that characterize your relationship with the Product Engineer.</i>	
L1 I communicate openly with the product engineer	.507
L2 Overall, I am satisfied with my relationship with the product engineer	.699
L3 The product engineer tries to carry out the responsibilities and commitments made to me	.632
L4 I have a give-and-take relationship with the product engineer	.426
L5 Information presented by the product engineer is accurate	.805
L6 In general, information from the product engineer maintains a high level of credibility with me	.826
L7 The product engineer tries to carry out the responsibilities and commitments made to me	.697
Sourcing Performance ($\alpha = .808$) ³	
<i>Please indicate the extent to which you agree with the following statements that characterize the performance of the [DIRECT MATERIALS] sourcing process.</i>	
H1 We selected the best supplier for [DIRECT MATERIALS]	.727
H2 We achieved the best possible price for [DIRECT MATERIALS]	.788
H3 We selected the supplier on-time	.621
H4 The supplier met our cost objectives	.731

¹ Capitalized words in square brackets represent variable fields that were customized for each buyer-engineer dyad

² Response scale: 1 = Not At All, 2 = Very Limited Extent, 3 = Limited Extent, 4 = Moderate Extent, 5 = Great Extent, 6 = Very Great Extent

³ Response scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree

⁴ Model fit: $\chi^2 = 641.170$, $df = 314$, $p < .000$; RMSEA = 0.077; CFI = 0.859; TLI = 0.830

Table 2b. Construct measurement scales and related statistics for engineer survey items ^{1,4}

Constructs & Items	CFA Loadings
Buyer's Core (Supply Market) Knowledge ($\alpha = .911$) ²	
<i>Please indicate the extent to which your Buyer is knowledgeable about the following supply market issues:</i>	
K1 Specifics about what other firms are paying for [DIRECT MATERIALS] (or similar items)	.756
K2 Companies that manufacture [DIRECT MATERIALS]	.834
K3 Likely future price trends for [DIRECT MATERIALS]	.904
K4 Supply conditions in the [DIRECT MATERIALS] industry (e.g., the availability of raw materials, labor rates, government interactions, etc.)	.876
K5 <<MFGR>>'s future volume requirements for [DIRECT MATERIALS]	.742
Buyer's Core (Supplier) Knowledge ($\alpha = .918$) ²	
<i>Please indicate the extent to which your Buyer is knowledgeable about [SUPPLIER]'s...</i>	
L1 ... manufacturing capabilities	.851
L2 ... design capabilities	.785
L3 ... costs to manufacture [DIRECT MATERIALS]	.798
L4 ... financial health	.786
L5 ... past (historical) performance	.819
L6 ... future products	.810
Buyer's Overlap (Technical) Knowledge ($\alpha = .904$) ²	
<i>Please indicate the extent to which your Buyer is knowledgeable about the following aspects of [DIRECT MATERIALS].</i>	
M1 <<MFGR>>'s long-range performance requirements for [DIRECT MATERIALS]	.852
M2 Cost-benefit trade-offs associated with variants of [DIRECT MATERIALS] technology	.855
M3 Manufacturing processes used to produce [DIRECT MATERIALS]	.789
M5 Technology that underlies [DIRECT MATERIALS]	.825
M7 How the design of [DIRECT MATERIALS] impacts <<MFGR>>'s total costs	.828
Buyer-Engineer Interaction ($\alpha = .900$) ³	
<i>Please indicate the extent to which you agree with the following statements that characterize your relationship with the Buyer of [DIRECT MATERIALS].</i>	
I1 I communicate openly with the buyer	.682
I2 Overall, I am satisfied with my relationship with the buyer	.857
I3 The buyer tries to carry out the responsibilities and commitments made to me	.760
I4 I have a give-and-take relationship with the buyer	.593
I5 Information presented by the buyer is accurate	.791
I6 In general, information from the buyer maintains a high level of credibility with me	.857
I7 My communications with the buyer are often timely	.728
Product Design Performance ($\alpha = .769$) ³	
<i>Please indicate the extent to which you agree with the following statements that characterize the performance of the product development process for [DIRECT MATERIALS].</i>	
E1 Product designs were released on-time	.701
E2 Product designs met cost targets	.531
E3 Product designs included desired features	.693

¹ Capitalized words in square brackets represent variable fields that were customized for each buyer-engineer dyad² Response scale: 1 = Not At All, 2 = Very Limited Extent, 3 = Limited Extent, 4 = Moderate Extent, 5 = Great Extent, 6 = Very Great Extent³ Response scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree⁴ Model fit: $\chi^2 = 580.287$, $df = 289$, $p < .000$; RMSEA = 0.072; CFI = 0.913; TLI = 0.895

Figure 1. Theoretical model of cross-functional integration

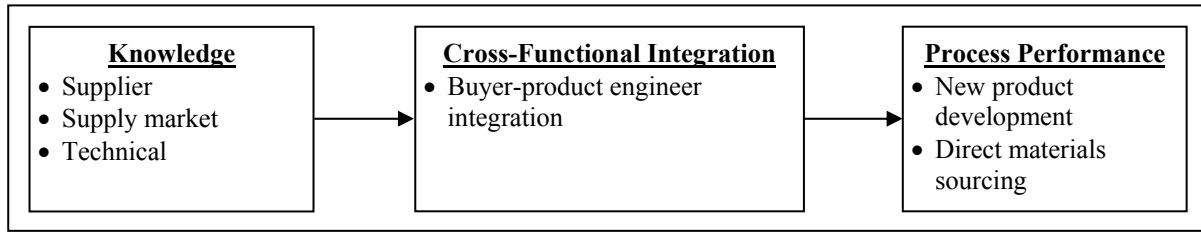
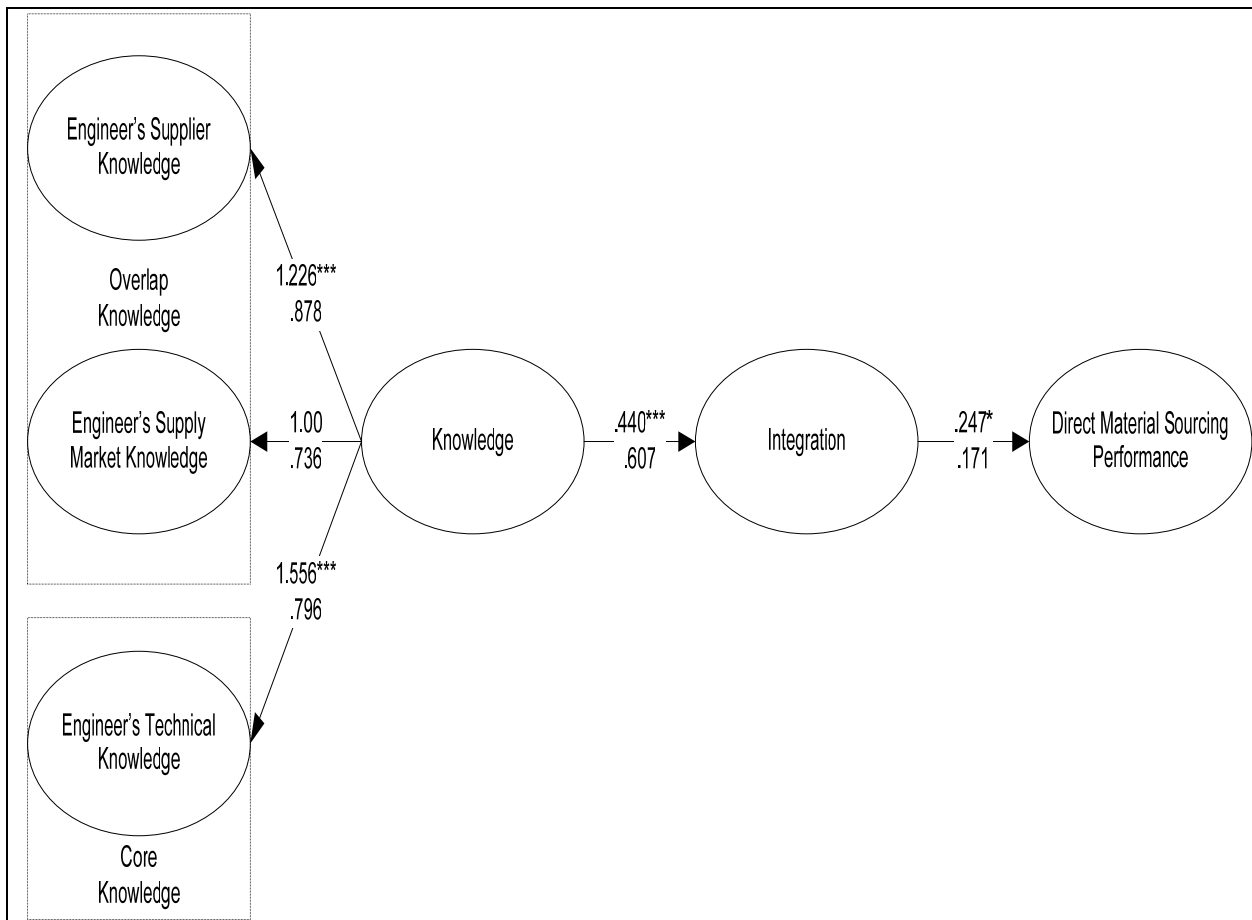


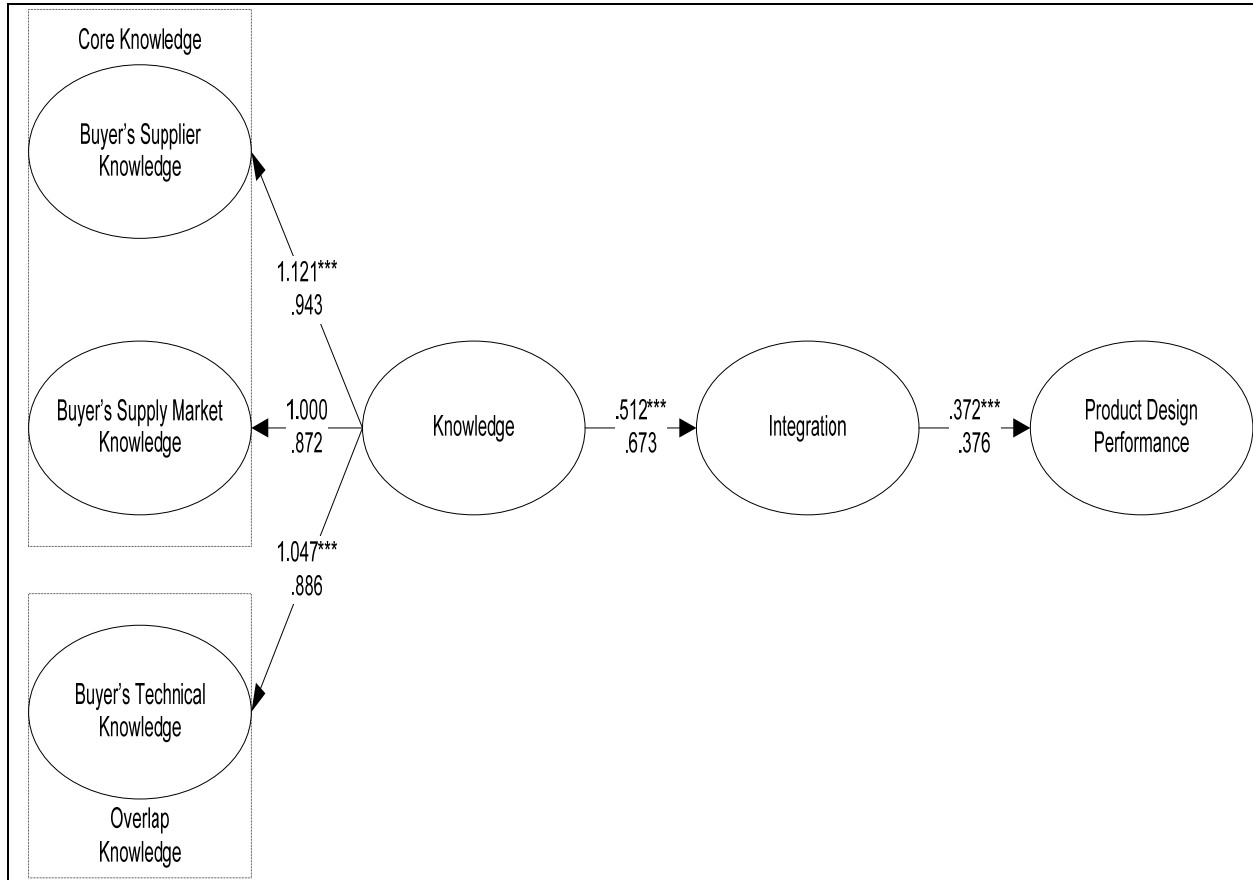
Figure 2a. Empirical model of buyer-product knowledge and integration – buyer’s perspective^{a,b}



^a Model fit statistics: $\chi^2 = 661.254$, $df = 319$, $p < .000$; RMSEA = 0.079; CFI = 0.852; TLI = 0.825

^b p-values: ^{***} $p \leq 0.001$; * $p = .067$

Figure 2b. Empirical model of buyer-product knowledge and integration – engineer’s perspective^{a,b}



^a Model fit statistics: $\chi^2 = 597.554$, $df = 294$, $p < .000$; RMSEA = 0.073; CFI = 0.909; TLI = 0.892

^b p-values: *** $p \leq 0.001$