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# Learning and innovation in small and medium enterprises — Source link

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**Institutions:** National Cheng Kung University

**Published on:** 16 Mar 2010 - Industrial Management and Data Systems (Emerald Group Publishing Limited)

**Topics:** Absorptive capacity, Small and medium-sized enterprises and Knowledge acquisition

# Learning and innovation in small and medium enterprises



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Received 20 August 2009
Revised 8 October 2009
Accepted 24 October 2009

## Abstract

**Purpose** – The purpose of this paper is to examine the relationship between knowledge acquisition, knowledge absorptive capacity, and innovation performance in small and medium enterprises (SMEs).

**Design/methodology/approach** – Questionnaire data were collected from research and development (R&D) managers or owners of 49 SMEs of the bicycle industry in Taiwan. The questionnaire was designed to measure variables including: knowledge absorptive capacity, knowledge acquisition of company, technical and industrial experiences of owner's and the R&D staff, innovation performance measures, and control variables.

**Findings** – The results show that the depth and the breadth of its owner's technical and industrial experiences best explained absorptive capacity of an SME. In turn, the absorptive capacity and the knowledge acquisition activities of an SME affect its innovation performance.

**Research limitations/implications** – The findings show that, first, SME owners' technical and industrial experiences are contributing factors to their companies' knowledge absorptive capacity; second, instead of R&D investment, SME personnel's scientific knowledge collection and diversity of knowledge sources contribute to innovation performance of companies. Because the data were limited to bicycle industry, future studies need to validate these findings in the SMEs of other industries.

**Originality/value** – The value of the paper lies in the fact that SME owner's and its personnel's contributions to company's knowledge absorptive capacity and the concomitant effects of knowledge acquisition and knowledge absorption capacity on a firm's innovation performance are two issues seldom addressed in previous studies.

**Keywords** Knowledge management, Small to medium-sized enterprises, Innovation, Learning, Bicycles, Taiwan

**Paper type** Research paper

## Background and the research framework

Unlike large firms, small and medium enterprises (SMEs), with limited financial resources and insufficient managerial infrastructure, tend to rely less on costly research and development (R&D) investment for innovation activities (Jones and Craven, 2000; Lim and Klobas, 2000; Nootboom, 1993). Consequently, to innovate and gain competitive advantage in the market, SMEs need to exploit other internal facilitating factors such as human capital.

Industrial Management & Data Systems
Vol. 110 No. 2, 2010
pp. 175-192

0263-5577
DOI 10.1108/02635571011020296

Human capital is the major agency for organizational learning which has been acknowledged as the primary source of value creation and critical innovation infrastructure (Casey, 2005). Organizational learning is the process of acquiring, interpreting, and creating knowledge among organizational members (Dixon, 1992; Huber, 1991; Nonaka *et al.*, 2006). Processes in organizational learning can be modeled after individual human learning (Daft and Huber, 1987; Daft and Weick, 1984). The individual learning process begins with external stimuli that trigger the individual to respond to the external environment. Prior experiences and knowledge of the individuals affect how they perceive and process the information and data they receive, and their interpretation of the information and updating of their memory content and structure. The acquired knowledge will then enable the individuals to respond to environmental demands with new and innovative performances. In this study, a model for organizational learning process analogous to individual learning was proposed in which three distinctive subproceses are used to account for organizational learning: knowledge acquisition, knowledge absorptive capacity, and creative and innovative responses to the environmental demands (Figure 1).

The model predicts that for organizational learning to occur, companies have to initiate search for knowledge from external sources for ideas that might be applied in their product or process innovations. But knowledge and information acquired externally are often tacit or complex. A certain level of knowledge absorptive capacity is needed to enable the companies to recognize the value of the externally acquired knowledge and to thoroughly exploit its applicability (Dyck *et al.*, 2005; Stock *et al.*, 2001). "Knowledge absorptive capacity" of an organization is its ability to understand and assimilate new knowledge and apply it onto new product development (Cohen and Levinthal, 1990). It was often regarded as a black box in the past. Proxies for an organization's knowledge absorptive capacity include an organization's R&D spending (Cohen and Levinthal, 1990; Fosfuri and Tribo, 2008; Lane *et al.*, 2006; Todorova and Durisin, 2007), the number of patents (Tsai, 2001), its membership in the scientific community (Deeds, 2001), its knowledge management

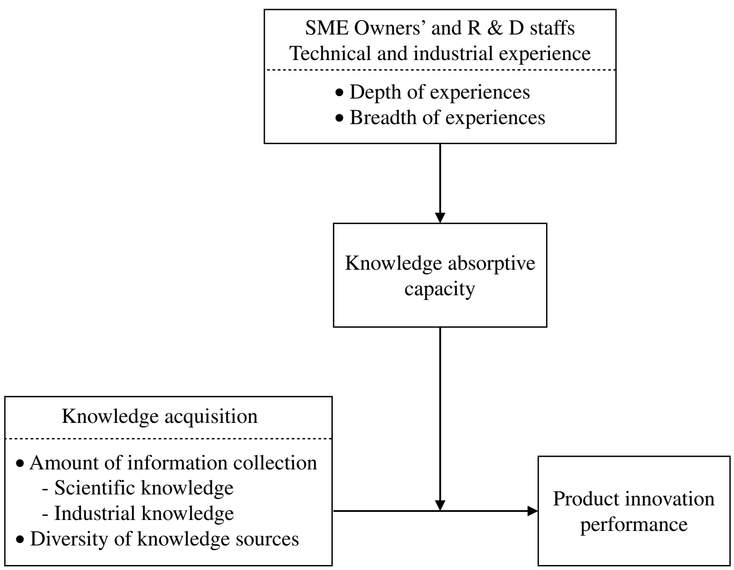


**Figure 1.**
A conceptual framework of organizational learning and innovation

routines (Jones and Craven, 2000), and its experienced workforce and enterprise owner (Lim and Klobas, 2000). Because SMEs are limited in financial capital and possess simpler organizational routines and structures and fewer links to scientific communities, we predicted that SMEs' knowledge absorptive capacity resides more on the breadth and depth of the prior experiences of their owners and critical R&D staffs.

Without taking actions to acquire knowledge and information, an organization's knowledge absorptive capacity will remain dormant and facilitate no innovations. In large organizations, abundant resources are available for R&D personnel to self-generate new knowledge, external knowledge acquisition may serve a lesser function in innovation. With fewer resources, however, SMEs rely more on external sources for new knowledge. However, different knowledge sources and diversity of the knowledge sources may have different effects on organization learning (George *et al.*, 2001; Jones and Craven, 2000). For example, knowledge released from related industries may be more readily absorbed and applied to innovation by SMEs, whereas spillover from the basic science studies may be more difficult to be absorbed and applied to innovation. In the present study, the knowledge sources will be classified into two types: the basic science knowledge and the industry knowledge (Cohen and Levinthal, 1990; Omta *et al.*, 1997). The influence of the type of knowledge and the diversity of knowledge on SMEs' innovation would be examined in this study.

Finally, in human learning, an individual's prior knowledge and cognitive ability set the limit on what can be learned. The possible interaction between knowledge absorptive capacity and knowledge acquisition on SMEs' innovation performance would also be examined. Details about the research problems and hypotheses are given below.

## SME personnel's prior technical experiences and organizations' knowledge absorptive capacity

The prior knowledge of an organization's personnel may contribute to its knowledge absorptive capacity because prior knowledge enables employees to assimilate, transform, and incorporate new knowledge into the knowledge base that already exists within the organization (Cohen and Levinthal, 1990; Zahra and George, 2002). An organization's prior knowledge can be measured by two dimensions: its depth and breadth. A greater depth of prior knowledge in a specialty provides a deeper understanding of the new knowledge and leads to a higher absorptive capacity of the new knowledge in the related domain. The breadth or diversity in the knowledge background and experiences of an organization's personnel also contributes to the organization's absorptive capacity (Cohen and Levinthal, 1990). When shared among members, diversity in ideas may bring forth novel associations and aid in creating linkages between old and new knowledge, and enhance the interpretation and understanding of new knowledge (Daft and Weick, 1984).

Various indices to tap the construct of absorptive capacity have been proposed. For example, Cohen and Levinthal (1990) used R&D spending as an indicator of knowledge absorptive capacity. Tsai (2001) used the number of patents as the measure of an organization's knowledge absorptive capacity. These indices primarily reflect the intensity of an organization's R&D activities. No study has yet examined the contributions of individual employee's prior knowledge to organization's knowledge absorptive capacity because it is often assumed that the capacity resides only in organizations, not in individual employees (Lane *et al.*, 2006; Verga-Jurado *et al.*, 2008). In SMEs, the number of R&D staffs who conduct research activities is often small. Consequently, the depth and the diversity of the staff's prior technical experiences may contribute more to an organization's knowledge absorptive capacity than the R&D activity *per se*. Because the personnel responsible for technological information scanning in an SME are its owner and R&D staffs (Raymond *et al.*, 2001), an experienced owner or staffs will absorb more knowledge than an inexperienced one from knowledge acquisition activities. Thus, we predicted that the depth and breadth of the industrial experiences of the owner and the R&D staffs of an SME would contribute positively to its knowledge absorptive capacity.

### Information collection, diversity of knowledge sources, and SMEs' innovation performance

Organizations often face many environmental uncertainties and must acquire knowledge and information from environment to reduce these uncertainties (Galbraith, 1973). Studies have shown that top managers of organizations with superior performance engaged in more knowledge and information acquisition than managers of organizations with mediocre performance (Daft *et al.*, 1998). Ancona and Caldwell's (1990) study on product development teams found that an increase in knowledge acquisition led to better performance in product innovation.

Previously, knowledge acquisition capacity was considered a constituent part of knowledge absorptive capacity (Zahra and George, 2002, p. 189). Knowledge absorptive capacity refers, nevertheless, only to "a firm's capacity to identify and acquire externally generated knowledge," which is not equivalent to actual knowledge gathering behaviors. Here, we differentiate knowledge acquisition from knowledge acquisition "capacity" because the latter refers to potential for acquisition behavior and the former, actual occurrence of acquisition behavior. We predicted that higher amount of knowledge acquisition and higher level of absorptive capacity in an SME would lead to higher innovation performance.

However, there are vast amount of, and huge variety of information in the environment. Different sources of information provide knowledge that differs in nature. Knowledge available from external sources can be classified into two categories: those spilled over from industries and those released from basic science and technology by academia or other research institutions outside the industries (Cohen and Levinthal, 1989; Soh, 2003). The spillover from industry, be it from customers, materials and equipment suppliers, or competitors, provides readily information about the market potential of the new products in the industry. The information from academia or research institutes provides, instead, knowledge previously unknown to the industry and thus, if properly assimilated, may contribute to the technological breakthroughs within an industry (Julien *et al.*, 2004). Therefore, we predicted that collection of both types of information is instrumental for SMEs to create a new, marketable product.

Inclusion of various knowledge sources may be a key to organizational innovation. For example, Jones and Craven's (2000) case study on a small and medium business in Birmingham showed that the use of diversified sources, such as literature scan, customer contact, trade shows, competitor monitoring, customer input, supplier input, and reverse engineering for collecting external information and knowledge contributes to organizational learning. George *et al.* (2001) found that various inter-organizational alliances in bio-technology firms, including horizontal, vertical, and attractive alliances (purchasing or licensing agreement), provided these firms with access to multiple resources of new knowledge and enhanced their knowledge absorptive capacities and innovation performance. Hence, we predicted that a greater diversity in knowledge sources would benefit SME's overall innovation performance.

## Knowledge acquisition and knowledge absorptive capacity on SMEs' innovation performance

To exploit knowledge from different sources may require different levels of knowledge absorptive capacity. For example, knowledge from basic research relates less directly to product manufacturing and is more difficult to understand; hence, it requires a higher level of knowledge absorptive capacity (Cohen and Levinthal, 1990). Not only understanding complex, profound knowledge, but also solely processing and assimilating a larger amount of knowledge require a higher level of absorptive capacity. For example, Tsai (2001) found that organizational units that received more information and knowledge because of their centrality in information networks performed better in innovation if they had a higher knowledge absorptive capacity. In contrast, Malhotra *et al.* (2005, p. 169) found with a sample of 41 enterprise-supplier relations that the enterprises capable of acquiring information from their suppliers were, nevertheless, unable to create market knowledge because of their lack of ability in assimilating and transforming the acquired information. It was therefore predicted that to fully exploit the benefit of acquired knowledge, an adequate level of knowledge absorptive capacity is required.

Previous studies on organizational learning have either stressed the importance of information and knowledge collection through internal and external organizational communications on innovation performance (Brown and Eisenhardt, 1995), or emphasized the process of making sense of, assimilating, transforming, and utilising information in organizations (Cohen and Levinthal, 1990). Little attention has paid to the possible interaction effect of knowledge acquisition activities and knowledge absorptive capacity on innovation performance. The last purpose of the present study was to explore this interaction effect. We predicted that with a higher level of knowledge absorptive capacity, an SME's knowledge acquisition would make a greater contribution to its innovation performance.

Taiwan ranks top two in the world's bicycle industry. To maintain its advantages in a very competitive market, the bicycle industry in Taiwan must innovate constantly to create and/or respond to new market needs (The Ministry of Economic Affairs, 2006). Except a few big companies, the industry comprises mostly SMEs. We therefore chose to test our theoretical framework with the SMEs in the bicycle industry.

## Method

### *Participants and data collection procedure*

Survey research was employed to address the aforementioned research questions. Prior to data collection, the R&D personnel of three bicycle companies and of the Industrial Technology Research Institute (ITRI), a semi-official agency that provides technical assistance to the industries in Taiwan, were interviewed to provide background information about the bicycle industry in Taiwan as well as information about the processes of organizational learning and product innovation in the bicycle industry. The information they provided served as the basis for the design of the measurement indices of the studied variables.

A total of 122 bicycle companies with 70 or more employees each were drawn from the 2003 Directory of the Taiwan Bicycle Exporters' Association and the companies that participated in the 2001 and 2002 Annual Innovative Bicycle Parts and Accessories Competition. They were chosen for two reasons: the ITRI researchers suggested that the bicycle companies greater in size (with at least 70 employees) were more likely to engage in R&D activities; and the companies participated in the annual innovation competition were those that had innovative products. Questionnaires were mailed to the R&D managers or owners of the firms. Because survey response rates for academic research from business organizations typically are low and fall within the range of 20-30 percent (Tootelian and Gadeke, 1987), the questionnaire was followed by mails and phone calls to remind R&D managers or owners to complete the survey. As a results, a total of 49 firms responded to the questionnaire (a return rate of 39.8 percent).

Among the 49 participant firms, the sizes of bicycle companies range from 55 to 510, and 51.02 percent of them have $<100$ employees. About 71 percent of the firms have a capital of less than NT$ 6,000,000. Most of them (61.22 percent) have $<10$ R&D personnel (range: 2-40). Their R&D investment ranged from 1 to 15 percent of their annual budgets and was mostly (75.52 percent) $<6$ percent in the past five years. Most company owners have about 20 years of technical experiences, whereas the length of technical experiences of their R&D staffs averages to only eight years (Table I).

### *Measuring instruments*

A questionnaire was constructed for the measurement of the research variables. The content of the questionnaire included the following.

*Knowledge absorptive capacity*. A firm's knowledge absorptive capacity was measured by 24 items (Appendix Table AI), covering the four underlying dimensions of the capacity (Zahra and George, 2002):

(1) The capacity in knowledge acquisition (seven items), to assess a company's ability in self-assessing its technical potentials and in evaluating, learning, and documenting technical knowledge imported from external sources.

| Variables | Mean | SD |
|---|---|---|
| Number of R&D staffs | 9.82 | 4.10 |
| Ratio of R&D investment | 4.96 | 4.00 |
| Size of company | 122.41 | 73.03 |
| Amount of information collection ($A + B$) | 9.45 | 3.34 |
| *A. Scientific knowledge collection (*a × b*)* | 8.00 | 2.78 |
| a. Use of scientific knowledge sources | 2.75 | 1.11 |
| b. Importance of scientific knowledge sources | 2.65 | 1.09 |
| *B. Industrial knowledge collection (*c × d*)* | 11.38 | 3.28 |
| c. Use of industrial knowledge sources | 3.38 | 1.56 |
| d. Importance of industrial knowledge sources | 3.26 | 1.23 |
| Diversity of knowledge sources | 4.18 | 1.03 |
| *Technical and industrial experience* | | |
| 1. Owner's depth of experience | 19.59 | 6.27 |
| 2. Owner's breadth of experience | 2.96 | 0.89 |
| 3. R&D staff's depth of experience | 7.82 | 3.22 |
| 4. R&D staff's breadth of experience | 3.02 | 1.27 |
| Knowledge absorptive capacity | 3.84 | 1.02 |
| Innovation performance | 2.99 | 1.89 |

**Table I.**
Raw mean scores of the variables

(2) The capacity in knowledge assimilation (three items), to evaluate a firm's use of other companies' intellectual patterns and other external know-how on the firm's own R&D work, and the extent of R&D personnel endeavouring in various new knowledge study activities.

(3) The capacity in knowledge transformation (11 items), to measure R&D personnel's involvement in technical problem solving and strategic planning with other personnel such as production personnel, marketing/sales department, top managers, and satellite companies.

(4) The capacity in knowledge utilization (three items), to assess a firm's numbers of new products, technologies, and intellectual patterns developed from the externally imported ideas and knowledge.

The respondents rated each item by a five-point rating scale according to their firm's behavioral manifestation on the item in the past five years (1998-2002). The sum of 24 ratings represents a company's score of knowledge absorptive capacity. The higher the score, the higher is the knowledge absorptive capacity of the company.

*Diversity of knowledge sources*. Eight possible knowledge sources for a bicycle company were identified. They include ITRI, the Taiwan Bicycle Industry's R&D Center, competitors, material or equipment suppliers, universities and other academic institutes, customers, satellite companies, and governmental and industrial research units (Appendix Table AII). The respondents were asked to rate by five-point rating scale the frequency of use of these eight sources of knowledge in the past five years. A knowledge source that received a rating in frequency of use equal to or $>3$ was assigned a weight of "1." A rating $<3$ was assigned a weight of "0." The weighted sum of the eight knowledge sources was the measure of diversity of knowledge sources used in knowledge acquisition activities. The higher the score, the more diverse in knowledge sources that a company used to collect knowledge in the past five years.

*Knowledge acquisition*. A firm's knowledge acquisition was assessed by the sum of the $T$-scores of the amount of information collection and diversity of knowledge sources. To measure the amount of information collection, respondents were asked to evaluate, on a five-point scale, the perceived importance or relevance of each of the above eight knowledge sources to them. They then used a five-point scale to rate how frequently they actually used the knowledge source. The rating of frequency of use for each knowledge source was then weighted by the importance of the knowledge source. The sum of the weighted ratings of all eight sources serves as the measure of a firm's amount of information collection.

Bicycle industry's eight knowledge sources were divided into two categories: those coming from basic science research and those coming from industry itself. The amount of scientific knowledge collection was computed by summing the weighted ratings of all the sources associated with basic science research (ITRI, the Taiwan Bicycle Industry's R&D Center, universities and other academic institutions, and industrial research units). Similarly, the amount of industrial knowledge collection was computed by summing the weighted ratings of all the sources related to the industry (competitors, material or equipment suppliers, satellite companies, and customers of the industry).

*Technical and industrial experience*. Owner's and his/her R&D staffs' breadth and depth of technical and industrial experience were measured separately. An owner's technical and industrial experiences were classified into four categories: research, marketing, manufacturing, and others. His/her breadth of experience was measured by the number of job categories he/she has ever held so far in the industry. R&D staffs' breadth of experience was rated by five-point scales on their involvement in five categories of jobs in the past five years (Appendix Table AIII). The sum of the five involvement ratings represents the R&D staffs' breadth of experiences. Owner's depth of technical and industrial experience was measured by the number of years he/she has been involved in the bicycle-related business. R&D staffs' depth of experience was measured by an item estimating the mean tenure of R&D staffs in the bicycle industry.

*Innovation performance*. Seven items were used to assess a bicycle firm's performance in product and process innovation projects conducted in the past five years (Appendix Table AIV). These included:

(1) the speed in commercializing innovations in new products or new processes from their R&D projects;

(2) the contribution of innovations to technological leadership in the industry;

(3) the increase in sales volume from innovations;

(4) the speed of innovations relative to the leading companies in the industry;

(5) customer satisfaction with innovations;

(6) profit gained from innovations; and

(7) increases in market share from innovations.

The respondents were asked to evaluate the performance of their innovations according to the goals they set at the beginning of the R&D projects using five-point rating scales.

*Control variables*. Because a firm's innovation performance may vary with the firm's size, its number of R&D staffs, and the amount of its R&D investment, these three variables served as the controls in the study. The size of a firm was estimated by its number of employees. The number of R&D staffs was measured by the number of personnel who were responsible for firm's product and process innovation work. The amount of R&D investment was estimated by the ratio of the firm's annual R&D spending to its annual budget in the past five years (1998-2002).

The construct validity of the questionnaire was examined by item-total correlation and principal component factor analysis with Varimax rotation. All items were found to have significant item-total correlation (see the Appendix). Internal consistency reliability of each measure were assessed by Cronbach alpha. Based on Bryman and Cramer's (1997) criteria, Cronbach alpha $>0.80$ is an indication of high reliability, whereas Cronbach alpha $<0.60$ is an indication of low reliability. Construct validity and reliability of each research variable are described as follows.

*Measure of knowledge absorptive capacity*. Factor analysis on the 24 items measuring knowledge absorptive capacity yielded four factors that correspond to the four underlying dimensions of knowledge absorptive capacity: the capacity in knowledge acquisition, the capacity in knowledge assimilation, the capacity in knowledge transformation, and the capacity in knowledge utilization, accounting for 15.7, 20.4, 27.37, and 19.7 percent of the total variance, respectively, (Appendix Table AI). Cronbach's alpha of the scale was 0.82.

*Measure of knowledge acquisition*. Factor analysis on the eight items measuring the amount of information collection and diversity of knowledge sources yielded two factors: industrial knowledge acquisition and scientific knowledge acquisition, accounting for 47.60 and 25.10 percent of the total variance, respectively, (Appendix Table AII). Cronbach alpha of the scale was 0.79.

*Measure of R&D staffs' technical and industrial experience*. Factor analysis on the five items measuring breadth of R&D staffs' technical and industrial experiences yielded only one factor that accounted for 79.68 percent of the total variance (Appendix Table AIII). Cronbach alpha of the scale was 0.83.

*Measure of innovation performance*. Factor analysis on the seven items measuring a SME's innovation performance yielded only one factor and accounted for 65.12 percent of the total variance (Appendix Table AIV). Cronbach alpha of the scale was 0.86.

## Results

To investigate the contributions of knowledge acquisition and absorptive capacity to an SME's innovation performance, hierarchical regression analysis was used. That is, the control variables (number of employees, number of R&D staffs, and R&D investment) were entered into the regression first (Model 1) and then followed by the set of independent variables specified in the respective research questions to estimate the additional contribution of these variables to an SME's absorptive capacity or innovation performance (Models 2 and 3). All analyses were done on $T$-scores of the variables.

Table I lists the means of each research variable. The simple correlations between the variables range from 0.02 to 0.64 ($M = 0.36$) and suggest that an SME's innovation performance is significantly correlated with the organizational learning variables such as diversity of knowledge sources ($r = 0.62$), knowledge acquisition ($r = 0.55$), and R&D investment ($r = 0.48$), whereas the owner's depth and breadth of technical experience are the two variables significantly related to SME's knowledge absorptive capacity ($r = 0.52$; $r = 0.44$) and innovation performance ($r = 0.41$; $r = 0.38$).

### *Personnel's experience and SMEs' knowledge absorptive capacity*

Because the firm size (the number of employees) did not correlate with knowledge absorptive capacity ($r = 0.02$), it was not included as a control variable in the regression analysis. Two control variables (R&D investment and the number of R&D staffs) together accounted for 33 percent of the total variance in SME's knowledge absorptive capacity (Table II). However, there was a 41 percent increase in the total variance explained when the four experience variables were added to the regression model (Model 2 of Table II). The total variance explained amounted to 74 percent ($F_{6/42} = 19.44$, $p < 0.001$). The R&D investment ($\beta = 0.38$) and the owner's depth ($\beta = 0.36$) and breadth ($\beta = 0.22$) of experience were the factors significantly related to an SME's knowledge absorptive capacity. After removal of the variances explained by the owners, the R&D staffs' depth and breadth of experience, and the number of R&D staffs failed to show a significant contribution to an SME's knowledge absorptive capacity. Apparently, the owner is more critical than the R&D staffs in determining an SME's knowledge absorptive capacity.

### *Knowledge acquisition and SMEs' innovation performance*

Because the number of R&D staffs was not related to innovation ($r = 0.12$), it was not included as a control variable in the regression analysis. Table III shows that initially

| Predictors | β Model 1 | Model 2 |
|---|---|---|
| R&D investment | 0.36** | 0.38** |
| Number of R&D staff | 0.35* | 0.12 |
| Owner's depth of experience | | 0.36** |
| Owner's breadth of experience | | 0.22* |
| R&D staff's depth of experience | | −0.01 |
| R&D staff's breadth of experience | | 0.03 |
| $R^2$ | 0.33 | 0.74 |
| $\Delta R^2$ | | 0.41 |
| $F$ | 11.11 | 19.44 |

**Notes:** $^*p < 0.05$; $^{**}p < 0.01$

**Table II.** Technical and industrial experiences as predictors of knowledge absorptive capacity

| Predictors | β Model 1 | Model 2 |
|---|---|---|
| R&D investment | 0.44** | 0.23* |
| Number of employees | 0.27* | 0.05 |
| Amount of information collection | | 0.35** |
| Diversity of knowledge sources | | 0.42*** |
| $R^2$ | 0.30 | 0.61 |
| $\Delta R^2$ | | 0.31 |
| $F$ | 9.71 | 19.62 |

**Notes:** $^*p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$

**Table III.** Contribution of knowledge acquisition to innovation performance

R&D investment ($\beta = 0.44$) and the number of employees ($\beta = 0.27$) together accounted for 30 percent of the total variance in SME's innovation performance. Inclusion of the two subcomponents of knowledge acquisition, the amount of information collection and the diversity of knowledge sources, added another 31 percent of variance explained. The total amount of variance explained was 61 percent ($F_{4/44} = 19.62$, $p < 0.001$, and the diversity of knowledge acquisition ($\beta = 0.42$) and the amount of information collection ($\beta = 0.35$) appear to be relatively more important factors to SME's innovation performance than R&D investment ($\beta = 0.23$).

When the amount of information collection was divided into scientific knowledge collection and industrial knowledge collection, results of regression analysis showed that scientific knowledge collection ($\beta = 0.39$), rather than industrial knowledge collection ($\beta = 0.23$), predicted an SME's innovation performance (Table IV).

### *Knowledge acquisition, knowledge absorptive capacity and SMEs' innovation performance*

When amount of knowledge acquisition (sum of information collection and diversity of knowledge) and knowledge absorptive capacity were entered into the regression model after the number of employees and amount of R&D investment, they accounted for an additional 16 percent of residual variance in innovation performance (Model 2 of Table V). The total variance explained amounted to 46 percent ($F_{4/44} = 12.33$,

| Predictors | β Model 1 | Model 2 |
|---|---|---|
| R&D investment | 0.44** | 0.28* |
| Number of employees | 0.27* | 0.09 |
| Scientific knowledge collection | | 0.39** |
| Industrial knowledge collection | | 0.23 |
| $R^2$ | 0.30 | 0.50 |
| $\Delta R^2$ | | 0.20 |
| $F$ | 9.71 | 10.83 |

**Notes:** $^*p < 0.05$; $^{**}p < 0.01$

**Table IV.** Knowledge sources as predicators of SMEs' innovation performance

| Predictors | Model 1 | β Model 2 | Model 3 |
|---|---|---|---|
| R&D investment | 0.44** | 0.27* | 0.18 |
| Number of employees | 0.27* | 0.18 | 0.08 |
| Knowledge acquisition | | 0.42** | 0.29* |
| Knowledge absorptive capacity | | 0.30* | 0.22* |
| Knowledge acquisition * knowledge absorptive capacity | | | −0.22 |
| $R^2$ | 0.30 | 0.46 | 0.50 |
| $\Delta R^2$ | | 0.16 | 0.04 |
| $F$ | 9.71 | 12.33 | 15.45 |

**Notes:** $^*p < 0.05$; $^{**}p < 0.01$

**Table V.** Stepwise regression analysis of the contributions of organizational learning variables to SMEs' innovation performance

$p < 0.001$). Knowledge acquisition ($\beta = 0.42$) and knowledge absorptive capacity ($\beta = 0.30$) contributed significantly to innovation performance. However, adding their interaction term into regression only increased another 4 percent of the residual variance (Model 3 of Table V). It seems that knowledge acquisition and knowledge absorptive capacity influence innovation performance independently. Our prediction for an interaction effect between knowledge acquisition and knowledge absorptive capacity was not supported.

*Relative importance of personnel's experiences and knowledge acquisition on SMEs' innovation performance*

When the relative importance of the diversity of knowledge acquisition, the two types of knowledge collection (scientific and industrial), the four measures of technical experiences, the firm's number of employees, and the R&D investment were estimated by stepwise regression, Table VI shows diversity of knowledge sources and knowledge from basic science research were the two factors that predicted the innovation performance most. These two variables alone explained 41 percent of the total variance. R&D investment and the owner's depth and breadth of technical experience contributed another 16 percent of variance to innovation performance and the total variance explained amounted to 57 percent ($F_{5/43} = 13.25$, $p < 0.001$). The number of R&D staffs, their depth and breadth of experience, and the amount of industrial

**Table VI.** Relative contributions of organizational learning variables to SME's innovation performance

| Predictors | $R^2$ | $\Delta R^2$ | $\beta$ | $F$ |
|---|---|---|---|---|
| Diversity of knowledge sources | | 0.37 | $0.46^{**}$ | 38.12 |
| Scientific knowledge collection | 0.41 | 0.04 | $0.40^{*}$ | 25.78 |
| R&D investment | 0.48 | 0.07 | $0.35^{*}$ | 20.31 |
| Owner's depth of experience | 0.52 | 0.04 | $0.28^{*}$ | 17.68 |
| Owner's breadth of experience | 0.57 | 0.05 | $0.26^{*}$ | 13.25 |
| R&D staff's depth of experience | | | | |
| R&D staff's breadth of experience | | | | |
| Industrial knowledge collection | | | | |
| Number of R&D staff | | | | |

**Notes:** $^{*}p < 0.0$; $^{**}p < 0.01$

knowledge collection failed to be selected into the stepwise regression. The findings confirm again that an SME owner's technical experience (depth, $\beta = 0.28$; breadth, $\beta = 0.26$) plays a role more critical to innovation than the technical staffs'. The results also indicate that although direct R&D investment is critical ($\beta = 0.35$), the diversity of knowledge source ($\beta = 0.46$) and the amount of scientific knowledge collection ($\beta = 0.40$) are even more influential on SME innovation performance. Clearly, industrial knowledge collection does not have a significant effect on innovation performance when the effect attributed to knowledge from basic sciences has been explained. This finding is contrary to the common belief that knowledge acquired from the industry is more useful for innovation performance than the knowledge acquired from basic science research.

## Conclusions and discussion

The purpose of this study was to investigate the contributions of organizational learning, in terms of knowledge acquisition and knowledge absorptive capacity, to SME's product innovation. In SMEs, not only the R&D staff but also the owners may play a major role in acquiring and applying the new knowledge for performance innovation (Migdadi, 2009; Omerzel and Antoncic, 2008). It was postulated further in this study that the prior technical experience of the owner and of the R&D staffs constitute a major part of SME's knowledge absorptive capacity which in turn might affect its knowledge utilization. Data from 49 Taiwanese companies in bicycle industry showed that aside from R&D investment, the depth and the breadth of an owner's prior technical experience contributed significantly to an SME's knowledge absorptive capacity. This finding provides support to the argument that an organization's knowledge absorptive capacity resides not only in the organization itself, but also in the individuals in the organization (Lane *et al.*, 2006).

When the owner's contributions to knowledge absorptive capacity have been accounted for, the depth and the breadth of the R&D staff's technical experience and the number of R&D staff did not contribute significantly to the residual variance of an SME's knowledge absorptive capacity. This finding is comparable to Lim and Klobas's (2000) findings that owners of smaller enterprises play a critical role in knowledge management while their staffs only assume a limited role in knowledge management as defined by the owners. This is because for SMEs, unlike those of large enterprises, the owners' prior technical experiences may constrain their organization's absorptive capacity because they are they key person involved in technological scanning (Raymond *et al.*, 2001) and in R&D investment decisions. Therefore, the present finding implies that to develop a SME's knowledge absorptive capacity, the owners of SMEs' technical and industrial experiences must be enriched.

Although data show that both the R&D investment and the size of the company contributed positively to an SME's innovation performance, their contributions disappeared after knowledge acquisition and knowledge absorptive capacity were accounted for. It appears that neither R&D investment nor organizational size but organizational learning factors such as knowledge acquisition and knowledge absorptive capacity determine a SME's innovation performance. Furthermore, the positive relation between knowledge acquisition and product innovation in Taiwan's bicycle industry primarily existed only between scientific knowledge acquisition and product innovation performance. Industrial knowledge acquisition was unrelated to an SME's innovation performance when the effect of scientific knowledge acquisition had been accounted for. Knowledge from the industry concerns mainly market and commercial activities such as the actions of competitors, changes in customer preferences, and fluctuations in product demands. It is likely that for both SMEs and large enterprises, this type of knowledge is relatively more low-end and thus contributes less to technological breakthroughs. Knowledge from scientific and technological research provides, instead, ideas fundamental for technological innovation and problem solving. Deeds' (2001) study also provided evidence that knowledge from basic science communities significantly influenced the innovation performance of biotechnology companies. Apparently, even for SMEs, acquiring know-how from basic science research is more beneficial to their product innovation than collecting information and knowledge from the industry itself.

However, our prediction for an interaction effect of knowledge acquisition and knowledge absorptive capacity on SME's innovation performance was not confirmed by the data. One possible reason for the lack of interaction effect may be the small sample size of this study ($n = 49$). It is also likely that knowledge absorptive capacity and knowledge acquisition activities have only independent effects on product innovation performance. Another possibility is that our prediction for the interaction was derived from a model of human learning in which an individual's cognitive capacity imposes a sever constraint on what one can learn from external knowledge sources. The insignificant interaction effect between absorptive capacity and knowledge acquisition activity may in fact signal an important discrepancy between individual learning and organizational learning. The cognitive agent in organizational learning is a collection of individuals, rather than an individual, which enable the organization to overcome the stringent constraint imposed by the absorptive capacity in learning processes. The differences between individual learning and organizational learning may have important theoretical implications for a general theory of learning. Future study with larger sample is necessary to clarify the issue.

In sum, the results of this study highlight a significant implication for developing theories to account for SMEs' organizational learning and innovation. Current literature suggests that R&D investment determines the level of knowledge absorptive capacity in an organization. However, to SMEs, their owners' prior technical experiences serve as another important factor contributing to knowledge absorptive capacities. In contrast, in a large enterprise where the ownership and management are usually separated and knowledge management process is standardized, its owner's direct influence on its knowledge absorptive capacity may diminish. Therefore, owner's characteristics should be included as a key factor in theories concerning SMEs' knowledge absorptive capacity. Similarly, although the size and the experiences of R&D personnel are keys to a large enterprise's knowledge absorptive capacity, our findings suggest that an SME's owner is likely to be more important than its R&D staff to its knowledge absorptive capacity. The theories posited for explaining SMEs' organizational learning may need to include enterprise owners as an actor or agent of organizational learning.

The attenuation of the role of R&D investment on SMEs' innovation performance after the inclusion of knowledge acquisition and absorptive capacity in the model suggests an interesting implication for the innovation management of SMEs. While their shortages in funding and resources prevent them from investing in R&D, SMEs can use sources such as an experienced workforce to enhance their knowledge absorptive capacity. Furthermore, theories of organizational innovation argue that information imported from sources outside an organization facilitate the creation of new ideas and enhance product innovation. The insignificant role of industrial knowledge acquisition together with the significant role of scientific knowledge acquisition on an SME's knowledge absorptive capacity suggests that a theory of organizational learning may need to place a greater emphasis on the role of knowledge acquisition in basic sciences and absorptive capacity to better account for SME's knowledge and innovation management.

The findings of the present study may have both practical for improving SMEs' business performance. SMEs usually constitute over 90 percent of a nation's business population. Increase in a SME's innovation performance may constitute a significant increase in national income. Enterprises with limited financial resources like SMEs or nations with limited natural resources like Taiwan can invest on their human capital as a innovation strategy for competitive advantage (Chen *et al.*, 2005). Learning at the individual and organizational levels are sources of organizational strategic renewal and innovation. The findings of present study suggest that the owner of SMEs must take initiative in organizational learning by enriching the depth and breadth of their own technical and industrial experiences and by actively acquiring various sources of knowledge for future uses. Capacity to absorb knowledge released from basic sciences is the critical to keep the company at the front of the market. At the national and strategic level, programs sponsored by the government, universities, and industries' must be freely accessible to SMEs to facilitate their learning of basic science knowledge.

However, because the small sample size of this study prevents the application of more vigorous hypothesis-testing method, and the data are limited to Taiwan's bicycle industry, the findings of the present study must be cross-validated before they are generalized to other industries. In addition, future studies may include variables such as social networks, supportive leadership, and time course to have a more comprehensive understanding of how organizations learn and innovate.

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## Appendix. Construct validity of the research variables

| Factors | Item-total correlation | Factor loading |
|---|---|---|
| *1. Capacity in knowledge acquisition* | | |
| In the R&D process, we refer to: | | |
| Techniques/products from competitors | 0.64 | 0.66 |
| Techniques/products from academic research institutions | 0.63 | 0.65 |
| Published patents in the bicycle industry | 0.53 | 0.89 |
| Technical publications in the bicycle industry | 0.45 | 0.86 |
| The required R&D knowledge and experiences are documented in our organization | 0.66 | 0.86 |
| Our organization has a standardized administration process in managing and acquiring knowledge for R&D processes and techniques | 0.57 | 0.75 |
| Our organization has a well established knowledge system in saving the R&D outcomes | 0.63 | 0.74 |
| *2. Capacity in knowledge assimilation* | | |
| Our R&D personnel are capable in learning and assimilating new techniques | 0.88 | 0.84 |
| Our organization not only focuses on R&D related to our main product but also on research indirect to our main product | 0.72 | 0.78 |
| Compare to other division, R&D division is highly valued in our organization | 0.65 | 0.72 |
| *3. Capacity in knowledge transformation* | | |
| Our R&D personnel discuss the future R&D strategy/plan with: | | |
| Top managers | 0.73 | 0.79 |
| The marketing personnel in our organization | 0.65 | 0.76 |
| Material or equipment suppliers | 0.68 | 0.67 |
| With customers | 0.71 | 0.83 |
| In the project development process, R&D personnel: | | |
| Discuss with material or equipment suppliers | 0.82 | 0.80 |
| Discuss with the production division personnel in our organization | 0.69 | 0.66 |
| Discuss with the top managers | 0.57 | 0.80 |
| Discuss with marketing personnel in our organization | 0.69 | 0.76 |
| Visit the manufacturing site regularly | 0.53 | 0.68 |
| Hold regular meetings | 0.58 | 0.67 |
| Invite material or equipment suppliers to visit the manufacturing site regularly for suggestions | 0.58 | 0.65 |
| *4. Capacity in knowledge utilization* | | |
| We have acquired significantly more patents than competitors | 0.67 | 0.76 |
| We have developed significantly more new techniques than competitors | 0.71 | 0.70 |
| We have developed significantly more new products than competitors | 0.65 | 0.63 |

**Table AI.** The knowledge absorptive capacity measure

| Factors | Item-total correlation | Factor loadings |
|---|---|---|
| *1. Scientific knowledge* | | |
| The frequency of adopting knowledge from: | | |
| ITRI in bicycle industry | 0.42 | 0.64 |
| Taiwan Bicycle Industry's R&D Center | 0.66 | 0.67 |
| Governmental and industrial research units | 0.65 | 0.86 |
| Universities and other academic institutes | 0.75 | 0.89 |
| *2. Industrial knowledge* | | |
| The frequency of adopting knowledge from: | | |
| Material or equipment suppliers | 0.77 | 0.90 |
| Customers | 0.72 | 0.87 |
| Satellite companies | 0.69 | 0.84 |
| Competitors | 0.77 | 0.94 |

**Table AII.**
The knowledge acquisition measure

| Factor | Item-total correlation | Factor loadings |
|---|---|---|
| *1. Breadth of technical and industrial experience* | | |
| In the past 5 years, R&D personnel have been involved in: | | |
| Manufacturing and production job in bicycle industry | 0.76 | 0.82 |
| Marketing-related jobs in bicycle industry | 0.76 | 0.86 |
| Research-related jobs in bicycle industry | 0.67 | 0.64 |
| Manufacturing-related jobs in bicycle industry | 0.68 | 0.74 |
| Marketing jobs in bicycle industry | 0.57 | 0.60 |

**Table AIII.**
R&D staffs' breadth of technical and industrial experience

| Factor | Item-total correlation | Factor loadings |
|---|---|---|
| *1. Innovation performance* | | |
| Our new techniques/products: | | |
| Make great contribution to the bicycle industry | 0.65 | 0.86 |
| Can be commercialized quickly | 0.62 | 0.82 |
| Are quite profitable | 0.59 | 0.74 |
| Have high market share | 0.55 | 0.73 |
| Meet expected sales | 0.49 | 0.71 |
| Can compete with the leading brand in the bicycle industry | 0.52 | 0.71 |
| Meet customers need | 0.56 | 0.61 |

**Table AIV.**
The innovation performance measure

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